AGRICULTURE BLOCKCHAIN

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Foreword

The rapid development of blockchain technology in recent years facilitates a verifiable approach of enhancing information transparency between producers and customers in the agri-food systems. Today, blockchain technology has improved the traceability of agricultural products, this not only strengthens consumer trust and confidence in food safety but also provides a reliable pledge to human health.

In addition to the achievement of enabling traceability of agricultural products, blockchain technology has been undergoing diverse development with the aid of recent advancement of information technology that benefits agriculture including e-commerce platform, security certification, label accreditation, brand innovation, e-finance, and even the related fields of "Meta Universe". This has added extra value on the various innovative potentials of agriculture and food sectors. Nevertheless, despite the critical advantages of blockchain technology, maintaining the authenticity and honesty of the agricultural production represents its core value that is the scaffold for success.

Smallholder farming is vital for transitioning for more sustainable agriculture, and it plays significant role in many developing countries. As another core concept and skill of the blockchain technology is decentralization of the governance of data, production and agribusiness resources, it is hoped that this decentralization concept will effectively be implemented to ensure the well-being of smallholders from the spirit of "inclusive sharing" in the agricultural value chain.

Focusing on this decentralization console, this book provides cases and applications of blockchain technology in the agriculture sector. In addition, it also will strengthen readers' knowledge of the concept of decentralization. Please enjoy it.

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Foreword

If you are confused by the chatter about artificial intelligence, blockchain or big data, you are not alone. Our progress with technology over the last two centuries is astounding. In the 1820s, the clock moved from the town hall to the private home, and the first clocks sold were too expensive for the average buyer. In the 1840s, the sewing machine changed the lives of many people. The first automobiles were costly playthings for the wealthy. Blockchain, like much of our latest technology, is in the same condition as the first clocks, the early sewing machines, and the original horseless carriages.

Fred Smith, founder of Federal Express, believes that blockchain is the next frontier in global logistics management.

Any discussion of blockchain should start with definitions. *Blockchain is a decentralized database or digital ledger that is maintained and updated by a network of participating computers.* This technology allows parties to create a record, known as a block. Each block is time stamped and linked to the previous block in a way that prevents it from being retroactively altered without changing all of the previous blocks. The ledger is usually available to the public, but it can also be made private.

All logistic activities involve *seeing, thinking* and then *doing*. Seeing is about supply-chain visibility, illuminating process flows throughout the supply-chain. Thinking is about making connections faster than human logic. Doing is employing human or autonomous labor to perform work processes. In the area of *thinking*, also known as supply-chain connectivity, perhaps the biggest excitement is reserved for blockchain. Distributed ledger technology (DLT), of which blockchain is a primary form, provides unalterable records and tracing of transactions. It should, and will become an integral link in the supply chain of products calling for utmost integrity in origins, as well as the ability to trace the product through the chain. Food ingredients are one of the prime commodities that offer the most immediate promise for blockchain.

Having defined the concept, it is important to point out the misunderstandings. Blockchain is often confused with crypto-currency or bitcoin. While crypto currency works through distributed ledger technology, typically a blockchain, the concept goes far beyond the currency application.

Which activities are most likely to employ blockchain? Here is a list in the order of priority:

1) Track products moving through the supply-chain;
2) Share information with suppliers;
3) Track payment information;
4) Share information with customers;
5) Manage trade documentation;
6) Monitor suppliers;
7) Manage risk;
8) Manage inventory;
9) Control transportation of freight;
10) Facilitate product returns.

As we consider the contents of *AGRICULTURAL BLOCKCHAIN,* it seems clear that the capability of tracking products should be the most widely used feature in any implementation of the concept. The pallet or other load can be tracked and traced via blockchain technology as that particular load moves through various locations, creating a detailed record of the load's pedigree and chain of custody. Having such data is particularly beneficial for those involved in the transportation of food products, and even more when a product recall need arises. Food safety is critical in the developed world, and a major challenge in emerging nations. Marketing of agricultural products starts with convincing the potential buyer that the process is free of risk. Some food products are perishable, and blockchain can aid in controlling the need to isolate and destroy merchandise that is dangerous because it has grown too old. Production error or other mishaps can cause agricultural products to be changed and no longer fit for consumption. Blockchain provides the control to allow users to isolate and then destroy ingredients and/or finished agricultural goods that are no longer safe to consume.

In developing nations, agriculture is the industry that employs the most people and contributes the greatest amount of revenue. Yet the process is not without risk, and the distribution of tainted product has the potential to damage or even destroy the reputation of the agricultural grower or the food processor. Traceability is critical in discovering that problems exist, and then isolating dangerous items, before the product reaches the consumer.

For all these reasons, blockchain can and should be critical in the development of agriculture throughout the globe. This book covers the application of blockchain for agriculture sector, specifically for *Halal* supply chain, food safety, the policy, food supply chain, and rural economy. This book provides insights on how blockchain plays a role in the development of agriculture.

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Preface

Blockchain is one of the hot and yet promising technologies in recent years. It's also immature hence there are so many new issues of blockchain among the countries. The book contains 5 chapters which are written by the scholars from different countries to introduce the perspectives on blockchain technology in agriculture.

THE CHAPTER 1 – "*Halal* **Supply Chain 4.0 with Big Data and Blockchain**" by Dr Rika Ampuh Hadiguna presents the competitive strategy concept with big data and blockchain, Halal Supply Chain 4.0, which is from the halal industry to provide certainty of halal product status and to increase competitiveness.

THE CHAPTER 2 – **"The Application of Blockchain in Food Safety, Production and Marketing: Taiwan Perspective"** by Dr Tzong-Ru Lee uses three cases in Taiwan to introduce the application of blockchain in food supply chain.

THE CHAPTER 3 – **"The Challenges of Agricultural Blockchain: A Review of Policy Steering and Actions in Thailand"** by Dr Nirote Sinnarong is about the action and policy of government and society in response to the development of agricultural blockchain.

THE CHAPTER 4 – **"Using Blockchain & Internet of Things (IoT) in Agri-Food Supply Chain Traceability"** by Dr Lin Jun talks about the blockchain and IoT based smart agriculture ecosystem.

THE CHAPTER 5 – **"Blockchain Technology for Inclusive Development of Agrarian Rural Economy"** by Mr. Sharbendu Banerjee introduces how blockchain can solve the problems for smallholder. Based on these 5 chapters in this book, the readers can know more about the blockchain technology in agriculture.

Editor

Lee, Tzong-Ru

Tzong-Ru Lee
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Preface

The challenges in agriculture are rapidly increasing with the impact of climate change, land degradation and natural disasters. This is affecting the global food production and supply chain which has been aggravated due to Covid-19 pandemic and this calls for more resilient and sustainable food systems. The Asia-Pacific region which has the largest number of small holder farmers and is trying to meet the sustainable development goals of United Nations has lot of responsibilities to mitigate the challenges. In this scenario Blockchain Technology has come as a respite to contribute as one of the ways to mitigate the challenges. The benefits of Blockchain in agriculture include easy and cheap food batch recalls in case of emergencies, availability of the complete history of the product status, increased customer trust and loyalty, fairer payments, approved vendors, and proper compliance management. The global blockchain in agriculture and food supply chain market size estimated at USD 133 million in 2020 is expected to reach USD 948 million by 2025. Factors such as the increasing need to lower operational costs in financial transactions and the reduction of the number of layers required for data sharing and risk management and the regulatory compliances that automate and conduct only authorized transactions are driving the technology adoption.

The key drivers to blockchain in agriculture and food supply chain market are an increase in demand for the agricultural produce output surge, the use of smart agriculture among the growers or producers, government initiatives to support modern techniques that can be used in agriculture, and rising concerns for food safety among the consumers driving the increase in demand for the transparency in the supply chain. Increase in the popularity of blockchain among retailers/ distributors is due to rise in the tracking and tracing of various food products. Data management and data aggregation are major challenges in the precision farming market. The lack of standardization of the communication interfaces and protocols may result in the misrepresentation of the data.

The present volume is intended to collate the information on the status of blockchain in the Asian region with various case studies. APAARI is grateful to its member the International Association of Agricultural Sustainability for joining hands in this venture and sincerely acknowledge all the contributors for their excellent chapters on various aspects of blockchain. We also acknowledge the support of Dr KS Varaprasad in his meticulous

support in editing of the chapters. We also hope that the present volume will bring more awareness on the status and challenges of blockchain technology in the region to various stakeholders and may help in increased application of the technology.

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Halal Supply Chain 4.0 with Big Data and Blockchain

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1.1 THE CHALLENGE OF *HALAL* PRODUCTS IN THE INDUSTRIAL REVOLUTION 4.0

Consumer needs are key to success in increasing product competitiveness. Three latent components of competitiveness are price, product quality, and delivery time. Industries need to enhance their competencies to increase competitiveness. Consistency in the maintenance of customer satisfaction is one of the main goals of the industry to sustain their business. Consumer knowledge confidence about the product and the process are important to sustain and enhance product competitiveness. Customers' characteristics are another important aspect in terms of market segmentation. As market segmentation, Muslim consumer needs product quality assurance based on Islamic Sharia (law). Islamic Sharia is a standard to guide how to select and process products. *Halal* products must be hygienic and free from unclean elements from the food industry perspective, certainly containing *halal* ingredients (An Introduction to *Halal* Foods and Ingredients https://www.thespruceeats.com). Likewise, *halal* implementation for the non-food products such as perfume, the product is assessed with fragrance according to the wishes of consumers and must be free of alcohol. *Halal* product process is a complex problem, and it must be supported by technology to ensure the fulfillment of Islamic Sharia.

Aziz *et al.* (2015) have examined the emergence and growth of *halal* products from 2007 to 2014. The scope of the study is *halal* products in the food industry sector. *Halal* studies have some issues, namely consumer perception, system design, and software and hardware, to detect or validate *halal* products. Consumer product value and traceability are key elements of *halal* studies. The producer as a responsible actor facilitates the consumer to trace their product in terms of *halal* status. The study of consumer perceptions of *halal* products includes Hamid *et al.* (2016). They reviewed the government policies in Malaysia and Indonesia, ensuring the quality of *halal* products in the food industry. The effectiveness of RFID as a tracking system tool for *halal* products was studied (Anir *et al.,*

2008). Kamarulzaman *et al.* (2016) concluded from their studies that social media is very effective for Muslim consumers in the US to verify the status of *halal* products. Research on *Halal* included mainly the design of systems, devices, and equipment. Khosravi *et al.* (2017) succeeded in developing a device for checking the *halal* status of food products in Malaysia. Rahman and Abdul (2017) studied the similarities between *Halal* Assurance System (HAS), ISO 22005: 2007, and HACCP (Hazard Critical Control Points). Tan *et al.* (2012) found that Logistics Service Providers in Malaysia could improve their efficiency if they adopted *halal* transportation technology supported by Information and Communication Technology.

Some of the above study's results showed that *halal* issues are across the processes of handling these products from upstream to receipt of the products by consumers. Initially, the main issue for Muslim consumers was the type of material contained in the finished product in the context of guaranteed *halal* products. According to Islamic Sharia, increased consumer knowledge on ingredients and product handling process, enhanced awareness, and critical thinking about products increased the responsibility of industry to guarantee *halal* products. Industry can anticipate this demand by implementing *halal* supply chain or logistics management. Some studies that address this topic include Bruil (2010), Yusoff *et al.* (2015), and Hasan *et al.* (2016).

Halal supply chain management challenges are increasing when advances in information and communication technology have driven the emergence of the fourth Industrial Revolution. Industries transformed their business to adapt to the Industrial Revolution 4.0 (IR 4.0). Hence, the *halal* industry must implement the principles of IR 4.0. They manufacture products using HAS supported by the latest technologies such as artificial intelligence, the internet of things, big data, and blockchain. Applying the principles of IR 4.0 in *halal* supply chain management is referred to in this paper as *Halal* Supply Chain 4.0.

The purpose of this study is to formulate *Halal* Supply Chain 4.0 in the food industry. The supply chain 4.0 formulation is needed as a fundamental to build a *halal* supply chain system relevant to IR 4.0. This study shows the characteristics of *Halal* Supply Chain 4.0 and the transformation needs of the *halal* food industry.

The concept is formulated by exploring the published literature and deep situational analysis. The literature study examines various references on *halal* products, the concept, and the need for Industry 4.0 and *halal* supply chains. Understanding the real situation is important by analyzing various reports about the challenges and obstacles for *halal* products. *Halal* requirements, the fundamentals of IR 4.0, and supply chain management are synthesized and integrated as *Halal* Supply Chain 4.0.

1.2 HALAL SUPPLY CHAIN

The definition of the supply chain used in this study is a series of supply activities from upstream to downstream, including procurement, production, storage, and shipping. Supply chain management is an approach to maximize mutual benefits among actors in a standardized system. A supply chain system involves many companies as main actors such as suppliers and manufacturers and supporting actors such as transportation services, warehouse rental services, etc. The *halal* supply chain is specific supply chain management practice with Islamic Sharia consideration.

The definition of *halal* in the Qur'an has a broad and comprehensive perspective. Conversely, non-*halal* goods are known as haram. A simple *halal* definition and scope can be summarized as follows:

1. "All of the human, you can eat the food sources on earth, *halal* and *tayyib*. Don't you do satan deeds who violates rules. In fact, Satan is your very real enemy" (Qur'an 2:128).

2. "Forbidden to you all carcasses, blood, pork, and animals that have been slaughtered not in the name of Allah, strangled beasts, beaten, fallen, gored, and torn by wild beasts unless you have slaughtered them, and forbidden to you animals slaughtered to offer to idols. (Qur'an 5:3) ".

Rafi'i (2010) explained that Qur'an mentions the term *halalan thoyyiban*. *Halal* means permissible or justified, while haram is the opposite of meaningful *halal* words or not justified according to Islamic law. The next term is *tayyib,* meaning quality and good for health. *Halal* foods and beverages include (1) *halal* by substance; (2) *halal* to process it; (3) *halal* to obtain it; and (4) non-*halal* beverages.

The application of *halal* concepts in supply chain management includes aspects of material, processes, and activities. *The halal* concept is known as zero tolerance. Supply chain management is solving challenges in managing goods, information, and money flow. Goods flow in the activity of procuring materials, processing materials, and shipping materials or products. Information flow is all required data records that accompany material movements (forward) and information from customers to be followed up by the producer (backward). Money flow is a payment transaction process in the entire supply chain.

There is a difference between conventional and *halal* supply chain management. Table 1 is a summary of the comparison of the two supply chains. This comparison shows that there are more constraints from *halal* supply chain management. Zero tolerance

TABLE 1: *Comparison Conventional and Halal Supply Chain Management*

Aspects	Conventional	Halal
Definition	Coordinating production, inventory, location and transportation between participants in the supply chain to achieve the best responsiveness and efficiency in the market.	Maintaining from preparation, processing and shipping final products to customers following Islamic Sharia.
Objective	Cost minimization or profit maximization	Cost minimization or profit maximization, maintaining the integrity of *halal* and *thayyib.*
Cross contamination	Avoid cross contamination	Avoid direct contact with unclean ingredients between *halal* and haram materials.
Separate facilities	*Halal* and haram ingredients not discriminated against as efficiency is the consideration	Separate facilities for *halal* and haram materials, special facilities are needed for each.

(Sumber: Yusoff *et al.,* 2015)

requirement eliminates material forbidden categories throughout the production process. This commitment to zero-tolerance includes ensuring the sanctity of the various sources present in the storage facility and shipping activities.

1.3 Fundamentals of Industry 4.0

Industry 4.0 is an interesting topic in daily discussion for scholars and executive officers today. The concept of Industry 4.0 is applied by European countries especially manufacturing companies in Germany, the US, and other English-speaking countries, by mentioning several other terms, including the internet of things, internet of everything, smart factories, and industrial internet. The study conducted by consulting institution Deloitte stated that the main value of Industry 4.0 is the interface between various intelligent infrastructures such as smart mobility, smart grids, intelligent logistics, smart homes, and buildings (Schlaefer and Koch, 2015). They explained that Industry 4.0 is a digital transformation so that links between business networks and social media networks can increase competitiveness. The internet of things, services, data, and people are all connected parts. Figure 1 explains the development of the industrial revolution so that it reads clearly that the complexity in Industry 4.0 is increasing compared to the previous industrial era.

Price Waterhouse Coopers as a professional consulting agency, states that the drivers of Industry 4.0 are vertical and horizontal digitization which includes value chain
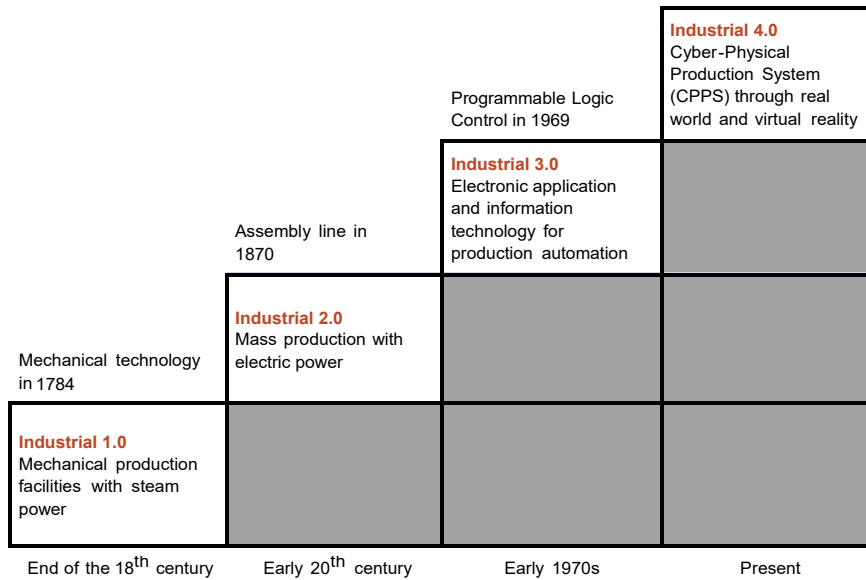
FIGURE 1: *Industrial Revolution Development (Source: Schlaefer and Koch, 2015)*

integration, digitizing product and service offerings, digital business models, and digitizing customer access (Geissbauer *et al.,* 2016). Digitizing means that all data about operations, process efficiency, quality management, and operational planning are available in real-time, supported by augmented reality, and optimized in integrated networks. Value chain integration is carried out vertically across all organizational lines ranging from product development, purchasing, manufacturing, logistics, and services. Horizontal integration is the involvement of outsiders to support the main operating process as a key-value chain partner. This integration needs to be supported by track-and-trace technology to meet real-time data so that execution is more efficient. Companies seek as much data as possible to be analyzed to meet the consumer's needs. Interaction service with customers is excellent as the main characteristic of Industry 4.0.

1.4 *HALAL INDUSTRY*

The definition of *halalan thoyyiban* is the key for implementing *halal* product processing. For example, the Indonesian government published the *halal* products act, namely the Republic of Indonesia Law Number 33 in the Year 2014. Some regulations focused on products, including materials and processing methods. In the context of the supply chain, the concept of *halalan thoyyiban* is an application of the Islamic Sharia to business, and industry practices as a whole encompass materials, products, processes, and methods of business practices. Scope of goods comprises food, medicines, cosmetics, food additives, food supplements, vaccines, clothing materials such as leather, and other products. So, goods that are consumed or used must conform to *halalan thoyyiban* principles.

Industrial activities will involve other sectors needed to support the achievement of business targets. The financial sector in the *halal* industry includes banking and insurance. This sector has not been a concern in the current practice of the *halal* industry. The concept of *halalan thoyyiban* is a concept to guarantee the product or service in terms of *halal,* and the process must *tayyib*. The banking and insurance sectors are supporting the business activities of the *halal* industry. The sources of financing and the method of payment of goods transactions must follow the rules of Islamic Sharia.

Industrial activities will involve procurement, transportation, processing, packaging, storage, and distribution. Every activity requires materials (main and auxiliary) and facilities (machinery and equipment). These components must meet *halal* requirements, namely raw materials not prohibited by Sharia and free of unclean element contamination. Each activity can be carried out by the company itself or using the services of other parties such as sub-contracts or leasing facilities. The *halal* concept requires every actor who produces a product to perform the *halal* concept, including sub-contractors and companies providing facilities for leasing services. Table 2 describes the *halal* industry's characteristics that connect the sources of threats to *halal* and industrial actors.

TABLE 2: *Halal Industry Characteristics*

No	Infringement sources	Actors
1.	Raw material	Suppliers
2.	Processing facilities	Factories
3.	Material and product storage	Warehouse
4.	Transportation	Service provider

1.5 FUNDAMENTAL OF *HALAL* SUPPLY CHAIN 4.0

Jain *et al.* (2010) formulated the era of a supply chain consisting of creation, integration, globalization, specialization, and SCM 2.0. Specification of each era shows the influence of industrial development and management science. Table 3 specifies the supply chain era.

Applying *halal* in supply chains obligates Muslim consumers to consume ingredients (food, beverages, and medicine) and non-food materials such as clothing. Supply chain management is a strategy to compete until the emergence of SCM 2.0. IR 4.0 encourages a revolutionary system for supply chain management with Islam Sharia principles known as *Halal* Supply Chain 4.0. These three components are the pillars of *Halal* Supply Chain 4.0 requirements, namely Sharia *halalan, thoyyiban, halal* industry, and SCM 4.0 (see Figure 2).

TABLE 3: *Supply Chain Era*

Era	Description
Creation	The term of supply chain management (SCM) was created by American industrial consultants in the early 1980s, even though it had become important before the 20th century when the assembly lines were created.
Integration	The use of Electronic Data Interchange (EDI) systems in the 1960s which continued to be developed by introducing Enterprise Resource Planning (ERP) in the 1990s.
Globalization	Aims to enhance competitive advantage with value addition and cost reduction through global sources.
First phase specialization: Manufacturing and single distribution source	Specialization model and core competencies.
Second phase specialization: Supply Chain Management as service	Transportation service provider, warehousing management and non-asset vehicles.
Supply Chain Management 2.0 (SCM 2.0)	Creativity, information and collaboration sharing with user.

(*Source: Jain et al., 2010*)

The *halal* supply chain serves to support the *halal* industry. *Halal* food business activities manifest the commitment of Muslim producers who practice *halal* as a ministerial responsibility. Strong interaction between producers and consumers as Muslim is the basis of the emergence of *halal* responsibilities. The demand for *halal* products increased along with the growth of the Muslim population in the world and non-Muslim consumers. Applying *Halal* Supply Chain 4.0 can be analyzed by adopting the stages of the industrial revolution (see Figure 3).
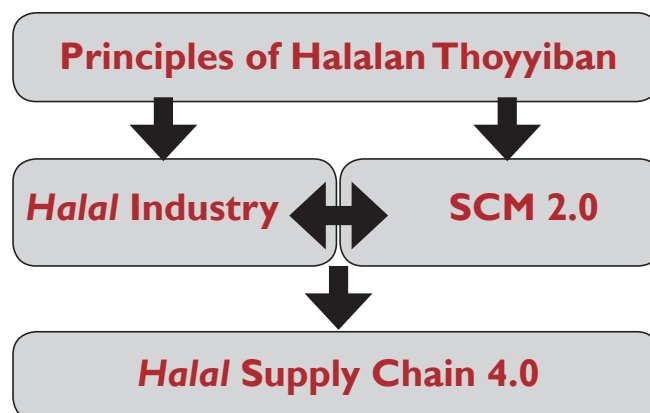
FIGURE 2: *Construction of Halal Supply Chain 4.0*
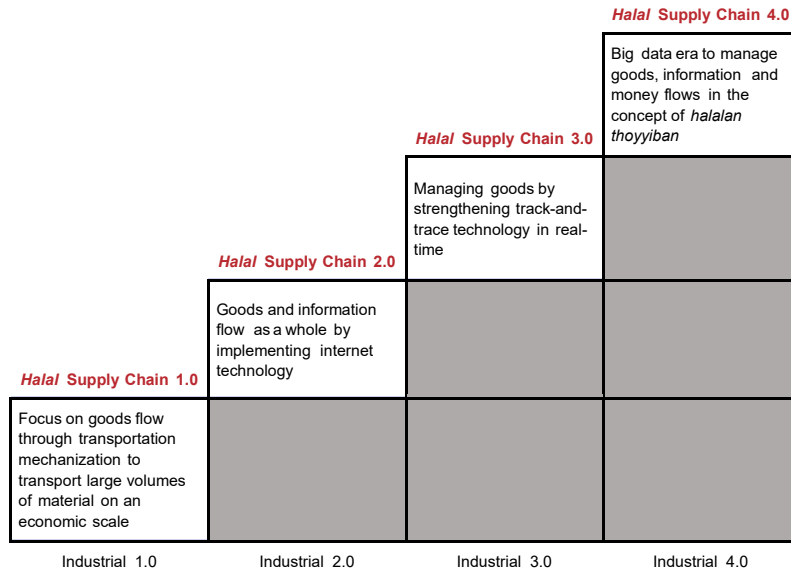
FIGURE 3: *Staging and Characteristics of Halal Supply Chain*

There are four stages and characteristics to achieve *Halal* Supply Chain 4.0 as follows:

1. *Halal* Supply Chain 1.0 in the Industrial 1.0 perspective is the mechanization of production and transportation activities driven by steam power. This era depends on producer religion because the producer's commitment is determined by whether he is Muslim or non-Muslim so that the material may be processed following Islam Sharia. This phase transported several materials, such as livestock, from one region to another in large numbers. The era of globalization broadens the supply of resources so that *halal* recognition needs to be carried out by official Islamic institutions. This era prioritizes a goods flow.

2. *Halal* Supply Chain 2.0 provides internet technology or the World Wide Web to share information using e-mail or websites. Supply chain operations are more efficient because information can be sent quickly, with strong collaboration and more creativity. This era pays attention to the flow of goods and information with the help of information technology. Information technology plays an important role in increasing the efficiency of broad communication. This information technology support can provide supply chain activity reports to all actors but not in real-time. The types of reports provided to customers include a list of halal-certified products via the internet.

3. *Halal* Supply Chain 3.0 exploits information and communication technology as the main backbone. Track-and-trace play a role in building transparency of *halal* product guarantees. Transparency is built through real-time data to inform material flow status

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to all actors such as suppliers, processors, distributors, transportation services, and warehousing facilities. All events in real-time are entered into a database to support decision-making and comply with zero tolerance. This era amplifies goods and information flow with realtime implementation.

4. *Halal* Supply Chain 4.0 replicates the challenge of the digital era. The superiority of the digital era is information supremacy in detail and accuracy. This era answers the emergence of big data by relying on data mining and artificial intelligence. In terms of *halal* products, Industrial 4.0 can fulfill *halalan thoyyiban* in the entire supply chain. In this era, consumers have direct access to information online and in real-time in the entire supply chain. As producers, the digital era is very helpful for optimizing supply chain costs. Collaboration between suppliers, producers, and logistics service providers is more efficient. Islamic financial services can take an important role in embodying *halalan thoyyiban* in interactions among suppliers, distributors, and manufacturers. The issue of payment transactions must be following the rules of Islam Sharia, which avoid usury.

1.6 BIG DATA IN *HALAL* SUPPLY CHAIN

Big data is a challenge and opportunity for the industrial world to understand the market and consumer behavior. Data can realize a powerful strategy to face competitors through boosting efficiencies. Supply chain management employs big data in managing customer needs. Goods status is the main issue in supply chain operations. *Halal* supply chain practices require clarity on the status of goods starting from the upstream to the goods received by consumers. Goods flow recorded as big data provide benefit to the producers and consumers at the same time. Consumers can trace *halal* status in a whole supply chain, and producers may quickly clarify if the customer needs clarification about material source and processing. This strategy is to enhance visibility and in-depth insights into the entire supply chain.

Big data helps to describe a large volume of both structured and unstructured data. The source of big data encompasses machines and people that interact with structured or unstructured processes using internet-enabled devices to document information. For example, smartphones, android tabs, social media, voice records, videos, and photos are raw data in terms of the big data model. This data type is enormous and dynamic. People communicate every day using text, photos, videos, recordings about real situations. As consumers, they can post a particular product as free promotion or complaint. In companies, the big data sourced from regular and sustainable activities such as ERP, CRM, financial software, etc. Thus, the big data model is a monumental discovery for information system design and development. In conjunction with the latest analytics technology, big data

enables companies to quickly gain useful knowledge from massive volumes of structured and unstructured data from multiple sources.

Various sources of big data become a distinctive challenge in *halal* supply chain management. The principle of *halal* is to be transparent and document detailed and complete information. Three elements of the *halal* supply chain, namely *halal* certification, *halal* control, and *halal* monitoring systems. Material procurement production process, transportation of materials and products, and storage must apply these elements. Many parties are involved in this system, such as supplier, processor, distributor, and retailer. Each of the parties and activities generates big data required by the *halal* supply chain to verify the conformity of goods. Complexity will grow up for the global supply chain.

Unavailable data and inaccurate information on problems are challenges. When an organization can analyze big data to generate information, then it may do better planning. Strategic business steps are important in making decisions. Big data analysis explores hidden patterns, unknown correlations, market trends, customer preferences, and other useful information to support organizations' more informed business decisions.

Big data accomplishes information systems in terms of data collection, data management, and data utilization to support business needs, spread new business models, and improve existing processes. Big data and supply chain management face the same problems as generating data: volume, velocity, variety, veracity, and value. Benabdellah *et al.* (2016) formulated big data in supply chain management, as seen in Table 4.

The strategic role of big data can improve responses to *halal*-related issues. Big data in the *halal* context contributes to increased benefits, cost efficiency, customer satisfaction, and traceability. Big data is collected and analyzed using real-time information so that decision-makers can optimize, monitor, and control processes according to *halal* principles. Real-time information and various big data sources are more valuable compared to static historical information. This information assists in the decision to accept or reject the product. If a company finds violations of *halal* principles, the company must reject all of these products. This situation reflects a big loss because all parties are involved in making a new product. Otherwise, real-time information is very helpful for management in controlling the process according to *halal* standards. The benefit is eliminating the risk of violating *halal* principles. The result is reduced product defects, and ultimately real data can reduce costs resulting from rejected products.

Customer satisfaction and traceability are complementary elements. Customers will be satisfied when *halal* principles can be traced direct and indirectly. Direct means material flow can be monitored online and real-time while indirect provide material flow record

TABLE 4: *Big Data of Supply Chain Management*

Aspects	Big Data	Supply Chain Management
Volume	E-mail, social media mentions, photos, video clips, sensor data, etc. may generate every second	Several data emerge every second from sensors, bar codes, ERP, and database technology
Velocity	Data is produced and collected in real time through streaming.	Its main speed depends on data collection, the reliability of data transfer, the efficiency of data storage, the speed of excavation to find useful knowledge, models and and decision-making algorithms.
Variety	Multiplying source of data as well as structured data, semi-structured data and unstructured.	Variety of source, heterogeneous format, some sensors in factories, highway, retailers and particular consumers
Veracity	Double the data source is structured, semi-structured and unstructured. Refers to chaos or belief	Extensive data from SCM usually varies due to various sources, heterogeneous formats and various sensors used at the location of factories, highways, retail stores, and facilitated homes. It is not easy to examine the impact on insights, benefits and business processes in both sector and report values, statistics, and decisions.
Value	More subjective aspects are associated without exploitation of this large data set	Difficult to check impact on insight, benefit and business process based on organization report, statistics and decisions.

(*Source: Benabdellah et al., 2016*)

completely. Data can magnify customer satisfaction significantly. Traceability must monitor intensively from upstream to downstream. Data monitoring as a traceability process can control quality and *halal* practice in the entire supply chain system simultaneously.

1.7 BLOCKCHAIN IN *HALAL* SUPPLY CHAIN

The blockchain is a safe and permanent transaction approach between parties using distributed ledger technology. Blockchain operates by eliminating the role of intermediaries as third parties to verify, record, and coordinate transactions. This approach can be performed because of the application of a shared database between many parties involved.

In summary, the blockchain is a peer-to-peer distributed ledger technology that securely and permanently records transactions between parties within a block. Blockchain's virtue is to provide a trusted, accountable and transparent environment. The blockchain is a ledger shared among a network of stakeholders that one administrator cannot update,

but it can update with a collective agreement. A similar process can track other asset transfers, commit new data in the blockchain, and update data on the blockchain.

Halal or haram is a decree of Allah, prohibition of certain materials because of impurity and harmfulness. *Halal* practice must leave doubts behind. If a party violates the *halal* principle, goods are non-*halal* goods, and responsibility of all the parties in the entire supply chain. Creating and distributing *halal* goods is extraordinarily complex due to the involvement of several stakeholders, diverse interests, and any third parties. Blockchain is a suitable system to manage these complexities. The degree of complexity depends on product demand and flexibility. The supply chain depletes over a hundred locations at some stages, including international locations, diverse invoices and payments, business entities, and time involved. Trust and commitment to *halal* practices among all the parties are extremely important. Blockchain efficiency depends on skillful management of complexity and enhancing transparency.

Blockchain implementation in the *halal* supply chain can increase efficiency because it greatly reduces bureaucracy and documents. All information converts to digital format so that decision-makers can trace through automated processes. Blockchain works with advanced database development to track the product's life cycle and transfer ownership from origin to final sale, including material sources, processing, logistics service providers, distributors, retailers, and consumers. Each actor can build a direct relationship. Data validity can be supported by cryptographic techniques to guarantee identical copies, transactions not duplicated, and access to data with special permissions.

Blockchain is more efficient and cheaper because it facilitates and tracks transactions and regulates data transactions. Data management of blockchain is a combination of distribution, decentralization, and consensus distribution. Even though the ledger is shared, the level of security is higher and ensures that previous records cannot be corrupted using cryptography. Cryptography is a coded message. It is like a decoder ring, but it is much longer and harder to solve.

The involvement of many parties in the *halal* supply chain requires consensus. Blockchain synchronizes data upon approval by members only. The data in the ledger in each supply chain actor are the same as each other. Blockchain classification is a blockchain with permission and a blockchain without permission. Licensed blockchains require prior approval before use, whereas unlicensed blockchains give direct permission to anyone who participates in the system. Both of them cannot be used at once, even though they sound similar. The identifier enables an organization to set its policies and rules regarding transaction details and data access. Otherwise, permissionless blockchain allows anyone

to join the system. The unlicensed blockchain is safer because it carries more ledgers to confirm or deny claims. The unauthorized blockchain reduces bad actors from entering the network.

How to anticipate breaking of the *halal* supply chain? It is good to question in terms of blockchain implementation. The *halal* supply chain is a simple practice because geography is local and business entities involved are few. The Muslim population has been growing rapidly and spread worldwide, leading to the globalization of *halal* manufacturing. *Halal* goods demand has been increasing significantly. Blockchain's main challenges are incredibly complex for customers to understand the true value of halal due to lack of transparency, producer's temptation to illegal practice, and communication between parties.

Blockchain facilitates transparent transactions across multiple copies of the record to many computers. Blockchain allows consensus so that there is no controversy in entire transactions. The parties on a block cannot erase the same version of records and documents. *Halal* goods producer uses blockchain technology to track food from the raw material source point to consumers. This pattern ensures and certifies to the consumers that they are purchasing the *halal* product. Table 5 shows an example of conceptual blockchain.

Companies can create added value when they apply blockchain in context to implement a *halal* supply chain. *Halal* supply chain parties have high-quality data to transfer real-time speed across the supply chain tiers. Blockchain capability increases valuable *halal* operations using effective traceability, process acceleration, and cost reduction. The *halal* supply chain is facing complex data sets so that blockchain can be replaced by automation. The performance of parties in a blockchain is verified. It is helpful to control each other in processing goods following *halal* principles. Shipping and warehousing are elements crucial in replacing manual to be automated. Traceability in blockchain adds value by detracting the *halal* zero-tolerance cost problem. A product is categorized as *halal* if it is free from the elements that are prohibited. Supply chain management must ensure the achievement of this *halal* standard to control zero-tolerance guarantees. The manual process could increase cost because a large number of data set copies are created and maintained.

1.8 CONCLUSION

Halal Supply Chain 4.0 is a competitive strategy concept from the *halal* industry to ensure *halal* product status to meet consumer needs and increase competitiveness. The basic principles of SCM 2.0 and Industrial 4.0 encourages the development of *Halal* Supply Chain 4.0. Maximizing trust and commitment is an important issue to develop *Halal* Supply

TABLE 5: *Blockchain Conceptual for Halal Supply Chain*

No	Parties	Activities	*Halal* Aspect
1	Suppliers	– Procuring and shipping goods – Supplier propose a transaction to producer	– Upload data of slaving process and footprint of transporter as a clean facility
2	Producers	– Producer verifies transaction involving contracts, records, or other information about *halal* components – Producer proposes a transaction to distributor	– Tracing goods flows using record data that tagged chip on goods – Add information using code on packaging
3	Distributors	– Distributor receive notification about goods that have been approved by producer – Distributor verifies transaction involving contracts, records, or other information about *halal* components – Distributor proposes a transaction to the retailer	– Tracing goods flows using record data related with *halal* information
4	Retailers	– Retailers receive notification about goods that have been approved by distributor – Retailer verifies transaction involving contracts, records, or other information about *halal* components – Retailer control inventory level	– Tracing goods flows using record data related with *halal* information

Chain 4.0. Characteristics of *Halal* Supply Chain 4.0 analyzed big data into information and presented it online or recorded as part of proving the fulfillment of *halal* Sharia. This concept integrates material, information, and money flow with a financial system. The Internet of Things, the industrial internet of things, and the internet of everything are the backbone for generating big data. Blockchain is the technology to manage the transaction of actors in the entire supply chain. Blockchain using big data is the key to success in implementing *Halal* Supply Chain 4.0.

The supply chain consists of material flow, information flow, and money flow that generate data to manage operations. Material flow is related to the movement of materials from upstream to downstream. Information flow is the processing of data from upstream to downstream. In contrast, money flow is the payment of goods from all parties involved from upstream to downstream. Big data can support many areas, namely finance, manufacturing, market, website, social media, etc. Big data can become a new capability with the competitive advantage to practice a *halal* supply chain. Parties of the supply chain can augment visibility and harmonize demand fluctuation in real-time, including *halal* issues as the fulfillment of customer behaviors and patterns.

Blockchain is a sophisticated technology that verifies and coordinates transactions with shared databases among supply chain parties. Value addition of blockchain is increased supply chain transparency and automation of administrative operations. Blockchain is integrated with the internet of things and artificial intelligence, strengthening the *halal* supply chain.

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The Application of Blockchain in Food Safety, Production and Marketing: Taiwan Perspective

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2.1 SUMMARY

With the changes of the times, the process of food production and marketing has increasingly diversified. Food safety has also become an important issue of concern to the public. Although there have been different solutions in the past, they have not been able to solve problems conveniently and thoroughly. The development of blockchain technology not only allows us to see the prosperous development of virtual currency, but also it brings great inspiration to the information industry, who are now actively exploring possible changes in the future and trying to apply this technology to food production and marketing.

This article is based on the challenges faced by Taiwan's food safety, food production and marketing. In addition to the introduction of the blockchain, it includes the food safety traceable blockchain, fishery product traceable blockchain application, food production, marketing blockchain application program, and the cases such as blockchain ecosystem. Hope that readers will have a clearer understanding of the application of blockchain in the food industry through these case studies.

2.2 INTRODUCTION AND BACKGROUND

2.2.1 Food safety importance to national health

Food is the source of nutrition on which human beings rely. The food industry has a long history. From the perspective of human civilization history food supply and consumption is assumed to possess a quite mature operational and management mechanism over thousands of years. Since the arrival of the industrial era, however, food safety problems have frequently occurred. Particularly in recent years, though science and technology has made great progress, food safety related incidents have increased instead of going down. Food safety issues were sporadic and isolated in the pre industrial era as there was no mass produced chain in that era. Most of the food was produced and consumed locally

in its natural form. One of the reasons for increased food safety issues in the industrial era could be due to businessmen pursuing profits while deliberately seeking to reduce costs, and intentionally or unintentionally they tend not to pay attention to the baseline of morality to supply safe food.

In addition to the "Thousand-faced-man" beverage-poisoning incidents in Japan and Taiwan in the early days, the following are some of the biggest incidents among all international food safety incidents in the 21st century:

1. July, 2000, the "Snow Brand Milk Products Co. poison milk incident" in Japan. The staphylococcal-contaminated raw milk was produced into low-fat milk and hit the store shelves, eventually leading to food poisoning of 15,000 people (Shippai.org).

2. September, 2008, infants who drank milk powder produced by SanLu Group Co., were found to have kidney stones. Shortly after, melamine was found in milk powder, resulting in 12,892 hospitalizations and 4 deaths (Reuters.com, 2008).

3. July, 2014, Shanghai Husi Food Co. provided expired meat products to McDonald's. Japan's McDonald's and Family Mart convenience stores were also affected (Forbes.com, 2014).

In Taiwan, there are several local food safety incidents. Although the health and hygiene units have regular inspections, food safety incidents still occur. Incidents happen every now and then, such as these three incidents cited by Lin *et al.* (2016):

1. May, 2011, the Plasticizer Incident. The Department of Health seized beverages and food illegally and added toxic plasticizer DEHP. There are tens of tons of concentrated fruit powder, fruit juice, fruit pulp, yogurt powder, etc., made by illegal cloudy agents. The offenders include many well-known beverages and food manufacturers.

2. May, 2013, the Toxic Starch Incident. The manufacturer added the sweet potato powder into unapproved maleic acid, highlighting that large food companies did not strictly control their raw materials.

3. October, 2013, the Adulterated Oil Incident. The manufacturer added low-cost sunflower oil and cottonseed oil to edible oil, and also added copper chlorophyll for toning.

Food is quite diverse and complex, and the food safety problem is also very complicated. It is not easy to solve the food safety problem. However, it is generally believed that making the production and exchange process of the food industry chain transparent is an important and foremost step in solving the food safety problem.

2.2.2 Blockchain technology content

First, the virtual currency mechanism proposed by Satoshi Nakamoto, bitcoin, was considered to be the earliest application of the blockchain. It was intended to establish an operational mechanism that all parties can trust under the framework of decentralized management, but the name of the blockchain was not clearly defined then. However, through the description of thesis, it can be seen that the characteristics of the blockchain which Nakamoto (2008) recognizes, include: peer-to-peer network transmission mechanism, consensus mechanism proved by computing power, block content structure that cannot be tampered, maintaining privacy via asymmetric encryption and signature mechanisms.

After nearly a decade of development, the blockchain has the following five characteristics:

1. **Distributed Database**

The parties involved in the blockchain have the right to access all the information on the blockchain. There is no single party that is in control. When it comes to verifying the correctness of the data, all parties have the right to verify.

2. **Peer-to-Peer Transmission**

Direct transmission from node to node, without the need of a unified central node to transfer or a management mechanism similar to an address book, each node can store and transfer the message to other nodes, and all nodes in the blockchain share information.

3. **Transparency with Pseudonymity**

The transaction information on the blockchain can be shared by everyone, so all the participants can theoretically see all the transaction information, which can ensure the transparency of the data. However, each participant does not record with a real name, but with an account pin represented by a string of numbers. Although the information can be seen, it does not relate to whom this information belongs to and thus anonymous. Only when the counterpart of the transaction is willing to show the identity information, can the object of the transaction and the content of the account be known.

4. **Irreversibility of Records**

One of the important features of the blockchain is that once the record is registered on the blockchain, it cannot be changed or deleted after confirmation and remains permanently on the blockchain. Subsequent records will only continue to be recorded in sequence.

5.   **Computational Logic**

In addition to the account book mechanism, the computational logic has the most developing potential in the blockchain, also known as smart contracts. This is a piece of code that can link to the transaction ledger and sets the conditions. Once the conditions are met, the code will be executed.

If the above-mentioned blockchain characteristics are properly used, it is expected to solve food safety, production and marketing problems currently faced by the industry and these challenges could not be solved in the past.

2.3 ANALYSIS OF BLOCKCHAIN APPLICATION ON FOOD SAFETY AND SOURCE TRACEABILITY

2.3.1 Correlation between food control and source traceability

When it comes to Food Control, it is mainly divided into two parts in accordance with the degree of influence – Food Safety and Food Quality. Food safety involves health hazards. Whether intentional or not, it is an important protective issue in modern society. The quality of the food is relatively mild, mainly those that do not conform to the specification, such as offering expired products or replacing ingredients with low quality or low-priced ones. Although there are differences between the two, traceability is a basic requirement in the food field. Only by tracking and tracing can we obtain complete information, and other management measures can be implemented.

Traceability alone does not guarantee food safety. However, when it comes to food safety issues, traceability is a risk management tool. The importance of tracking and tracing is reflected in two aspects. As far as health is concerned, if a problem is found, it can immediately track the whereabouts of the food with problem, notify it to remove them from the shelves, thus reducing risk and prevent people from consuming it, while acting as a layer of protection for the health of the people. In addition, after the food safety incident occurs, it can be used to find out the root cause of the problem, and further track problematic raw materials that have been sourced facilitating corrective actions.

Moreover, with tracking and tracing mechanisms, potential huge economic losses can be avoided. From the industrial point of view, since there is a complete tracking mechanism, the root cause of the problem can be identified in advance, reducing the loss of cost, therefore, the range of influence can be found more quickly and damage control can be done. It may help in avoiding complete removal from the shelves due to failing standards. Otherwise, it would be a great damage to both the industry and social confidence.

The meaning of food traceability covers different opinions, but the general concept is that during the delivery process of food production and transactions, relevant information can be fully recorded to facilitate the search for the initial source of its ingredients, or to know where it has been finally sold.

The International Standards Organization (ISO) has many regulations on this:

1. According to the ISO 8402 standard, the definition of traceability is: "the ability to trace its history, application or location, etc., via the direction of the record".

2. ISO 9000 is extended beyond the facts that have already occurred, including also those still in the planning process. The ISO guidelines also emphasize that tracking and tracing should include the source of the raw materials, the production process, and the information about the end point also, where the product is sold.

3. The European Union's Code 178/2002 also addresses the traceability of the food industry and considers that "traceability" refers to the ability to track food, feed, and animals or substances that provide food. For each stage of the food production process, including production, processing, transportation and sales, etc., it is considered that it is necessary to trace the whole information along the supply chain members.

From the tracking and tracing direction of the supply chain, tracking and tracing can be divided into internal traceability and chain traceability or external traceability, which are respectively aimed at internal traceability of single-company operations throughout the entire supply chain and cross-company traceability across the entire supply chain.

2.3.2 The difficulty of tracking food safety is expected to be solved effectively by using blockchain

Internationally, there are some corresponding regulations for tracking and tracing, which have been implemented in advanced countries and have become necessary to comply with. Such as:

1. EU directive 178/2002, which came into force on 1/1/2005, requires EU members to implement tracing control on all food and feed.

2. US, the Bioterrorism Act of 2002, requires those who enter, produce, manufacture, package, and transport food to establish maintenance records and allow the FDA to request access.

3. The US FDA's Food Safety Modernization Act (FSMA) became effective on 4/1/2011 and became a law.

However, efforts over the years have been limited to the supply chain environment of individual vendors and could not be fully promoted to the overall industry. This is because the existing systems are the efforts of independent individual manufacturers. In order to enhance the brand value of their own products or the manufacturers themselves agree with the concept of food safety, utilizing the influence of their own companies in the industry to promote cooperation between upstream and downstream manufacturers in order to promote the footprint traceability of their own products. Although their efforts are worthy of admiration, there is still a considerable distance to its full implementation in the food industry. Observing the root cause of its problems from a business perspective, there are several reasons:

1. The industry lacks mutual trust and the cooperation can't work out due to the competitive relationship between them. There is a competitive relationship between up/downstream and those of the same trade. Disclosure of too much information also means that the competition strategy is exposed, and manufacturers are unwilling to cooperate.

2. The industry lacks standards, making information interconnection difficult. The data connection includes two parts: internal traceability and external traceability. First, the internal production process of the company traces the link from raw materials to finished products. This is the traceability of internal production. In addition, cross-company transactions, the transfer process of goods is part of the external transaction traceability.

3. The platform architecture is limited, and the cooperation procedures for small factories are cumbersome. Taiwan's current industry ecosystem is based on large factories. Since they have the advantages as buyers or sellers, the up/down stream cooperating small factories can only cooperate in one-way. However, most of the small factories do not do business with only a single large factory. They must cooperate with many large factories, and each has its own structure. If there are no reasonable multi-to-many operation methods, there will be many inconveniences in the operation.

4. Worried that costs are too high, investments affect operations. Since tracking and tracing involves the entire supply chain and even the process changes of the entire industry, the industry is worried that the investment is too high, and they tend to hesitate a bit.

5. The effect is difficult to grasp, and it is uncertain whether consumers will pay for it. In addition to worrying about the cost of investment being too high, it is unable to know whether the consumers would accept it, therefore manufacturers' hesitation is

inevitable. Whether the food safety is easily forgettable for the consumers, the changes in the market still need to be observed through time.

In addition, from the consumer's point of view, the traceability of food is provided by the manufacturer. If the manufacturer deliberately defrauds, most consumers can't identify. Unexplained doubts can also cause consumers to hesitate, so the cycle allows manufacturers to question the effect of implementing the traceability mechanism. Such a vicious cycle only makes the problem unable to be solved.

In recent years, due to the development of blockchain technology, the industry has found that the immutability and the mutual-trust-establishing characteristics of the blockchain may help the construction of the production footprint. Therefore, the introduction of this technology has become the implementation of active exploration of food tracking.

2.3.3 Food-tracing blockchain application

The construction of the production and sales resume is mainly for the transaction object, item, batch, quantity and other information in each step of the production, processing, packaging, transportation and sales of the product. The possible use of this information includes several aspects:

1. Traceability of ingredients: Consumers want to know what are the ingredients and sources of the things they've eaten. Manufacturers also hope to have a clearer understanding of the relevant information of their own products. On the one hand, this makes them more confident in their own products, and on the other, boosts the brand image.

2. Removed and recalled: In addition to making the source traceable, the product flow can be clearly understood in the tracking data of the blockchain. Therefore, should incidents of food contamination occur, clear information can be complied with about in which finished products have the contaminated raw materials been used, and which batches are affected, in order to remove them from the shelves or recall them.

3. Preservation time: The refrigeration technology can improve the shelf life of food, but the quality of the refrigeration and application process is difficult for manufacturers to control fully. In particular, the control of the cold chain quality of agricultural products directly affects the number of days that products can be put on sale, the scheduling between stores, the number of days that consumers can enjoy after purchase, and even the amount of waste that is expired.

4. Production specifications: The process of production in food processing factories must comply with safety regulations such as Hazard Analysis Critical Control Point (HACCP) to ensure that manufacturers abide by standard procedures of the SOPs. However, will there be any uncertainties in the relevant information? For the purpose of internal audit and ensuring that the production process can meet the specifications, the management unit can directly load the data recorded by the production equipment into the blockchain, thus preventing the alteration of the data.

To establish a system for tracking and tracing, we need to first define a traceable resource unit, that is, what is each tracking batch? Then we can further define that the information is indispensable for inter-agency tracking. Determine the content of the data, and then review whether the cross-institutional corresponding is correct.

1. Traceable Resource Unit (TRU): According to the GS1 standard, it is defined as "any item upon which there is a need to retrieve predefined information and that may be priced, or ordered, or invoiced at any point in any supply chain". In fact, it usually refers to the batch, which is the smallest unique identification unit created in the internal production process. The design of the TRU is the first factor that determines whether the traceability system is successful or not. The transformation of TRU comes from the operation in the process. The process of production in a single company, will cause splitting and polymerization between batches due to different production machines, different sources of materials, etc.,

2. Tracing the common information content: Although the source of the tracing data is from different companies, the data items should be the same, so that they can be aggregated into a whole series of traceability data. However, to organize this information, first define the events that need to be collected, including:

*   Shipment (delivering goods to customers);
*   Receiving goods (receiving goods from suppliers);
*   Production process (including cleaning, cutting, packaging, etc.);
*   Consumption (user consumption or expiration discard).

The content of the data mainly includes:

*   Company organization (owner of information);
*   Trading partners;
*   When and where the event occurred;
*   Food items;

- Batch;
- Unit and quantity.

The special information to be noted is the acquisition of the order forms, including the numbers of customer orders, purchase orders, manufacturing orders, delivery orders, etc.

3. Correspondence of cross-organizational data: After the data is obtained, the data concatenation process will reveal that the data may come from different companies and may be synonymous (the names of the data are different, but the meaning is the same), or on the opposite, they have the same name but different meanings. There are three types of data for which correspondence has to be processed:

- Trading partners;
- Transaction batch number;
- Item number.

Among them, the transaction partner has a Government Uniform Invoice (GUI) number, making it easier to handle. The transaction batch number is mainly for the internal manufacturing and working orders of the company, or the documents of internal goods transfer. Due to internal use only, plus the company's GUI number, the uniqueness of it can be distinguished. Practically it is possible to follow all these steps. Intercompany invoices, such as orders, shipments, etc., will also be operated by the internal systems of both parties according to the same number, since the data transfer process must be confirmed by both parties, therefore it won't be a problem.

The problem is that the item numbers and the company numbers are inconsistent, which makes it impossible to correspond. The intuitive idea is to compile a unified numbering system. The principle of numbering is that the same item cannot have two different numbers, and two different items also cannot have the same number. However, this method does not work because the national unified number is too large and difficult to maintain. How do you know the goods to be numbered and have not been numbered in the past? The number will not be repeated. The number is not only for the computer, but also for people to read, if the staff can not tell the difference from the meaning of the number, it will greatly reduce the work efficiency.

The same goods, numbered differently in different companies, have different logic of their usage behind them. Simply taking sugar as an example, the company that produces sugar has a variety of sugar products in the company, so it is necessary to subdivide the types of sugar, perhaps from the ingredients, or from the manufacturing process, according to

the company's operational usage. But for a company that makes bread, it may be as simple as distinguishing between brown sugar and white sugar. The logic of distinction is color, and over complicated numbers might just confuse the staff. Therefore, we understand that having national unified numbers is not feasible, let alone international.

The method of processing is to establish a correspondence between the numbers, and only the two parties of the transaction have to establish a comparison chart of the item numbers corresponding to the two parties. This way, the traceability mechanism can be extended. The other is to adopt the central standard number in correspondence. As mentioned above, it is still necessary to establish a national numbering system. The difference is that it is not for direct use, but merely for corresponding, each company can still maintain their own numbering system. The advantage of this is that each company does not need to compile a comparison chart with each transaction partner, they just need to make a comparison chart with the central numbering system. The shortcoming is that correspondence mistakes are still likely to happen. Same items, and two dealing companies, due to various judgments of the personnel, they are corresponded to different central numbers, which still causes errors (Chain Agri Digital, 2017).

2.4 CASE DISCUSSION

2.4.1 Case one: Fishery-products-sourcing blockchain application

Taiwan is an important fishery resource country in the world. According to the statistics of the Agricultural Food Organization, Taiwan is one of the countries that fish in the six main high seas in the world and ranks 20th in the world in terms of sea fishing. Taiwan's fishery production can be divided into four major projects, including offshore, inshore, coastal fisheries and aquaculture. In 2016, the annual output is a total of 1005,800 metric tons, of which offshore fishery production accounts for 58%, of which 91% are exported from Taiwan. While the global market is paying more and more attention to food safety and food sources, how to upgrade traditional fisheries to meet the international trend, the transparency of food production and marketing processes is a major challenge (Taiwan Fisheries Statistics Annual Report, 2016). In future, Taiwan may apply blockchain technology to convince consumers that their amount of catch is within the legal quota.

The Provenance Company, UK's case can act as a mirror. The company uses blockchain and smart label technology to track fish caught by fishermen in Indonesia. This case has been reported in several articles. The main technique is to mark each batch of fish with a unique ID so that it can be digitized and the products can be tracked in international circulation. Traditionally, when fish are caught and processed to a table, consumers can only see processed products, from which sources of their ingredients are indistinguishable.

Consumers in Europe have a large demand for tuna, which in turn causes a large amount of fishing. The main source of this fish is Indonesia. However, the fishermen at the grassroots level in Indonesia have not benefitted from this blockchain application. Instead, large fishing companies account for the majority of the market share and benefits. Due to the productivity gap, the traditional fishermen who rely on fishing for their livelihoods can hardly make a living. Therefore, whether the source of this fish based on the blockchain technology is in line with justice, whether it is in line with the application of conservation and recycling economy, and whether it has been produced by sweatshops workers while the profits falls only into the pockets of capitalists, has gradually become a topic of concern for European consumers.

Provenance believes that the application of blockchain technology can offer a ray of light in solving this problem. The company first lets the participating fishermen join the membership. From the time they become a member, they must register on the blockchain. Each operation after the fishing begins has to be registered on the blockchain, including catch resale, slaughtering, processing, and even packaging production. In order to facilitate the operation, the fishermen can register with the mobile phone, and the user mobile phone can read the relevant production footprint from the smart label on the packages. In this whole process, the blockchain plays the role of an impartial third party. Due to the immutability of the data registered, it established a highly reliable data system.

The contribution of this case is not only the establishment of a leading food production footprint which applied the blockchain technology, but also a demonstration of the solution to the questioning of the data authenticity. Generally speaking, there are two doubts about the use of blockchain in the traceability of food production history. One is the necessity of using blockchain, and the other is that though blockchain is immutable, if the data is forged from the beginning, the blockchain cannot prevent it.

The necessity of using blockchains is based on the premise that multiple parties do not have trust between each other. If there is a centralized management organization with considerable credibility, blockchain usage may increase the trust between parties. This case is a mechanism for transnational operations. It is not easy to have a management organization. Even if there is such an organization, it is not easy to establish credibility in the short term, while blockchain has its quickness and feasibility. Secondly, how to ensure the authenticity of the original data, such as the registration of the basic information of the fishermen, the time, place, method and process of the catch are all authentic information. In addition to the use of timestamps in the blockchain to establish the time sequence during the process, and to lower the chance of data tampering, this case also makes use of the cooperation with local public welfare organizations to improve the credibility of the data

through third-party verification, so it can really reduce the doubt that the data may be forged.

The third-party may also help in data selection. As data is the main focus in the blockchain, the management needs to consider what data and how to collect data that they will input to the blockchain. The third-party may help to select or filter the input data in order to make sure all data is useful, so less garbage in and less garbage out. This also can be done by passing the responsibility to the third party to manually enter the data.

2.4.2 Case two: Food production and marketing blockchain application program

The global population will break through the 8 billion mark in five years. In particular, Taiwan is densely populated and has a heavy environmental load. The supply of food needs to be more efficiently used. Growers, processors, carriers, retailers, regulators and consumers should have this awareness to maximize the benefits of Taiwan's food supply.

In recent years, with the development of blockchain, Taiwan IBM has also begun to pay attention to the issue of food production and marketing, security and the possible application of blockchain. Arvind Krishna, senior vice president of Taiwan IBM Hybrid Cloud, said: "With the impact of climate change and limited water resources, our food supply will only face more and more challenges. To be able to face this future, we will need new breakthroughs in technology, science, and equipment."

According to statistics, up to 45% of the fruits and vegetables grown by farmers are wasted (IBM, 2018). Taiwan IBM believes that from farmers to food suppliers, every participant in the supply chain must be aware of the amount that needs to be planted, ordered, and shipped.

When blockchain, Internet of Things (IoT), and AI algorithms are integrated, this type of problem can be solved. To put it simply, the IoT device can track the process of fruit and vegetable from harvesting to retailing. The AI algorithm helps the retailer find out the consumer's eating habits through data analysis, so that the fruits and vegetables can be ordered at the right time, avoiding excessive purchases and causing waste. Also, the fruits and vegetables that consumers buy are relatively fresh, (Andreas Kamilaris, 2018).

The concatenation of upstream and downstream information relies on blockchain technology. Through the decentralized ledger, the condition of the entire vegetable and fruit supply chain is recorded. When the information is safe and transparent, the information gap between the production and the sales as well as the wastage of fruits and vegetables can be reduced (Built to Adapt, 2018).

So Taiwan IBM proposed the Taiwan IBM Food TrustTM solution, which is built on the base of the blockchain, enabling all network participants to benefit from a safer, smarter and more sustainable food ecosystem. The digitization of transactions and data provides a more efficient way for the cross-supply-chain operation, including growers, processors, carriers, retailers, regulators and consumers. The solution allows authorized users – from farms to stores to the ultimate consumers – to instantly access actionable food supply chain data. The complete footprint and current location of any individual food item as well as the accompanying information (such as vouchers, test data and temperature data) will be available in a few seconds once uploaded to the blockchain.

The Software as a Service (SaaS) solution is dedicated to ensure that trust can be carried out rather than hinder the expansion of food systems. By providing safer food, longer shelf life, reduced waste, faster traceability, and easier access to shared information, IBM Food Trust enables the food production process to meet new standards of transparency and trust.

The blockchain can help achieve business goals such as traceability, compliance, and freshness by enabling a comprehensive ecosystem. The blockchain solution is not just technology, it also solves business problems that were previously unsolvable due to the inability of the ecosystem to share information in a transparent and unshakeable way. Unlike other recording systems, blockchain technology provides a credible record of data. Chain technology creates unprecedented visibility and accountability in the food supply chain.

The blockchain provides the foundation for next-generation transactions, building trust and transparency while streamlining business processes. Some blockchain networks (such as Bitcoin) are public and anonymous networks. Anyone can join and view any transactions that occur on the web. These networks typically require resource-intensive computing to help prevent fraudulent transactions. Conversely, the IBM Food Trust's blockchain solution is licensed, and the invited members will know exactly who they are trading with, similar to the current situation between current business partners. Participants will also decide what information can be seen by whom, in order to provide information that must be understood. Smart contracts are also used in our blockchain, allowing business logic to help resolve disputes, automate contracts and build trust.

IBM Food Trust provides the highest level of commercial tamper-resistant food supply chain transaction data protection. Use the IBM Cloud to provide the sole protection against internal authentication abuse, malware and hardware encryption protection.

Its features include:

• Provides continuous, uninterrupted high availability with seamless software and blockchain network update projects;

- Enhanced security stack without privileged access (blocking malware);
- 24/7 IBM blockchain support;
- Built-in blockchain monitoring with full network visibility;
- Adopting Linux Foundation's Hyperledger Fabric technology.

(Source: IBM Food Trust™ https://www.ibm.com/downloads/cas/EX1MA1OX)

IBM Food TrustTM is the only solution of its kind that can connect growers, processors, distributors and retailers with certified, permanent, shared food system data records via network. Simplifying the food footprint from farm to table involves many transactional processes between different staff and companies to be able to share transactional information safely and efficiently among the actors in the supply chain, with the goal of improving food for everyone.

(IBM Food Trust™ https://www.ibm.com/downloads/cas/EX1MA1OX, 2019)

2.4.3 Case three: Blockchain that combines the campus and surrounding food vendors

Ecosystem-Blockchain of University and Shops (BUS) Coin & Local Economy

In terms of food, the value of the blockchain, in addition to the application of the production process, is also a topic of concern for promoting sales. Professor Lee Tzong-Ru of National Chung Hsing University (NCHU) started from this point of view and established the BUS coin currency ecosystem on the campus. For one thing, to encourage students to increase participation during class, and for the other, with the issuance of BUS coins, the students are allowed to spend them at the cooperative vendors and get concessions, thus promoting the economy of selling food stalls near schools and increasing their income (Lee *et al.*, 2018).

NCHU spent about 30,000 US dollars in research funding, and commissioned the Institute for Information Industry (III) to develop the platform of Blockchain for BUS coin.

Through the efforts of Professor Lee and the cooperation with the institute, the first phase of implementation is as follows:
- There are 100 students who actually participated in the program;
- There are 5 small stores that actually participated in the project;
- 1 coin is equal to 1 NTD (New Taiwan Dollar, 1 US dollar = 30 NTD);

- Teachers are able to link each student wallet to a student identity;
- Students can exchange the tokens between themselves;
- The small stores we chose are the stores which had no money in the past to promote themselves.

It is hoped that through the establishment of this blockchain Ecosystem, the project will be tested on a small scale and continuously modified during the process, with a view to maximise the benefits of the school/students/surrounding vendors through the issuance of BUS coins.

The case is also extended to a large scale in the next year. NCHU improves the blockchain platform and cooperates with the local farmers' association, to construct the students' agricultural literacy. Based on the same concept, the new platform connects the students in NCHU and the farmers through the transaction of the virtual coin. Then, we present the case in the 68th United Nations Civil Society Conference with the international team of International Association for Agricultural Sustainability (IAAS).

2.5 CONCLUSION: THE LIMITATIONS OF BLOCKCHAIN AND FUTURE IMPROVEMENTS

The blockchain is still a developing technology. There are still many shortcomings. Take its main application, bitcoin for example, the efficacy aspect is its most denounced issue. It can be seen mainly in several aspects. All these are things to be improved:

1. Transaction confirmation time is long;
2. Transaction processing efficiency is low;
3. Bandwidth and block capacity are small;
4. Information security issues exist;
5. Consensus mechanism overuses energy;
6. Insufficient ease of use.

Blockchain technology has been proven to work well in preventing data tampering. Even so, the question remains, how can we ensure that the information is authentic from the very beginning? Everyone knows, "Garbage in, Garbage out." If the information entering the supply chain is deliberately fraudulent, inferior things disguised as good ones. Even if the blockchain technology prevents data from being tampered, it is still impossible to meet the requirements assuring food safety via the establishment of food history tracing and tracking (Adele Peter, Fast Company, 2017) There are still management mechanisms that need to be matched as follows:

1. Control of incoming goods: The purpose of controlling incoming goods is to ensure that the ingredients used by the manufacturer are consistent with the claim, as long as the original transaction data is placed on the blockchain during the transaction (the transaction data on the blockchain needs to be confirmed by both parties). The tracing of purchase information can be found after accounting.

2. Source control: The source tracing of the raw materials mentioned above, after tracing back to the past, you'll come to the source of supply. If the raw materials were imported, the current general practice is to adopt only the inspection at the border and the relative supporting documents, such as the certificate of origin. If it is produced domestically, it may be the source of agricultural products such as agriculture, forestry, fishery, and animal husbandry. At this time, the traceability system in production will be the process of how these agricultural and pastoral products are planted, cultured, or hunted.

3. The consistency of the ledgers and the physical object: Another thing that is also possible to fake is the replacement of the actual item, since the food blockchain is not like bitcoin, which is only in the virtual environment, but has a direct connection with the actual thing, so the considered scope of anti-counterfeiting is more extensive. In addition to the fraudulent ledger, it is possible that the ledger is correct due to the replacement of the physical object, while the object is actually not the original.

Although there are still many developments and applications in blockchain technology that need to be continuously modified, with continuous development and attention, the technology is moving forward at a rapid pace. There are already obvious success stories in various fields concerning the application of pure virtualization. The combination of virtual and physical applications will be the next focus of development. The application of various agricultural productions such as food production footprint and the production and marketing blockchain is expected to have more and more successful cases. The cases discussed in this chapter and the problems identified can be applied to the implementation of the blockchain technology. In case of food safety tracking, if the production history is changed from the QR code or barcode, the application blockchain technology should be able to solve the current safety problem. Taiwan is a resource-rich island. The current international market is also paying more attention to the safety of food. The fishery should also upgrade itself by embracing the improved blockchain technology to increase the industry competitiveness. After solving the food safety problem, the next step should also pay attention to the fact that Taiwan's small yet highly populated characteristics may bring about problems for the future food quality and quantity. We believe that Taiwan can have a better future in the food industry. Taiwan's food-related industries can refer

to the above cases, and with the continuous exploits of blockchain technology, we can be optimistic about the future of both blockchain technology and food-related applications.

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Abbreviations List

ISO	:	International Standards Organization
FSMA	:	Food Safety Modernization Act
HACCP	:	Hazard Analysis Critical Control Point
TRU	:	Traceable Resource Unit
GUI	:	Government Uniform Invoice
BUS Coin	:	Blockchain of University and Shops Coin
NTD	:	New Taiwan Dollar
IAAS	:	International Association for Agricultural Sustainability

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The Challenges of Agricultural Blockchain: A Review of Policy Steering and Actions in Thailand

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3.1 SUMMARY

Blockchain-based transactions are being piloted in many sectors including the financial, manufacturing, energy and government sectors. They are also being used in relation to agriculture supply chains, land registrations, and digital IDs. Initially born out of a need for a more decentralized financial system. Moreover, Blockchain-based implementations still suffer from traditional challenges such as a lack of or poor infrastructure, failures of interoperability, and other technological issues. Blockchain solution development without careful assessment of the existing challenges faced, including infrastructure, digital literacy, connectivity, and other overheads involved would unnecessarily increase the overheads substantially and could result in the initiative failing miserably.

However, Blockchain can perhaps essentially sway the manner in which rural business is finished. Blockchain innovation can build trust between gatherings, encourage data sharing all through the production network and essentially lessen rural exchange costs. Blockchain gives off an impression of being an elixir on different issues, which have been tormenting the agriculture and food sector for innumerable decades. The coordination of Blockchain innovation will make the procedure of payment of agricultural appropriations increasingly straightforward, safe to spillages, and productive. This chapter proposes an example of agricultural training Blockchain as a new potential model for promoting farmers digitally in the form of Knowledge-Based instead of supporting and subsidizing the agricultural sector directly by the government. This new type of support is to promote knowledge and skills for farmers. Through participation in training activities, seminars, visits to Agri. Center of excellence, participating in the best practice contest, including receiving agricultural information from universities and government agencies in agriculture.

3.2 AGRICULTURE IN THAILAND

In 2006, agriculture, forestry, and fishing contributed less than 10 percent of gross domestic product (GDP) but employed about 39 percent of the workforce. Thailand is one of the world's leading exporter of rice and also a major exporter of shrimp. Other agricultural products produced include coconut, corn, rubber, soybeans, sugarcane, and tapioca. Agriculture has long been the mainstay of the Thai economy, with abundant natural resources, and majority of the Thai population is engaged in agriculture based activities. In the 1980s, agriculture-crops, livestock, forestry, and fisheries-employed about three-quarters of the labour force, and it was estimated that four-fifths of the total population was dependent on this sector for its livelihood. At that time agriculture accounted for an average of about 25 percent of GDP, and agricultural commodities annually accounted for over 60 percent of value out of all exports (Hays, 2008). Agriculture used to be an engine of economic growth in Thailand. Before 1980, the expansion of agricultural land increased the outputs of the economy. Thai agricultural sector became a major comparative advantage in international trade. In addition to being a labour-abundant country, agriculture supplied the industrial sector with cheap labour and other factors of production. The role of agriculture in economic growth was undeniable. However, in the 1980s, land surplus began to disappear (Siamwalla, 1996). Industry and service sectors then stepped up their contribution to the economy. Hence, agricultural value-added share to GDP became small as the industrial sector became a bigger entity. Nevertheless, the majority of labour force still belongs to the agricultural sector even when employment is in decreasing trend. NESDB (2008) indicated that households in the agricultural sector are among Thai's poorest population. Solving the agricultural problems would help most of the poor population in Thailand. Timmer (2003), who studied the relationship between the agriculture, growth, and poverty of several countries including Thailand, expected the direct positive impact in agriculture to the farmers who are normally classified as poor. Additionally, Thai agriculture is well-known as a major agricultural exporter, and ranks fifteenth in the world. Figure 1 introduces export statistics for milled rice and natural dry rubber as the first and second rank respectively in the world. Thereby agriculture turns to be a key source of export earnings and rural income (Suphannachart and Warr, 2010). Agriculture also plays a crucial role as shock absorber for unemployed labours in non-agricultural sectors during adverse circumstances, such as the Asian financial crisis in 1997 and the sub-prime crisis in 2008-2009. Unemployed labours from the non-agricultural sector went back to agriculture as the second-best solution at their hometown. Further, Thai agriculture suits for the future source of income and growth if Thailand could be able to maintain itself as a net food supplier during the anxiety of food security around the world (FAO, 2008). Therefore, Thai agriculture should not be taken out of consideration.

Oxford Business Group (2019) reported that Agriculture remains crucial to Thailand's economic growth. Although Thailand in recent years has focused on creating a more forward-thinking, modern economy, ranking second only to Singapore in financial clout within the ASEAN block, the country's agricultural sector still remains a crucial cog in engine driving the country forward. It continues to capitalize on its long-standing farming tradition and favorable climate as it retains its enviable position as a key exporter of products – including widely consumed agricultural commodities such as rice, sugar, and rubber – around the world. Agriculture, particularly paddy cultivation, is still a dominant economic activity in many of the rural regions of the country, in places where other economic development efforts have not yet made a significant impact. With rapid development in manufacturing, service, retail and other sectors over the past few decades, the direct economic impact of agricultural industry has been declining, although it remains a vital social backstop for Thais who have a lower income. In 2016, the agricultural sector accounted for 8.3 per cent of the national GDP at a value of BT 1.2 trn ($31.6 bn), up from BT 1.19 trn ($33.5 bn) in 2015 (Thailand's National Economic and Social Development Board, 2015) Agriculture, forestry, and hunting accounted for a vast bulk of this total, fisheries segment accounting for less than 10 per cent of the total sector, although this relatively small contribution is largely the result of the expansion of manufacturing and services sector rather than the result of a significant decline in agricultural productivity.

Second in export value only to machinery, food shipments out of Thailand are big business, with country producing a wide array of products around the globe, ranging from Jasmine rice to canned tuna. A total of BT 940.69 bn ($26.50 bn) worth food was sold to other countries in 2016, amounting to 12.5 per cent of total exports, up from BT 913.59 bn ($25.74 bn) the previous year. Broken down by commodity group, unprocessed agriculture products were valued at $15.04 bn in 2016 – significantly less than the record $23.68 bn exported in 2011 – marking the third consecutive year in decline. As sustained period of high prices began to lose steam, the softening of market prices affected not only the energy and metal markets but also food commodity prices. Within agricultural sector, rice is a dominant sub commodity of Thailand's agricultural economy and has also been an important source of the country's export earnings. In 2016 foreign rice sales netted Thai farmers $4.4 bn for a volume of 9.88 m tons for the year. Strong sales of rubber, amounting to 3.6m tons, netted the country's producers another $4.4 bn, along with $2.56 bn worth of tapioca, $1.4 bn worth of fruits and $1.5 bn worth of horticulture products, with the fisheries sector bringing an additional $2.05 bn. Thailand has also been highly successful in expanding its downstream, value-added manufacturing capacity within the agricultural sector to establish one of the largest export-oriented agri-business hubs in the region.

The successful extension of this value chain has fuelled the industry to become the third-most-valuable manufacturing subsector, with exports valued at $25.77 bn ($15.04 bn) in 2016, placing it third behind electronics, valued at $31.17 bn, and automobiles, at $33.38 bn. Manufactured rubber products are the most lucrative agro-manufactured products. In 2016, $3.9 bn worth of rubber products were exported, followed by $2.6 bn of canned and preserved fish, $2.37 bn of sugar and $2.2 bn of canned, preserved poultry along with significant amounts of crustaceans, fruits, vegetables, cereals, beverages, paper products, wood products and other products.

Apart from just the tangible economic benefits derived from the large amounts of foreign currency being brought in through agricultural exports and supplying the domestic market with food, this sector also plays an important role as the country's single-most prolific employer. Workers in the agricultural industry make up by far the largest single block in Thailand, accounting for 31 per cent of the total labour force, equal to 11.8 m workers out of a total labour pool of 38.3 m in 2016. This figure is nearly double to that of its next closest employment sector in the country, wholesale and retail, which employed 6.3 m workers in 2016. Yet, to the detriment of the sector, this wide lead in labour engagement has been diminishing for years, to the point that the industry is now experiencing labour shortages in certain sectors and seasons of the year. In the past five years alone, more than 3 m agriculture workers have left the sector as it thinned from 14.9 m in 2011 to the current level of 11.8 m. No one factor is at the root of this decline, although primary issues stem from increased retirement of an ageing workforce, urban flight as more younger Thais move to the cities, greater mechanization of farms and an increase in jobs in other industries. The retail and manufacturing sectors, for instance, have been rapidly adding the jobs now being shed by the agricultural sector, with these industries adding 294,400 and 987,140 jobs, respectively, from 2011-16 with the non-agricultural industries as a whole adding a total of 2.36 m jobs over a five-year period.

For rice output, Thailand has two annual rice-growing periods: the wet season, which generally accounts for around 70 per cent of the annual output, and the less productive dry season, which is heavily dependent on water levels stored in mountain reservoirs. The rice sector has experienced hard times in the past few years, with producers facing double threat of drought and the end of the subsidization schemes. In spite of these setbacks, the sector experienced only minor difficulties in its production for 2015-16 and is expected to make a full recovery in 2017. Domestic production dipped from 20.5 m tons of milled rice in the 2013-14 crop season to 18.8 m tons for the 2014-15 season, followed up by 15.8 m tons, the next season, with the losses primarily attributed to the country's prolonged drought. Thailand's rice farmers seem to be recovering as normal precipitation

returns. They are expected to produce an estimated 18.6m tons in the 2016-17 season, according to USDA's grain and feed update. This improvement was aided substantially by bountiful rainfall during the wet season which replenished important reservoirs that supply agricultural sector and enabled the government to lift restrictions on irrigated rice acreage during the 2016-17 dry season. Much of these projected gains are attributed to a 52 per cent increase in off-season rice planting as reservoir levels expanded to approximately 9.2 bn cubic meters in January 2017, compared to 3.8 bn cubic meters the previous year. Interestingly, removal of rice subsidies has so far had minimal effect on domestic production, with the annual fluctuations in output attributed largely to weather conditions, rather than any price disincentives for farmers. Rice farmers in Thailand worked on only small portion of land following the removal of the aforementioned subsidies, with a total of 11.23 m ha under production during the 2014-15 season compared to 10.65 m during the 2016-17 season. Unable to compete with other Asian countries, such as Vietnam and India, that produce and sell lower-grade rice at higher volumes in the international market, Thailand has been competing internationally on the basis of higher quality and is targeting niche segments. Organic rice, for instance, is increasingly popular in western markets and fetches a higher price, while the well-regarded, highgrade Thai jasmine (in particular, the prestigious Hom Mali variety) rice preferred by affluent Asian consumers also commands a premium price.

Thailand is set to continue to play an important role as a global food exporter, particularly in the key commodities of rice, sugar, rubber and horticultural products. As the effects of El Nino dissipate, production across the board should also continue to rebound and output should expand significantly over the next few years, barring any unforeseen major weather event. Ongoing regulatory and subsidization reforms should also help with reducing market distortions and inefficiencies going forward, although their effectiveness will ultimately depend on the willingness of policymakers to implement genuine reforms in the agricultural sector, rather than just rearranging subsidization in addition to other assistance schemes.

3.3 AGRICULTURAL BLOCKCHAIN

Blockchain-based transactions are being piloted in many sectors including the financial, manufacturing, energy and government sectors. They are also being used in relation to agriculture supply chains, land registrations, and digital IDs. Initially born out of a need for a more decentralized financial system (together with cryptocurrencies), this technology is finding innovative uses in a wide range of applications. A blockchain by design is cryptographically secure (the content is not necessarily encrypted), it is a write once-

append only, distributed and decentralized system. The statement that a blockchain is the only mechanism to build trust, reduce costs and accelerate transactions is not entirely true. Blockchain-based implementations still suffer from traditional challenges such as a lack of or poor infrastructure, failures of interoperability, and other technological issues. Although the trend now is to try a blockchain-based implementation of traditional processes, in most cases, this adds unnecessary overheads and does not yield tangible benefits. What it does promise is to deliver a transparent, decentralized, secure transaction process and may reduce transaction costs. This brings us to the main question – what processes in the agriculture domain are suffering from a lack of transparency, would benefit from decentralization and are now affected by non-secure transaction processes. To identify, if a challenge you face could benefit from a blockchain based solution, the first step is to identify the use case, then develop the key governing principles and then determine what technology or architecture would help address the challenges of that particular case. In most cases, a much simpler digital solution may be the answer. In the agriculture domain, self-executing smart contracts together with automated payments would be the game changer. The role of smart contracts especially in agricultural insurance, green bonds, and traceability could be very effective. Agricultural insurance built on blockchain with key weather incidents and related payouts drafted on a smart contract, linked to mobile wallets with weather data being provided regularly by sensors in the field and correlated by data from proximity weather stations would facilitate immediate payout in case of a drought or flooding in the field (FAO, 2019). However, the framework to support such innovation, such as high-quality data, enabling policies and regulations, should be first addressed in order to ensure the maximum efficacy for smart contracts. The process of designing, verifying, implementing and enforcing smart contracts in traditional agricultural value chains is still a work-in-progress, with only a few pilot implementations to show proof of concepts.

In land registrations, blockchain-based implementations could provide an incorruptible ledger of land records. Especially in the case of the rural poor, if this is linked effectively to sovereign ID/digital ID then the safekeeping of land records even in times of natural disasters or wars would not be an issue. The United Nations Development Programme (UNDP) in India is working with partners to make land registry more reliable. At a high level, this project will capture and permanently record each transaction throughout the sale of a property. This means you achieve near real-time traceability and transparency with respect to the state of the property (UNDP, 2018). The Swedish government's land-ownership authority, Lantmäteriet, has piloted the registry and property transaction on the blockchain. They believe that this provides a safe and secure way to have digital originals and that it could reduce hundreds of millions of dollars of expenses for the government

(Cointelegraph, 2017). The Republic of Georgia is experimenting on the use of the bitcoin network to validate property-related government transactions (Shin, 2017). In the case of bringing increased transparency in agricultural supply chains, a blockchain can assist in providing an immutable record from the provenance to the retail store of a product. This can give consumers increased trust in the products that they buy and it is also an opportunity to reward the producers who employ good agricultural practices to cultivate their production. This would eventually lead to sustainable farming practices and responsible consumption. Italian pasta and pesto sauce manufacturer, Barilla, has teamed up with IBM to tackle transparency and traceability in its pesto production cycle (Bitnewstoday, 2018). From the cultivation, treatment, and harvesting in the field of transportation, storage, quality control in production and then to the customer, all details are tracked and made available on a blockchain system that the customer can verify by scanning the pesto's QR code.

Experiments such as in India to undertake a research project to explore the use of blockchain technology for fertilizer subsidy disbursements to farmers have been done to streamline the distribution of subsidy payments to farmers without the need for documents or multiple points of authorization (Das, 2018). Combining this with digital ID would assist in efficient and targeted delivery of many government-to-citizens (G2C) services by eliminating the need for multiple verifications and the need to move paper documents through various offices. In the fisheries sector, this can be used to track and deter illegal, unreported and unregulated fishing (IUU), which poses the greatest threat to marine ecosystems. World Wildlife Fund (WWF, 2018) in New Zealand is working on a pilot project to stamp out illegal fishing and human rights abuse in the Pacific Islands' tuna industry. They have collaborated with various other organizations to track fish from vessel to the supermarket, this blockchain Supply chain traceability Project uses digital technology in the fresh and frozen tuna sectors of the Western and Central Pacific region to strengthen supply chain management. In forestry, Hangzhou Yi Shu blockchain Technology Co., Ltd, a company set up by Beichuan Qiang Autonomous County of Sichuan Province and Beijing Sinfotek Group in China aims to use blockchain for forestry economic development and rural poverty alleviation. The Spanish Ministry of Agriculture, Fisheries, and Food also plan to apply blockchain technology to develop the forestry industry. The operating group, Charnwood, aims to improve the traceability and efficiency of wood supply in Spain by implementing blockchain technology in the industry's logistics. The group is set to develop a cloud-based software that would improve the transparency of forestry processes – such as the creation of solid wood, disintegration, cellulose paste, and biomass – by applying blockchain, big data, and machine learning (Yakubowski, 2018). The pioneering efforts of the World Food Programme (WFP, 2018) with blockchain as a means

of making cash transfers more efficient, transparent and secure and their experiences in pilots in Pakistan and Jordan are documented in this publication. Yet another area for blockchain could be in sustainably monitoring, verifying and reporting on green or climate bonds. Green bonds were created to fund projects that have positive environmental and climate benefits. With the increase in bond value, it is necessary to have effective tracking, traceability and verification mechanisms to help increase investors trust in climatesmart-initiatives. Carbon credits and trading in them could benefit from the trust that a blockchain offers. Companies such as Poseidon are working on a blockchain-based system to track an individual or company's carbon footprint and then providing opportunities to offset it. IBM works with Veridium to tokenize carbon credits that are verified by third parties according to international standards. These are then used in incentivize companies to be more environmentally friendly and to offset their carbon footprint (Ocutt, 2018). These sort of initiatives would greatly support Reducing Emissions from Deforestation and Forest Degradation, plus the sustainable management of forests, and the conservation and enhancement of forest carbon stocks (REDD+) programme, which supports developing countries in their REDD+ processes and helps them to turn their political commitments into actions on the ground. The FAO-ICTSD issue paper on Emerging Opportunities for the application of blockchain in the agrifood industry examines public policy implications for food security and rural development in using DLTs (FAO, 2019).

In conclusion, blockchain has great potential. However, it is not a panacea for all problems. The right ecosystem and stakeholders are needed to sustain any kind of solutions and the same goes for blockchain. Blockchain solution development without careful assessment of the existing challenges faced, including infrastructure, digital literacy, connectivity, and other overheads involved would unnecessarily increase the overheads substantially and could result in initiative failing. The blockchain community has come a long way over the past couple of years. We have moved from a focus on crypto currencies to a wider understanding of different ways we can leverage blockchain technology across industries. Noel (2018) have counted more than fifty different initiatives focused on food and agriculture around the world that are doing more than just raising funds through an ICO (Initial Coin Offering) to build a platform. Here are the six main ways that blockchain can be applied to food and agriculture supply chains:

3.3.1 Traceability

The most common use of blockchain in food and agriculture supply chains is to improve traceability. It enables companies to quickly track unsafe products back to their source and see where else they have been distributed. This can prevent illness and save lives, as well as reduce the cost of product recalls. Information is collected and the stakeholder groups

involved varies based on the needs of the groups behind each initiative. The IBM Food Trust initiative started collaboration with Walmart China and Tsinghua University and that has grown into a global consortium including big companies such Dole, Driscoll's, Kroger, Nestle, Tyson, and Unilever. Frank Yiannas of Walmart has said that the improved data traceability provided by the IBM platform reduced the time it took to trace a mango from the store back to its source from seven days to 2.2 seconds. That reduction in time enables companies to identify contaminated supply chains and recall affected products before they are consumed and cause illness. OriginTrail is a Slovenia-based company that is getting attention around the world for its traceability initiative. Transaction processing and storing blockchain data to trace products can be expensive. OriginTrail has found a way to store only "fingerprints" of data on the blockchain, which founder Žiga Drev says reduces the cost to only cents per item, or even a fraction of a cent when the fingerprinting is being done at the batch level, as for low-cost FMCG (fast moving consumer goods), such as beverages or prepared foods. The team also understands that systems do not operate alone, and has created the Trace Alliance, a consortium of companies who are using blockchain for supply chain traceability. Members include Deloitte, HalalTrail, Oregon Tilth, and Phy2Trace. (Full disclosure: I am a member of the Trace Alliance through my company, Cultivation.) Viant is a supply chain traceability focused subsidiary of Consensus, which is making global waves for using blockchain to address many different challenges (civil.co is a platform for trustworthy journalism, uPort is an identity management platform, Ujo is a platform for musicians to share content and connect directly with their fans). Viant has partnered with in Fiji with WWF and Traceable Solutions to track albacore tuna caught by Marine Stewardship Council-certified fishing company Sea Quest Fiji. Automatic Identification System (AIS) transmitters were installed on their vessels and operate continually to track and monitor fishing activities. Fish are tagged with a sensor when caught; that sensor interacts with the AIS transmitter to record both the time and exact location. The location data confirms that the fish was caught in a place where fish stocks are not over-exploited. Belfast-based arc-net has incorporated DNA information into its blockchain platform. They begin by taking a tissue sample of an animal early in the supply chain and uploading part of the genetic code with other information being stored. When importers and others further along the supply chain receive the meat they can then test a sample and confirm that the DNA matches to that which they were expecting. They've also made headlines for a whiskey blockchain with Scottish distillery Ardnamurchan, which includes information on the water and grain used in production as well as the identity of the distillers who made the whiskey. Provenance is a London-based blockchain company with an overt social and environmental impact focus. Company founder Jessi Baker recognized that customers want to understand the social and environmental impact of their purchases. Provenance

provides transparency for both food and clothing companies, allowing customers to not just learn where their dinner or new jacket came from, but also confirm that the people who helped make the product were fairly compensated and that it was made in a manner that is environmentally responsible.

Chinese commerce giants Alibaba (parent of Taobao) and JD.com are using blockchain-backed traceability to improve consumer confidence in the authenticity of food products in an environment where food safety is an everyday concern for customers. Beijing-based JD.com started by tracking beef from Kerchin, a company in Inner Mongolia (a province in northern China), to customers in Beijing, Shanghai and Guangzhou. They've also worked with Australian exporter InterAgri and processor HW Greenham & Sons to track Black Angus beef from where it is bred and raised to processing and transporting. Josh Gartner, VP of International Corporate Affairs at JD.com says that they are hoping to offer the same products to customers of JD's new premium offline grocer chain 7FRESH as they continue to expand their offerings. The BeefChain was founded by Wyoming cattle ranchers who wanted to know where their beef was being sold. The "rancher centric" platform tracks beef along the supply chain and enables ranchers to recapture value from third-party actors along the chain. Blockchain is not the only technology changing the way things are done when it comes to agricultural supply chain data. What makes many initiatives noteworthy is how they combine blockchain with other technologies, such as IoT (Internet of Things), like the AIS sensors used by Viant's partners in Fiji, or AI (Artificial Intelligence). This can be especially useful because it removes the likelihood of human error—whether deliberate or accidental. Several companies in China are demonstrating different ways IoT can be used with traceability initiatives. ZhongAn Technology, based in Shanghai, has a platform called Bubuji that puts sensors on chickens when they reach a certain size. The sensors not only track the location of the chicks, it also allows customers to see how much they moved on a daily basis (think of it as an exercise and location tracker for chickens). Walimai has a sensor it places on baby formula canisters that registers when the canister has been opened. If a customer scans the QR code on a canister to learn about the supply chain they can confirm that the can has not been tampered with. This is especially important in a market like China, where food safety is a top concern of consumers due to multiple cases like the high profile 2008 baby formula food fraud food safety scandal, which caused a reported six deaths and resulted in kidney damage in hundreds of thousands of children. There are many other traceability-focused initiatives. A few noteworthy ones include Ambrosius (formerly known as Food blockchain.xyz), out of Switzerland, which provides tracking for both the food and pharmaceutical industries; BeefLedger, an Australian beef traceability initiative focused on exports to the Chinese market; the Chai Vault, a UK-based wine initiative focused on verifying the provenance

of investment-grade wines; OwlTing, founded by an ex-Google employee in Taiwan in 2010 to enable consumers concerned about food safety to buy directly from farmers; TE-FOOD, focused on providing farm-to-table traceability in emerging markets; and Zest Labs, another US company that uses sensors to collect data that enables companies to reduce food waste.

3.3.2 Commodity Management

Agricultural commodities are big business, and commodity managers have been plagued by data management challenges and payment time lags. Blockchain is enabling innovation that addresses these issues. Australian company, AgriDigital provides cloud-based agricultural commodity management services recorded onto a blockchain. CEO and co-founder Emma Weston says that she and her cofounders knew they "could create cost-effective, efficient and world-leading agri-commodity management and supply chain solutions that would have a global impact" by using emerging technologies. In 2016 they completed the world's first farmer-to-buyer wheat sale recorded on a blockchain; since then they have run pilots for food traceability and supply chain provenance, real-time payments, digital escrows, and supply chain finance. At the end of 2017, Rotterdam-based trading house Louis Dreyfus Co. completed its first agricultural trade using blockchain, for a sale of U.S. soybeans to China. Deal documents, including contracts, letters of credit, and government certifications, were all digitized, and data was automatically matched in real time via their blockchain platform, which avoided duplication and need for manual checks. This reduced document processing to one-fifth of the usual time and cut overall transaction time to half, from two weeks to one.

3.3.3 Marketplace Creation

One challenge for commercial food companies is sourcing quality ingredients in sufficient quantity. Farmers may not know who the big customers are or what end customers are looking for. Historically, intermediaries have controlled a significant percentage of profits. Digital marketplaces allow buyers and producer to connect directly, increasing the number of profits that go to the farmers, and investors to invest directly into farms producing commodities and then trade on that investment. Avenews-GT is an Israeli-based company that has created a trading platform which allows commercial buyers to find the growers who have what they need. Their first projects allowed coffee-buyers to find coffee growers in Rwanda, and cattle farmers in South Africa to find alfalfa to feed their animals, request a digital quote and manage payments all within the Avenews-GT platform. For commodity traders, London-based Binkabi has created a commodity marketplace that reduces foreign exchange expenses and increases profits. Their Barter Block™ protocol

groups opposite trades together for settlement, which improves the performance of each trade while keeping them independent of one another. It also allows bilateral trades to be conducted in local currencies on both sides. While most wine industry initiatives using blockchain are focused on traceability and authenticity, VinX is a platform for trading wine futures. Wineries can receive funding directly from consumers, enabling them to develop relationships directly with their customers and reduce stress around the often multi-year gap between receiving funds and sales.

3.3.4 Data Sharing

Companies that buy or invest in agricultural products have an inherent interest in having information about the product before they commit to a purchase. This can include everything from salt and sugar levels in tomatoes, which would affect flavor, to crop health information, which can help banks and others predict whether a farm will be able to repay a loan. California-based Ripe.io collects data from sensors, spreadsheets, manual surveys and other sources along the supply chain to give commercial buyers detailed information about product attributes. Their first project tracked tomatoes from Ward's Berry Farm in Massachusetts that was destined for the salad chain Sweetgreen. Data points such as light, humidity, air temperature, tomato color, salt, and sugar content, and pH levels were entered into the blockchain. Tracking this information helped Sweetgreen get the tomatoes into customers' salads when they were at their best and reduced waste from spoilage. Hara is an Indonesia-based agriculture-focused data exchange that brings together data from multiple sources and facilitates data access for banks, insurance companies, retailers, agriculture input suppliers, NGOs, and government agencies. One of the many benefits of having so many different types of data related to agriculture on a decentralized data exchange is that it enables improved access to funding for farmers, which in turn helps them to buy seed and other inputs to increase their production."

3.3.5 Access to Capital

Smallholder farmers around the world struggle to access funding through traditional financial models, like loans. Lack of significant credit histories, land ownership documentation and other issues make it difficult to access bank loans, so small farmers are often forced to borrow funds from money lenders, at significantly higher interest rates if the option is even available. Tech-savvy agricultural entrepreneurs are now using blockchain to create investment tokens and raise funds for their agricultural businesses. In Mexico, Agrocoin has created an investment token to enable investors at all levels to support agribusinesses across the Americas. Their first offering funded was a token backed by a square meter of habaneros being grown by Amar Hidroponia in Quintana Roo, south of Cancun. On the

other side of the world, Bananacoin was founded by a team of Russian entrepreneurs in Vientiane Province, Laos. They created token to raise funds to increase the size of the Banana coins plantation, where they grow Lady Finger bananas for export to China.

3.3.6 Payments

While there is much more to blockchain than just crypto currency, payments are still a critical issue for small farms and other businesses in agriculture. BitPesa was founded in Nairobi in 2013 by former banker Elizabeth Rossiello and was the first company based on blockchain to be recognized by the UK Financial Conduct Authority. Users can make same-day payments to employees, distributors or suppliers into their local or international bank accounts, as well as accept payment from local customers in seven major African currencies. The automated platform allows BitPesa to charge a fee that is a fraction of traditional payment transfers. This improves profitability for farmers and everyone else along the supply chain. San Francisco based Veem is used by Las Vegas-based online tea distributor Tealet to pay more than 30 different farmers and suppliers in different countries across Africa and Asia. Tealet founder Elyse Peterson has spoken extensively about how her frustration with fees as high as 12 per cent and long clearing times, sometimes five days or longer, for international payments led her to work with Veem. The Veem automated platform uses blockchain to convert payments from the source currency and then into the local currency in more than 80 receiving countries, including China. International payments are processed and available to vendors in one to three days, with a 1.9 per cent fee. Most of the initiatives named above are actually addressing several different challenges. There are many more that use blockchain technology in ways that focus on these and other issues in the food and agriculture supply chain. Some companies have blockchain-enabled initiatives that can be used in agriculture but also have wider uses. Whatever the industry, people working in the field or the end consumers may not know that blockchain technology is being used or how it works, just as many internet users don't know the technology behind the internet or how it works. While the term blockchain is being used widely to attract attention and investors, more important than whether or not a company uses blockchain is whether using blockchain effectively addresses an existing problem and if the company can deliver as per the expectations.

3.4 AGRICULTURAL BLOCKCHAIN POLICY STEERING IN THAILAND

3.4.1 Thailand 4.0 National Policy

Thailand 4.0 is the Thai government's new economic model aimed at pulling the country out of the middle-income trap. For agriculture, it means a seven-fold increase in average

annual income of farmers from 56,450 baht to 390,000 baht within the next 20 years – an extremely difficult, if not impossible objective to be achieved – a task that would require a drastic shift in strategy to encourage adaptation and adoption of modern technologies. In the past, Thai farmers have been receptive to technologies and innovations. By the late 20th century, Thailand had progressed from subsistence agriculture to agribusiness, and then to an industrialized economy. Manned by surplus labour and abundant land in rural regions, industrial agriculture took a turn and employed new crop varieties, nonorganic fertilizers, and machinery to increase farm productivity and yields. Today, more than 90 per cent of agricultural households in Thailand use machinery. Rice production has been mechanized throughout the process. Farm mechanization in Thailand has reached a saturation point where further increases in productivity become difficult. Introducing technological change also faces difficulties as research spending on agriculture dropped significantly from 0.9 per cent of agriculture GDP in 1994 to only 0.2 per cent today. Governments for the past decade have turned their backs on technological advances in favor of populist policies that gained votes. Agriculture 4.0 has to change this direction entirely and focus on technological developments and their commercialization – particularly with precision agriculture, agricultural robotics, and biotechnology. The path towards agriculture 4.0 requires funding from the government to monitor emerging technologies and best practices around the world – to determine the feasibility of applying those technologies in Thailand and how best to modify them to match local applications. This should be a continuous and systematic process that is open to the public to showcase opportunities for private investments in agricultural technologies. Ultimately, Thai agriculture will need a catalyst for change, in the form of a multi-stakeholder partnership platform that brings together companies, the government, universities, non-governmental organizations, and farmers to drive the technological transformation – providing and sharing access to information, technology, markets, and finance. This kind of platform is vital to foster competition that can bring down costs and prevent unfair treatment to poor farmers. Moreover, it will give stakeholders more bargaining power to correct the government's policies, and speed up much-needed progress.

Thailand 4.0 agenda is an economic model based on creativity, innovation, new technology and high-quality services (Bussi and Khatiwada, 2017), which is used to boost the quality of life. Thailand 4.0 is, however, the next step in the evolution of Thailand's development, with Thailand 1.0 (*agriculture*) having been farm mechanization and increased crop yields, Thailand 2.0 (*light industry*) used cheap processes to turn raw materials into finished goods for production and manufacturing such as textiles and garments, Thailand 3.0 (*advanced industry*) is the assembly and production of products such as computer disk drives, electrical components, compressors, and automobiles for export (Rojniruttikul

and Rodchom, 2014), while Thailand 4.0 (*fourth industrial revolution-4IR*) will be focused on turning Thailand's labour force into 'knowledge workers' across 10 key economic sectors. According to the Thai Embassy web site in Washington, D.C., the four stated objectives of Thailand 4.0 are as follows:

1.   **Economic Prosperity**: to create a value-based economy that is driven by innovation, technology, and creativity. *The model aims to increase Research and Development (R&D) expenditure to 4% of GDP*, increase economic growth rate to full capacity rate of 5-6% within 5 years, and increase national income per capita from 5,470 USD in 2014 to 15,000 USD by 2032.

2.   **Social Well-being**: to create a society that moves forward without leaving anyone behind (inclusive society) through the realization of the full potential of all members of society. The goals are to reduce social disparity from 0.465 in 2013 to 0.36 in 2032, *completely transform to social welfare system within 20 years* and develop at least *20,000 households into "SmartFarmers" within 5 years.*

3.   **Raising Human Values**: to transform Thais into "Competent human beings in the 21st century" and "Thais 4.0 in the first world. Measures under Thailand 4.0 will raise Thailand HDI from 0.722 to 0.8 or the top 50 countries within 10 years; *ensure that at least 5 Thai universities are ranked amongst the world's top 100 higher education institutions within 20 years.*

4.   **Environmental Protection**: to become a liveable society that possesses an economic system capable of adjusting to climate change and low carbon society. *The targets are to develop at least 10 cities into the world's most liveable cities* and reduce terrorism risk.

The process to achieve this according to Thailand's Prime Minister Prayut Chan-o-cha is to explore the usage of science, technology and innovation to boost the country's economy, focusing on industrial and agricultural sectors, medical technology and public health, together with the global trend for a robotics industry (Wipatayotin, 2017). Further challenges, however, will be overcoming "a middle- income trap", "an inequality trap", and "an imbalanced trap" (Thai Embassy-Washington, D.C., 2017). Also, according to the Thai Embassy website in Washington, D.C., Thailand 4.0 will overcome these traps through the use of "New Growth Engines" by:

•   Building economic prosperity through innovation, knowledge, technology, and creativity. This creates a "competitive growth engine" to unlock individuals from the middle-income trap.

- Building social security through equitable distribution of income, opportunity, and wealth, operating under a principle of "moving forward together without leaving anyone behind" to unlock Thai citizens from the inequality trap.

- Creating sustainability through environmental friendly development (Green Growth Engine), to unlock Thai citizens from an imbalance trap. The model follows the directions of the 20 years' national strategic plan by *building strength from within* and *connecting the country to the global community* under the principle of *Sufficiency Philosophy*, which is consistent with the United Nations' Sustainable Development Goals (also referred to as *Global Goals*) (UNDP, 2017).

For Thailand's Agribusiness Sector (Smart Farmers), since Thailand 1.0, there has always been a government focus on agricultural production, which in 2015 contributed 23 per cent to Thailand's gross domestic product (GDP) and US$25.5 billion in exports, which consisted of rice (17.1%), sugar (8.6%), chicken (7.8%), tuna (7.5%), and shrimp (6.3%) (Thailand Investment Review, 2016). As *Kitchen to the World* and under Thailand 4.0, the focus is being shifted to increase the farmer's 'life quality' however (Wipatayotin, 2017). Also, under the Thailand 4.0 model, emphasis will be given to upgrade small and medium-sized enterprises (SMEs) and usher in an era of *smart farmers* who can make the most of advances in technology to prosper (Sattaburuth, 2017). Additionally, according to Thailand's Prime Minister Prayut Chan-o-cha, Thailand 4.0 is a great opportunity for labours and farmers to develop and improve their career paths to obtain higher incomes and a better quality of life. To achieve these high goals, Prime Minister Prayut in a speech on March 2017 at Kasetsart University conference entitled 'Mobilising Thailand 4.0: Agriculture, Food and Biotechnology', stated that the Ministry of Agriculture and Cooperatives is the key to helping farmers learn how to adapt by changing traditional ways of farming to technology-led cultivation through more than 2,000 learning centers countrywide and that farmers should have proper plantations in line with soil quality and geographic locations suggested by the "Agri-Map" developed by the ministry (Wipatayotin, 2017). Furthermore, the Ministry of Agriculture and Cooperatives has been working to promote a change of farming patterns by upgrading farmers to "smart farmers", who can use technology for their plantations and sell products on the market for better prices. General Prayut said Thailand 4.0 will not leave anyone behind as "all walks of life go together", but people must learn and adapt to live with technology and make use of it. Labours must not be replaced by robots, but they should develop labour skills with the ability to speak foreign languages. They all need to adapt and develop to be "smart people". The Thai government recognizes the importance of food innovation with the Finance Ministry proposing establishing a US$ 283.8 million fund to support the Food Inn polis Project at the Thailand Science Park (TSP).

This project aims to position Thailand as a global food innovation hub and with Ministry of Science and Technology's coordination, plans to use the Food Inn polis Project as a hub for 3,000 researchers, 10,000 students in Food Science and Technology programs, 9,000 food factories, 150 food research labouratories, 20 pilot plants, and 70 universities (Thailand Investment Review, 2016).

3.4.2 Agriculture 4.0

According to the concept of European Agricultural Machinery (2017), agriculture also developed five stages in the development process:

1. **Agriculture 1.0** appeared in the early 20th century, a labour-intensive system of agriculture with low productivity;

2. **Agriculture 2.0** widely remembered as the Green Revolution, this phase of farming began in the late 1950s when agronomic management practices like supplemental nitrogen and new tools like synthetic pesticides, fertilizers and more efficient specialized machines allowed to take advantage of relatively cheap inputs, thus dramatically increasing yield potential and growing returns to scale at all levels;

3. **Agriculture 3.0**, its focus is moved from pure efficiency in terms of cutting costs to profitability which can be seen as objectively and creatively seeking ways to lower costs and enhance the quality or develop differentiated products;

4. **The evolution of agriculture 4.0** happens in parallel with similar evolutions in the industrial world, where it is marked as industry 4.0. Accordingly, the term agriculture 4.0 is often used in farming. In terms of definitions, agriculture 4.0, in analogy to industry 4.0, stands for the integrated internal and external networking of farming operations. This means that information in digital form exists for all farm sectors and processes; communication with external partners such as suppliers and end customers is likewise carried out electronically; and data transmission, processing, and analysis are automated. Agriculture 4.0 paves a way for the next evolution, including the present operation without direct human and system-based devices that can make decisions automatically;

5. **Agriculture 5.0**: This will be based on robotics and artificial intelligence. As summarized, the major components of agriculture 4.0 are generally included as follows: IoT Sensors: From soil fertility to connectivity, IoT sensors are critical parts of modern agriculture; LED's: The rise in indoor farming is being driven by advances in LED technology. Indoor farming is particularly demanding of LED precision because of the requirements to provide optimal growth and yields; Robotics: Some robots are doing what farmers

used to do in farms. This robotics also includes analytics which are software systems that assist in analyzing and making sense of trends in farms; Solar Cells: Most devices in farms are powered by solar and solar panels are important; Drones and satellites: drones and satellites are used for data collection of farm vegetation; Indoor Farming/ Aquaponics/ Hydroponics: Making use of a wealth of experience and resources in LED lighting, some OEM companies have sprung up offering full solutions for indoor farming/aquaponics and hydroponics; Farm Fintech: increasingly, new financial solutions are designed for farms and agriculture. These solutions are captured as farm financial technology and they include payment, lending, insurance, etc. which are done digitally for farming.

Agriculture 4.0 implies connotations of both crops, livestock (possibly broader understanding into both fisheries and forestry) for research, transfer, and production. Modern agriculture is interested in sustainability and safety solutions. Farming is implementing techniques such as tillage, sowing, pruning, crop rotation, tending, harvesting, with the aim of achieving higher productivity, protect the environment better, and based on progress of digital technology (Tien, 2017).

3.4.3 Agricultural Blockchain in Action

Thailand Board of Investment (2018) confirmed that smart farming is the future of agriculture in Thailand. There is a saying in Thailand that agriculture is the backbone of the country. More specifically, the phrase refers to the farmers who work tirelessly to ensure that their fellow countrymen and, increasingly, citizens beyond their own national borders are well-fed. An old sector upgraded with new technology. Through generations of such productivity combined with the fertile nature of Thailand's tropical climate, the country has established itself as one of the world's most renowned producers of agricultural products. Rice is, without doubt, the champion of that reputation with production recently soaring to a new high of over 11.48 million tonnages worth 5.1 billion USD in 2017. This figure represents a staggering 15.9 per cent annual growth from 2016 and, from a global point of view, reinforces Thailand's position among the world's leading producers of this staple food. Looking ahead, there is no doubt that Thailand will continue to be a leading supplier of rice and other agricultural products to the world. However, as the global economy expands, so too does its population, and with it, the obvious demand for agricultural produce. According to the Food and Agriculture Organization (FAO) of the United Nations, the global demand for agricultural commodities is expected to grow at approximately 1.4 per cent per year from now until 2030 and then at 0.8 per cent annually onward to 2050. These annual figures compound into a staggering 40 per cent increase for the 2018–2050 period. In such an environment, land scarcity will become one of the major challenges facing the world. While there are still untapped arable lands that can be put into proper use, the

volume of new cultivable land will simply not be sufficient to keep pace with the demand. As a result, productivity and yield rate are the keys to ensuring future food security for the planet. As is the case with other sectors, modern digital technology offers a solution. At every level of the agriculture industry supply chain, new technologies are transforming the sector. For upstream activities, the Internet of Things (IoT) and increasingly intelligent sensor systems are enabling farmers and growers to monitor their produce in real-time and adjust input accordingly. At the downstream end of the chain, the ongoing development of better machinery has made food processing more efficient and less costly. On the distribution front, eCommerce has also recently opened up to agricultural products. These are just a few examples of the innovations that are driving the agricultural industry into new territory. This article will be focusing on the digitalization of commodity production, an activity more popularly known as 'smart farming'. Samples of local innovation in smart agriculture Thai entrepreneurs are already setting their sights on how farming should be done in the future. Here are some examples of 100 per cent locally-made innovations that will revolutionize the agriculture industry in Thailand. Researchers at Mahidol University and Granmonte Farm, a renowned vineyard in Nakhon Ratchasima Province, have created the Micro-Climate Monitoring System. A dedicated network of sensors detects key data, including temperature, humidity, light intensity, wind speed, and air pressure, among others. These data are then analyzed by the intelligent system to increase the yield and reduce the risk of failure. As one specific example, the irrigation system is automatically activated when the detected humidity is low. This feature, combined with constantly-on internet connectivity, not only increases productivity but also gives growers the freedom to manage their farms remotely (Mahidol University, 2018).

A similar feature can also be found in the Smart Farming Kit, an IoT-based irrigation control system developed by the Faculty of Science and Technology at Thammasat University (2019). Using this product, watering cycle timing can be preset in advance, while at other times, irrigation can also kick in automatically when soil level humidity falls below a pre-designated threshold. Formed in 2015, FarmD Asia is a smart farm service provider that aims to boost agricultural productivity through its flagship product, a pre-programmable pesticide-releasing aerial drone which can cover approximately six to eight acres of land in a single flight. In addition to reducing farmers' risk of exposure to chemicals, this technology also saves time and lowers cost. Another of FarmD Asia's products is a specialized environmentally-controlled mushroom cultivation chamber. The internet-connected chamber enables growers to adjust and optimize temperature and humidity remotely in order to maximize output. Another agro-tech company, Thai Advanced Agri Tech, has enabled a reduction in planting spaces through its IStack planting kit, a stacked vertical hydroponic pot which can potentially save up to three times the space required

for conventional planting. The pot is made of food-grade plastics that are highly durable and last for four to five years. The companies and their innovative products mentioned here represent just a few basic examples that attest to Thailand's current standing as an emerging player in the global smart agriculture industry and its related services. Foreign investors are therefore invited to invest in Thailand and use the country as a base from which to expand their operations into the region as well as a compatible setting in which to test new products or services.

In a country with such well-developed expertise in agriculture as Thailand, the possibilities afforded by the digitally-enabled farm and agriculture business have long excited all related stakeholders and interested parties, including farmers, policymakers, academics, and industry business operators, among others. Through this openness to change and progress, a wealth of knowledge and expertise in the future of farming has already driven agriculture in Thailand into an exciting new era years before the term 'smart farming' came into the spotlight, making Thailand's agricultural industry second to none when it comes to institutional support and industry readiness. From the field of academia, the Agricultural System Integrator (ASI) launched by the National Science and Technology Development Agency (NSTDA) was a program designed primarily to equip modern farmers with the technology-agriculture integration mindset they require to start and run a smart farm successfully. This short course provides its participants with business and networking skills, knowledge on smart agriculture technology, and a standard accreditation framework, as well as a field workshop, which provides participants with a true sense of how an agriculture business and farmers in the 21st century should operate (The Nation, 2018). In terms of government support, Thailand Board of Investment (BOI) stands ready to provide its full support to smart farming investment in Thailand. Under the current investment promotion scheme, smart farming and its related services (i.e., the manufacturing of modern agriculture products and services related to modern agriculture, e.g. detection or tracking systems, resource regulation systems, and smart greenhouse systems) are activities classified under the A3 category of the Activity-Based Incentives. As a result, smart farming investment will be granted 5 years of corporate income tax exemption with no maximum capped amount, along with an exemption on import duty for machinery and raw materials used for the production of exported goods, given that such investment includes the development of system and software for resources management that are integrated and capable of collecting, interpreting and analyzing data. The readiness and support that Thailand provides underscore the country's determination to maintain its reputation as the world's foremost supplier of agricultural products and to continue supplying the world with the best quality agricultural products. To this end, Thailand has

committed to further enhancing technological absorption and integration in the agriculture sector in order to ensure that all previously mentioned goals can be achieved.

3.4.4 Agricultural Blockchain in Practice

This section presents news and sample information about Thai agricultural blockchain, which are as follows:

1.   Thai agricultural sector must cope with changes in 9 aspects

Jiarawanontha (2018) stated that the future of the agricultural sector is very important for Thailand, and in the midst of current world changes of digital age or 4.0, Mega Trend technology, which includes Biotech, NanoTech, SpaceTech, Robotic and Digital, which came to create disruptions. It's time to adjust to the changes of the world including Thai agricultural sector. The agricultural sector has become a great issue, because it's the main base of the country, it's importance is equivalent to that of the tourism and industrial sectors. However, Thai agricultural system is still in the age of 1.0-1.5. Most Thai farmers lack technology, no management, no marketing, no capital, no knowledge, with risks of epidemics, natural disasters and commodity price fluctuations. Farmers are therefore insolvent. This turns out to be a major problem that makes Thailand still stuck in the middle-income trap. Thailand will not be able to step out of the middle-income trap country unless the agricultural sector is improved. The direction of Thailand's agriculture is changing (Transformation) based on the driving of the digital era and these interesting phenomena are expected to occur in the Thai agricultural sector in nine aspects namely: 1. Satellite for Agriculture, 2. Zoning, Geo Strategy, 3. Water Management and IoT, 4. Seed and Soil Development, 5. Services or Smart Farming vs Contract Farming, 6. Traceability vs Blockchain, 7. Commodity to Process and Branded Food to Innovate in Health and Beauty, 8. R&D Agro and Food as Regional and Health Technology, 9. Sustainability and Landuse.

The first aspect, Satellite for Agriculture technology truly changed the world. It is reinforcing how people change their lives after having a Google Map. It can find precise locations; Google Map is a Satellite on its own. If we do not use satellite technology in agricultural systems, it means that we do not accept changes in the world. However, if the satellite is used in the agricultural system the changes will be enormous. Especially, the allocation of specific land to its appropriate crops. Now-a-days, satellite systems can capture clear images of specific shades of minerals, soil conditions and soil readiness. At the same time, the satellite system also helps to plan precise cultivation, including management of harvesting and production. This will be useful for planning purpose and help solve the problem of oversupply of agricultural products and price subsidies from the government.

The second aspect, which, talks about Zoning, Geo Strategy v/s Market, is another trend that will occur and create changes for the agricultural sector. Planning to manage the area or the zone of cultivation, that are suitable for the geography and market demand, will make Thailand rich. For example laying a stationary zone for growing coconuts, to support the needs of the Chinese market, whereby in their everyday life they drink more coconut water. But in China, there is no coconut growing area. The third aspect that will happen is Water Management and IoT, because water or irrigation systems are the heart of agricultural development. Most Thai farmers are still poor because they have water problems, this results in poor productivity. If water innovation technology management can be used to help plan more efficient farming, then it will help solve the problem. For example, the current Charoen Pokphand Group and True, together with the NSO, develop water level measuring equipment using IoT with SIM phones and wind energy to communicate to know the water level in various agricultural areas can manage water for maximum benefit. The fourth aspect is about seed and soil. For agriculture practice to be successful, it requires good quality seeds and suitable soil for cultivation. Soil preparation is important in the modern era. If the soil is not prepared properly, the output will not be as desired and can't compete globally. Currently we are keeping pace with the technology in soil improvement, most of them are applicable to large farm called Mega farming and cost intensive, but in Thailand the size of the farm is small. It is another important issue that every related sector must manage to help Thai farmers. Fifth aspect: Services & Smart Farming vs. Contract Farming, amid global changes the new agricultural trend will be a large farm or Mega Farming in foreign countries. If it is in Europe, it will be a "cooperative" model of agriculture (Co-Op). The success comes from the Entrepreneur Spirit of the cooperative leader. This is however, different from Thailand. In the United States, the success of "Contract Farming" and Mega farm was because of access to technology, marketing and management. The number of farmers decreased by being absorbed into various industries and services, causing no social problems because the United States is a large country with high per capita land available. But for Thailand the development of the agricultural sector to keep pace with global changes by bringing the cooperative system or contract farming might be a problem. The migrating agricultural workers to other industries or services may not be able to adequately support contract farming in Thailand. For this reason, a new concept was introduced by adopting the social enterprise system or community enterprise. It is a model that allows farmers to be shareholders, create new business called Service Farming or Smart Farming to replace the sustainability of farmers, and also create a new generation of farmers that are startup as well. The sixth aspect, and Traceability through Blockchain: For agriculture, it can be said that traceability is an important issue in the 4.0 era. The current problems of the agricultural sector which occurs, are caused by the lack of

traceability, such as the Thai fishery problem. In future there is going to be a new method called blockchain or data collection network, there are going to be new ways of forwarding data, be able to know the source, can check the source of the food and help create transparency in production, that has been involved with many stakeholders throughout the food supply chain. This is in accordance with international principles in order to get quality and safe products in a friendly environment which does not violate human rights. Seventh aspect: Adding value to agricultural products by processing food branding and innovation. Thai agricultural products are recognized for quality and have potential to penetrate the health and beauty market (Commodity to Process and Innovate in Health and Beauty). Value addition, branding and innovation including the privatization of Thai agricultural products will help enhance the potential of Thai agricultural products at the international level. However, the university, which has the ability to innovate the private sector with marketing and branding capabilities, should come together to enhance the potential of Thai products. Eighth aspect: is the research and development in agriculture and food (R&D Agro and Food as Regional and Health Technology) for Thailand to be a world-class talent in this era of Thailand 4.0. Thailand must recognise the importance of research and development. Thailand must bring in talented and world-class scientists in bio-technology related to agriculture and food in order to help transform Thailand into a premier center of research and development in agriculture and food in the region. Finally, Sustainability and Land Use: This new world in this 4.0 era, powered by a new generation that believes in sustainability. Even though sustainability importance is recognised by global organizations and world-class talent is available, there are no sustainability goals, this will however result into not being sustainable in the end. Therefore, in Thai agriculture development must adhere to the principles of sustainable development. In order to grow sustainably along with all other sectors, maintain balance in economic, social and environmental aspects.

2. **The concerted effort of 14 Thai banks to develop the first Thailand Blockchain Community Initiative**

The Thailand Blockchain Community Initiative is pushed forward by 14 Thai banks, in cooperation with 3 state enterprises and 4 large business corporations. With an aim to upgrade the business efficiency and competitiveness by adopting blockchain technology, this initiative will be initially implemented with Thailand's first project of blockchain-based letters of guarantee (LGs), fully integrating the LG system worth THB1.35 trillion into the era of electronic documentation wherein the operating costs will be cut by half. The system is currently being tested in the Bank of Thailand (BOT)'s regulatory sandbox, which facilitates the development of innovative and standardized financial products and services for maximum benefits of service providers, consumers and the Thai economy,

and is expected of interoperable launch in the third quarter of this year. Dr Veerathai Santiprabhob, BOT Governor, said the Bank of Thailand is delighted to witness the setup of Thailand Blockchain Community Initiative which will be beneficial to banking and business sectors as a whole and Thai economy, in particular, the adoption of high potential technology as such blockchain can diversely change how we conduct businesses. Participating banks will be able to share this infrastructure and technology without having to fully invest in such development individually. This will as well help achieve higher efficiency and lower costs. For the business sector, Thailand Blockchain Community Initiative will reduce the complexity of connecting to the same financial services provided by different banks, facilitate the data verification on the same blockchain network, mitigate counterfeit risks, and increase timeliness as well as security. This program is also deemed to be notable cooperation between the banking and business sectors with a common goal to boost the overall Thai economy and competitiveness of our country. Thailand Blockchain Community Initiative – the first cooperation of its kind in the country – has been developed with an objective of using cutting-edge technologies, such as blockchain to upgrade the Thai business sector through closer cooperation among 14 banks. These include, Bangkok Bank, Krungthai Bank, Bank of Ayudhya (Krungsri), KASIKORNBANK, Kiatnakin Bank, CIMB Thai Bank, TMB Bank, TISCO Bank, Siam Commercial Bank, Thanachart Bank, the Bank for Agriculture and Agricultural Cooperatives, United Overseas Bank (UOB), Standard Chartered Bank (Thai) and the Government Savings Bank, plus seven large corporations, including Metropolitan Electricity Authority, Provincial Electricity Authority, Electricity Generating Authority of Thailand, PTT Global Chemical, PTT Polymer Marketing, IRPC and SCG. Related technologies, legal aspects and overall picture of this initiative are supported by Accenture, Baker & McKenzie, NECTEC and IBM (Techsauce, 2018).

3. Thai Rice Exporters to Implement Blockchain Technology

Asia Blockchain Review (2019) reported that the rice export market is facing fierce competition, especially among exporters in Thailand, Vietnam, and India. To gain market share, Thai rice exporters have been encouraged to adopt blockchain technology, in order to verify the origin of rice and logistics in a transparent manner. Thailand, a leader in rice exports for over three decades, is facing problems of falling in export volumes to international markets. The Thai Ministry of Commerce revealed that the export of Thai rice in 2018 decreased to 11 million metric tons from 11.6 million tons the previous year. The Ministry has forecast rice exports for 2019 at only 10 million tons. Thai exporters and the private sector have put the estimate even lower at 9 to 9.5 million tons, due to external factors. Meanwhile, the United States Department of Agriculture has stated that from 2018-2019, the U.S. is Thailand's second largest rice export market. However,

Thailand is at the risk of being replaced by competitors that can offer lower prices for the household staple. To tackle this issue, Thai rice exporters have been advised to implement new technology in rice exports, such as blockchain. Blockchain offers a distributed ledger that can be used to store data about crop origins, farms, weather, and logistics as a means of increasing transparency and adding value to rice products. In using blockchain, Thai rice may gain an advantage over competitors and earn more trust from consumers in markets worldwide, leading to higher sales. Thailand should also seek to promote the uniqueness of Thai jasmine rice, while reinforcing its decades long reputation for high quality. The country must also develop variety and innovate to reduce production costs to keep up with competitors.

4. The Ministry of Commerce began to survey Solution Blockchain for agriculture and copyright

On October 9, 2018, Bangkok Post reported that Thailand Ministry of Commerce had begun to investigate the possibility of using blockchain technology in copyright, trade, agriculture and finance. The Director of the Trade Policy and Strategy Office (TPSO), Miss Pimchanok Wonkorphon, told the Bangkok Post newspaper that a survey was conducted in cooperation with the British Embassy, with the objective of studying decentralized solution or data center distribution system that can increase the competitiveness and credibility of the country, especially in small and medium businesses. Blockchain's feasibility study goals include managing digital code processing, IP registration, security and smart content. In addition, TPSO also wants to build a sandbox to use blockchain in the rice export industry. According to the Bangkok Post, report the exporting of agricultural products to foreign countries involves at least 7 government agencies and takes at least 15 to 20 days, which is a high cost. Moreover, with the expectation from Blockchain network will help reduce the delivery time to three days and increase trust at all levels of the food chain. Using blockchain as a guide in helping traceability or tracking every food chain in the system, IBM collaborates with major retailers such as Walmart in the United States and Carrefour in France launch Food Trust, which uses the platform. The Blockchain, technology enables the food chain system to be trusted since this method can be used to track food from farmers to retail store shelves. Many of Thailand's financial industries are actively considering the solution blockchain in practical use. The Thai Bond Market Association (TBMA) has created a platform for new registration services to issue bonds faster with the method of distributing such data centers can reduce the time for issuing bonds from about 15 days to about 3 or 4 days (Crypto reader, 2018).

5. The Ministry of Commerce holds "Blockchain" to help farmers and improve registration

The Ministry of Commerce revealed that the Office of the Prime Minister has provided a workshop to develop the knowledge of Thai government and private organizations about blockchain technology that has played a huge role in the modern economy today. In the present world, blockchain technology can be put into practice in varieties of applications, such as traceability, digital identity verification, commercial IP management, finance for International Trade (Trade Finance), etc. All these issues have to do with the responsibility of the Ministry of Commerce. The Ministry of Commerce requests for some support from the British Embassy in Thailand in order to prepare a feasibility study project. Blockchain will be implemented in 2 business sectors in Thailand, such as Private blockchain (this is to help with the registration of intellectual property) and blockchain for trade finance (which is to help improve the payment process of export processing). This will help create trade opportunity for the operator and it will reduce work procedures and increase efficiency in government services in the future. In addition to the two projects, the Office of the Prime Minister is discussing with a new generation of farmers to make sandbox or experimental processes to use blockchain in organic products methods by conducting a reverse data verification process. Normally, the organic standard certification process and the export permit takes 15-20 days, because, the documents are complex and need to contact many agencies, both public and private. Therefore, using blockchain will reduce the amount of time to be not more than 3 days and help increase transparency, reduce farmers' costs, reduce time and increase credibility of Thai organic producers in foreign countries. Matichon (2018) believed that many modern technologies such as blockchain will help SMEs, entrepreneurs, as well as small farmers, which is a large group of people in the country to compete in the world market and it will develop strong trade economy locally. Office of the Prime Minister believes that modern technology will help reduce inequality problems in the Thai economy.

3.5 AGRICULTURAL BLOCKCHAIN MODEL TO PROMOTE FARMERS DIGITALLY

This section proposes an example of agricultural training on blockchain as a new knowledge-based potential model for promoting farmers digitally instead of supporting and subsidizing the agricultural sector directly by the government. Such as giving money per person as material cost, production equipment, and compensation for fall in the price of agricultural product, however, some farmers do not use the money received for actual production and is just like government budget used for non-target purposes. This new type of support is to promote knowledge and skills of farmers through participation in training activities,

seminars, visits to Agricultural Centers of excellence (Agri.COE), in the best practice contests and receiving agricultural information from universities and government agencies in agriculture. This will, however, positively affect the development of the production of agricultural marketing image throughout the value chain, with the online mobile platform for a virtual coin collection that has real value compared to Thai money (1 coin = 100 THB). If the farmers accumulate coins to a specified level, they can use the coins to buy agricultural equipment, consumable goods from partner shops that are in collaboration with the program. Remaining coins can be converted into a savings account by a government agency. Such government agencies are Maejo University, Department of Agriculture, Department of Agricultural Extension, Office of Agricultural Economics, National Research Council of Thailand, Thailand Science Research and Innovation sponsored the budget by Farmer Bank and Bank for Agriculture and Agricultural Cooperatives (BAAC). These government agencies take care of internet banking account of farmers and transaction record including clearing house as shown in Figure 1.
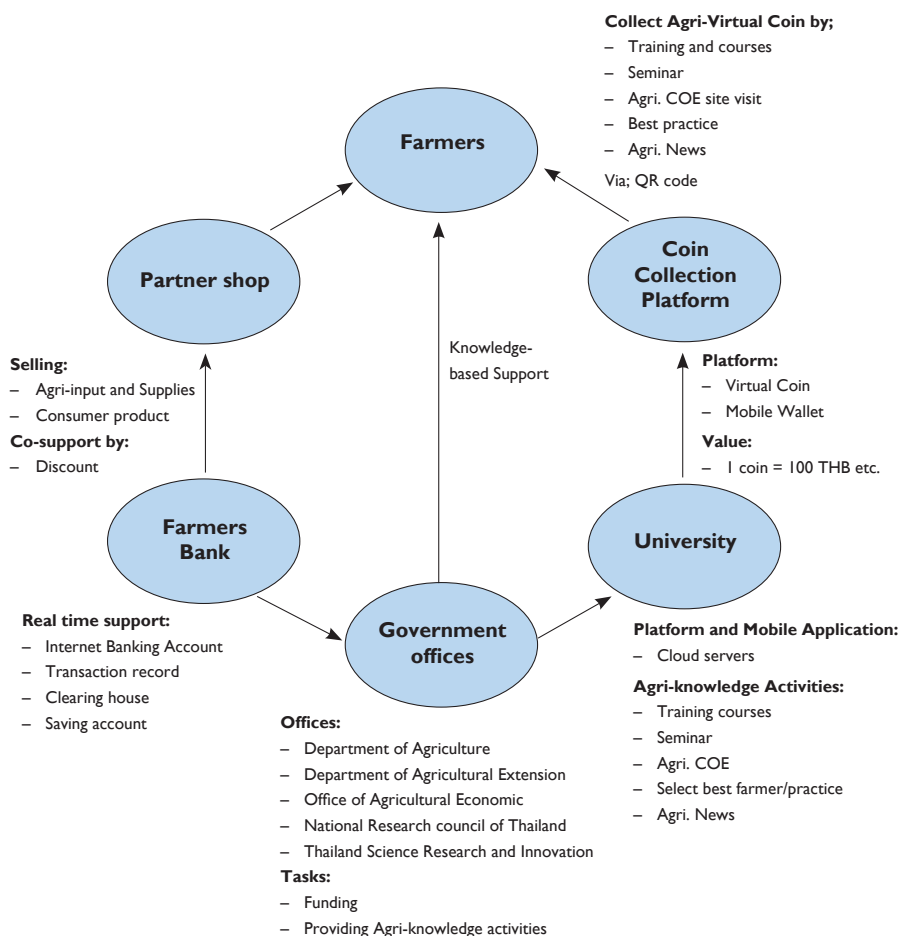

FIGURE 1: *Promoting farmers Digitally via Agricultural Training Blockchain*

3.6 Conclusion

Blockchain innovation has come up as the most vigorous and secure innovation of present date and this basic innovation will undoubtedly make advances in each area. Beginning from the banking and financial division, the innovation is upsetting other conspicuous enterprises including social insurance, vitality, retail, administration, store network, and farming in the most unbelievable ways. Blockchain innovation has a few chances to explain enormous difficulties tormenting the Agriculture sector. From dealing with the exceptionally unpredictable multi-mainland agrarian production network to transmitting ongoing information about harvests and animals, Blockchain innovation can give consistency to wide regions of the Agricultural business. Blockchain can perhaps essentially sway the manner in which rural business is finished. Blockchain innovation can build trust between gatherings, encourage data sharing all through the production network and essentially lessen rural exchange costs.

Blockchain gives off an impression of being an elixir on different issues, which have been tormenting the agriculture and food divisions for innumerable decades. The coordination of Blockchain innovation will make the procedure of payment of agricultural appropriations increasingly straightforward, safe to spillages, and productive. By giving a solitary database containing records of homesteads over the limits, Blockchain would limit the strain of record keeping and keeping up various record frameworks.

In any case, with every one of these guarantees ensured by Blockchain and its applications, it is essential to understand that Blockchain alone won't inspire poor farmers out of destitution. It would give the mechanical foundation to digitization, automation, and traceability while at the same time presenting a few new and little farmers into modern agriculture. This new headway will offer unlimited open doors for the farming business to develop and flourish.

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Using Blockchain & Internet of Things (IoT) in Agri-Food Supply Chain Traceability

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4.1 Introduction and Background

In recent two decades, with the rapid development of the economy and the continuous improvement in people's living standards, food safety has gradually become the focus of attention and has been developed into a worldwide concern. Some historical events of concern such as the outbreak of the Mad Cow Disease at United Kingdom in 1996, the Avian Influenza at Hong Kong in 1997, the Pig Encephalitis in South East Asia in 1998, the Foot-and-Mouth Disease in Europe in 2001, the SARS in Hong Kong in 2003, the Sanlu milk scandal at China in 2008 and the global pandemic H1N1 flu in 2009 increased the concern about safety in food production, supply chain and processing environment. Animal food contamination with hormones and plant foods with toxins and colorants are also issues of concern.

Some of the main reasons behind these food safety issues are as follows:

4.1.1 Excessive use of chemical fertilizers, pesticides and other substances into production

In agricultural production, some vegetable farmers and fruit growers often spray toxic or even highly toxic pesticides in order to safeguard the crop and to increase their income. This directly leads to excessive pesticide residues in vegetables and fruits. Consumption of such vegetables and fruits will certainly lead to severe health hazards.

4.1.2 Heavy metal contamination in food

Due to the illegal release of waste water by some industrial and mining enterprises into the water bodies in city or countryside, the drinking water source of human and livestock, as well as the irrigation water source of crops in some areas are polluted by excessive intrusion of heavy metal elements, such as lead, tin, mercury, and zinc which are harmful to human health. Drinking water and agricultural foods contaminated with these heavy metal elements when consumed, will cause great harm to human health. In addition, some

packaging papers, packaging bags and stainless steel utensils used to hold food are also important sources of heavy metal pollution such as lead, chromium, and nickel. Once these heavy metals are infiltrated into food, they will be accumulated and pose a great potential threat to human health.

4.1.3 The use of inferior raw materials in the manufacturing and processing of food poses a great risk to food safety

Examples include, processing cooked meat products from sick poultry and livestock, processing fried foods with illegally recycled waste cooking oil, and "water-injected pork" (supplying water to pigs is equivalent to poisoning, and it is extremely harmful to the human body after eaten). If these inferior raw materials with safety hazards are not totally destroyed in time, they may evolve into food safety accidents that endanger the health of consumers.

4.1.4 Excessive use of food additives and other chemical products in food processing

Some black-hearted enterprises and greedy commercial households are driven by money for business. In the process of food processing, they often use food additives, antibiotics, and hormones in excess quantities, and even add toxic and hazardous chemicals to enhance shelf life. In order to pursue profits, some food producers ignore the protection of consumers' lives and right to health, illegally use and add chemical substances beyond the scope of food laws and regulations. Examples include adding an ultra-fine amount of brightener, "benzoyl peroxide" in flour; using synthetic chemical sweeteners in beverages to exceed the limit; using steamed bread to make steamed buns; using mineral oil to brighten rice and biscuits; and soaking sea products with formaldehyde to make it tough, bright, and to extend shelf life etc. Other chemical products such as malachite green, sudan red, melamine used in some food processing units that have no distinct smell or taste can lead to food poisoning, chronic diseases and even death. In addition, hormones and other drugs are abused in agriculture and aquaculture to increase production and to mature fruits, vegetables, poultry, livestock, and aquatic products in shorter term. For example, sharp-edged tomatoes, hard kiwifruit, hypertrophy sprouts, etc. may all be the result of using hormones to promote long maturation. These practices not only significantly reduce the nutritional value of the food products, but also cause great harm to the health of consumers.

In order to tackle these issues technically and effectively, we need a safe and reliable food traceability system that can track and monitor the whole lifespan of food production, including the processes of raw material cultivation/breeding, processing, transporting,

warehousing, and selling etc., which involve a large number of untrustworthy business parties. In this chapter, we propose a blockchain and IoT technology-based food traceability solution, which integrates trustworthy blockchain verification mechanism and tamper-proof advantage into the low-power wide-area network (LPWAN) IoT system, such as LoRa/NB-IoT based smart agriculture system. We believe that this integration will help people to improve the food safety status.

4.2 STATE-OF-THE-ART AND STATE-OF-THE-PRACTICE: LITERATURE REVIEW

Smart agriculture is the application of technologies such as Internet of Things (IoT), Big Data, Global Positioning System (GPS), Cloud Computing, and Artificial Intelligence (AI) into traditional agriculture. The use of intelligent agricultural IoT platform, through a large number of sensing nodes in the target areas, such as farmland, greenhouses, forest gardens, pastures, can collect the information of breeding or sowing/ planting in real-time. Such information like temperature, humidity, light, gas concentration, soil moisture, electrical conductivity, and production images during production, processing, transportation, and sales process, are aggregated into the cloud based central control system for study or analysis using AI algorithms. Agricultural production personnel can analyze environmental big data through monitoring pests and diseases and various risk factors, so that targeted agricultural production materials can be put in place; various execution equipment can be mobilized as required to perform temperature control, dimming and ventilation, as well as other actions to achieve intelligent control for the growing environment of agriculture.

Smart agriculture is an innovative way of carrying out farming activities by reducing human efforts and by making maximum utilization of the available resources. It can solve the problem of shortage of agricultural workers, further improve the working ability and efficiency of agricultural production to minimise risks, as well as help small, weak farmers to produce large-scale network and intelligent transformation. The use of sensors, gateways, cloud servers, etc. to control agricultural production through mobile platforms or computer platforms will make traditional agriculture more "wisdom". In addition to precise perception, control and decision-making management, in a broad sense, smart agriculture includes agricultural e-commerce, food traceability and anticounterfeiting, agricultural leisure tourism, and agricultural information services.

The rest of this section will review the related work on different methods, technologies and applications for smart agriculture and food safety.

4.2.1 IoT Framework for Smart Agriculture

In paper [1], based on Material Conscious and Information Network (MCIN) model, authors proposed a method to design the MCIN-based architecture for smart agriculture, which is different from current vertical architecture and involves production, management and commerce. The architecture is composed of three components which are enterprises, individuals and commodity. It uses enterprises and individuals' personalized portals as the carriers which are linked precisely with each other through a peer-to-peer network called six-degrees-of-separation block-chain. The authors want to establish a self-organized, open and ecological operational system which includes active, personalized consumption, direct, centralized distribution, distributed production for smart agriculture. The authors think that new architecture improves current agriculture greatly and inspire a lot in production-marketing-combined electronic commerce.

In paper [2], authors studied the realization of IoT in the field of agriculture, including a comprehensive review of its framework, considerations and implications in implementation. The paper intends to brief the reader about the IoT technology and its operational requirements in agricultural practices. Some real-world examples about the working of agriculture IoT are discussed. The result shows that the use of IoT in the fields and orchards will help the farmers reap the benefits of its technology manifold.

In paper [3], authors surveyed some typical applications of Agriculture IoT Sensor Monitoring Network technologies using Cloud computing as the backbone. This survey is used to understand the different technologies and to build sustainable smart agriculture. Authors think that precision agriculture sensor monitoring network is used greatly to measure agro-related information like temperature, humidity, soil pH, soil nutrition levels, water level etc. so, with IoT farmers can remotely monitor their crop and equipment by using phones and computers.

In paper [4], authors reviewed state-of-the-art communication architectures for the Internet of underground things (IOUT), which consists of sensors and communication devices, partly or completely buried underground for real-time soil sensing and monitoring. An underlying sensing technology and communication mechanisms for IOUT are presented. Recent advances in the theory and applications of wireless underground communication are also reported. Major challenges in IOUT design and implementation are identified.

4.2.2 IoT Based Intelligent Irrigation

In paper [5], authors proposed a design of a smart IoT communication system used as a low cost irrigation controller. The proposed irrigation tool uses real time data such as the

variable rate irrigation and some parameters taken from the field. The field parameters, the index vegetation (estimated using aerial images) and the irrigation events, such as flow level, pressure level or wind speed, are periodically sampled. Data is processed in a smart cloud service.

In paper [6], authors proposed a novel fuzzy computational algorithm for IoT smart irrigation systems. It describes all the possible sensors, actuators and microcontrollers that could be used in the irrigation systems. The irrigation system continuously monitors air temperature, humidity, and ground moisture. The ground humidity sensors are interspersed all over the field. The measurements are sent into a microcontroller that applies a fuzzy computational algorithm and decides whether to open a servo valve or not. All the data collected from the microcontroller are sent to a cloud database for statistical information and processing.

In paper [7], authors also proposed an IoT application, named "Smart Irrigation Analysis", which provides remote analysis of irrigation on the field to the end user that is better than traditional irrigation of crop on field. Smart irrigation application has an automated recurring watering schedule, sensing and analysis of water used for crop and the moisture level given real time data. They use ESP8266 Microcontroller with built-in Wi-Fi module. Soil Moisture sensor is set in the field, which keeps track of moisture level in field soil. The collected data are sent over cloud to make people's nurturing activity pleasing and tranquil. Data from the cloud is analyzed and irrigation related graph report for future use for farmer is made to take decision about which crop is to be sown.

In paper [8], authors proposed a LoRa based smart irrigation system. The irrigation node is mainly composed of LoRa communication module, solenoid valve and hydroelectric generator. The irrigation node sends data to cloud through LoRa gateways via wireless transmission. The system can be controlled remotely by mobile applications. Their experimental results show that both transmission distance and energy consumption in the proposed system are reliable.

4.2.3 Blockchain for Internet of Things

In paper [9-10], authors proposed a blockchain built-in solution for LoRaWAN network servers to build an open, trusted, decentralized and tamper-proof system, which provides the indisputable mechanism to verify that the data of a transaction has existed at a specific time in the network. They think it is the first work that integrates blockchain technology and LoRaWAN-IoT technology, and utilizes advantages of both.

In paper [11], authors purposed a proof of concept to enable low-power, resource constrained IoT end-devices accessing a blockchain-based infrastructure. To achieve this aim, they designed an IoT gateway as a blockchain node and proposed an event-based messaging mechanism for low-power IoT end-devices. A demonstration of such a system was implemented using LoRa nodes and gateway in a private ethereum network.

In paper [12], authors discussed the integration of the blockchain with the IoT with highlighting the integration benefits and challenges. They think that moving the IoT system into the decentralized path may be the right decision. The blockchain is a powerful technology that is able to decentralize computation and management processes that can solve many of IoT issues, especially security.

4.2.4 Blockchain for Smart Agriculture

Blockchain technology has been applied in smart agriculture. Even UN FAO also recommended that ICT (Information and Communications Technology) e-agricultural infrastructure components are a confluence of ICT and blockchain technology requirements. They think that when ICT e-agricultural systems with blockchain infrastructure are immutable and distributed ledger systems for record management, baseline agricultural environmental data integrity is safeguarded for those who participate in transparent data management. In paper [13], authors reviewed blockchain-based concepts associated with ICT-based technology. Moreover, they proposed a model ICT e-agriculture system with a blockchain infrastructure for use at the local and regional scale.

In paper [14], authors proposed a lightweight blockchain based architecture for smart greenhouse farms to provide security and privacy. The IoT devices in greenhouses which act as a blockchain managed centrally to optimize energy consumption have the benefit of private immutable ledgers. In addition, they presented a security framework that blends the blockchain technology with IoT devices to provide a secure communication platform in Smart Greenhouse farming.

4.2.5 Smart Food Monitoring/Traceability System

Traceability is very important in the food supply chain to ensure the consumers' food safety. In recent years, many solutions with various emerging ICT technologies have been proposed to improve the traceability of animals, plants, and food products.

In paper [15], authors proposed a Radio-Frequency Identification (RFID) enabled traceability system for live fish supply chain. The system architecture is designed according to the specific requirement gathered in the live fish processing. Likewise, it is adaptive for the small and medium enterprises. The RFID tag is put on each live fish and is regarded

as the mediator which links the live fish logistic center, retail restaurants and consumers for identification. The sensors controlled by the PLC are used to collect the information in farming as well as the automatic transporting processes. The traceability information is designed to be exchanged and used on a web-based system for farmers and consumers. The system was implemented and deployed in the live fish logistic center for trial, and the results are valuable for practical reference.

In paper [16], the author proposed an agro-food supply chain traceability system that utilizes the RFID and blockchain technology. He analyzed the advantages and disadvantages of using RFID and blockchain technology in building the agro-food supply chain traceability system and demonstrated the building process of this system. He thinks it can bring the traceability with trusted information into the entire agro-food supply chain, which would effectively guarantee the food safety, by gathering, transferring and sharing the authentic data of agro-food in production, processing, warehousing, distribution and selling links.

In paper [17], authors presented their experimentation and implementation journey to open source IoT for cows tracking. They proposed a LoRaWAN architecture for long range communications and analyzed the high level system architecture for cattle tracking. Furthermore, they also developed and presented the design of software application and protocol.

In paper [18], authors proposed a new approach that lead to trusted cooperative applications and services within the agro-food chains. They used blockchain to enhance the transparency, information flow and management capacity allowing better interactions of farmers with other part of supply chain, especially the consumer. They think the research will provide better performing value chains by proposing new food-on-demand business model, based on new Quality of Experience (QoE) food metrics, bridging the gap between subjective experience and objective metrics based on quality standards.

In paper [19], authors proposed a decentralized, blockchain-based traceability solution, named AgriBlock-IoT, for Agri-Food supply chain management, which is able to seamlessly integrate IoT devices producing and consuming digital data along the chain. They defined a classical use-case within the given vertical domain, namely from-farm-to-fork, and developed and deployed such use-case, achieving traceability using two different blockchain implementations, namely Ethereum and Hyperledger Sawtooth. Finally, they evaluated and compared the performance of both the deployments, in terms of latency, CPU, and network usage, by highlighting their main pros and cons.

4.3 Blockchain & IoT based Agri-Food Supply Chain Tracing System

4.3.1 Trusted Trade Blockchain Network Cloud Platform (TTBNCP) and its Application on the Smart Agriculture Ecosystem

The above research works show that the applications of IoT and blockchain technologies can bring smart agriculture and food traceability system many benefits, but most of them are ad hoc solutions for one function or some specific aspects. In this paper, we propose and design a general blockchain and IoT based smart agriculture ecosystem as shown in Figure 1.
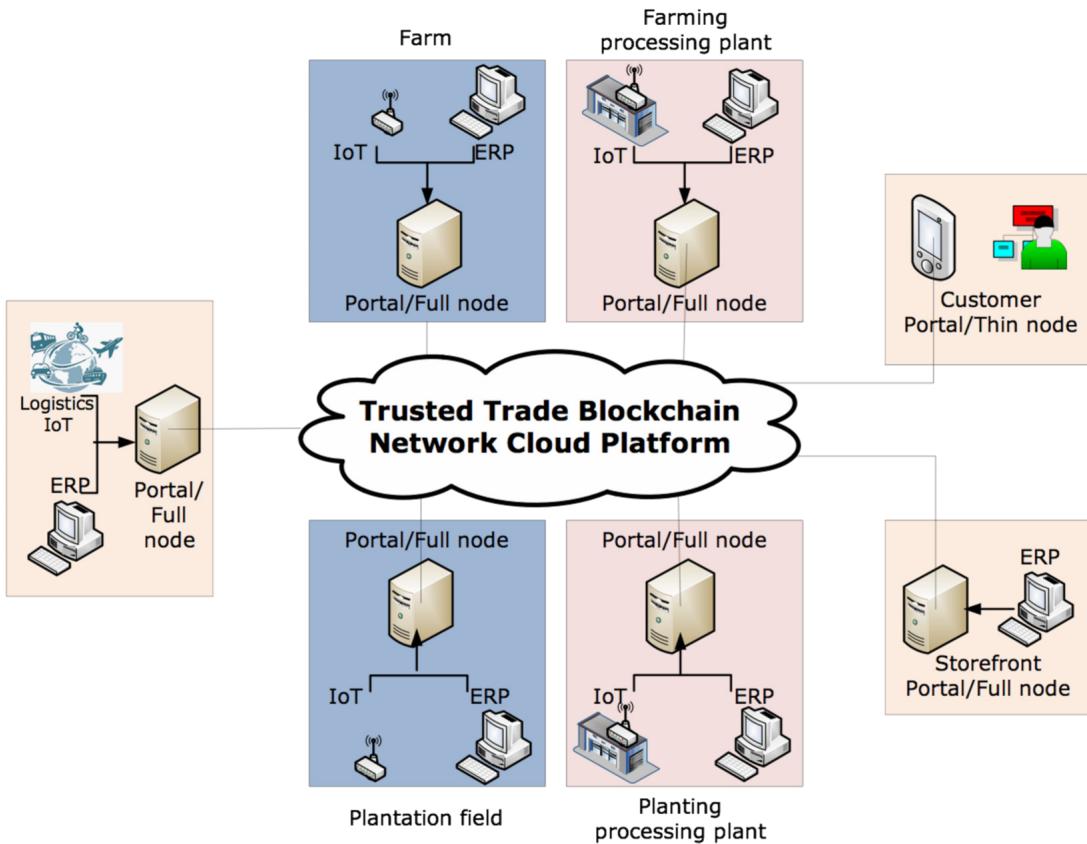
FIGURE 1. *Blockchain and IoT based smart agriculture ecosystem*

Our ecosystem involves the traditional Enterprise Resource Planning (ERP) legacy system and some new IoT systems that deployed in farm companies, farming processing plants, plantation companies, planting processing plants, logistics companies and food retail storefronts, etc. The core of the whole architecture is a virtual Trusted Trade Blockchain Network Cloud Platform (TTBNCP), which can help us to establish a trusted, self-

organized, open and collaborative mechanism among those different parties in an ecological smart agriculture application ecosystem. End consumers can use their smart mobile phone as a window even a thin computing node to access, retrieve and verify the data stored in the blockchain system, which may include different kinds of edge IoT devices, gateways, servers, cloud and so on.

4.3.2 Blockchain-IoT System Architecture

The virtual TTBNCP consists of all portals in the smart agriculture ecosystem physically as shown in Figure 2. Those portals are also nodes of blockchain Peer-toPeer (P2P) system. There are two types of nodes in the system: one is equipped with full functionalities of blockchain node, such as symmetric encryption and decryption, consensus algorithm, Merkle trees building, distributed ledger, etc.; another is the thin node that is just a simplified payment verification (SPV) node with simplified payment verification function and stored transaction related data.
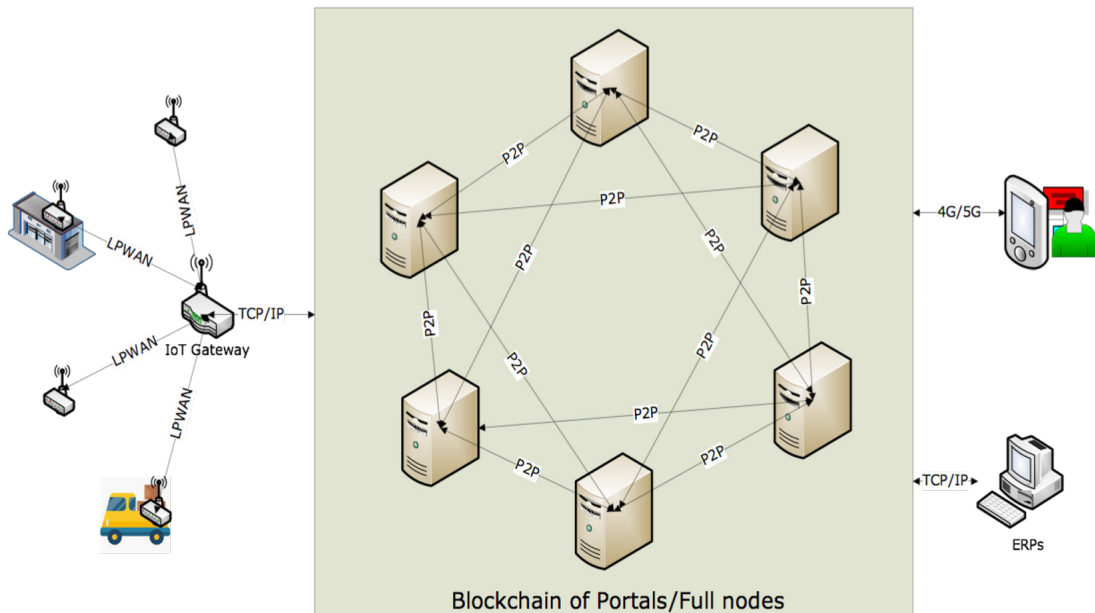
FIGURE 2. *Architecture of the blockchain IoT system*

4.4 DATA PROCESSING FLOW AND STRUCTURE

There are two types of transaction data that will be stored in the blockchain, as shown in Figure 3. One is that generated from traditional ERP legacy systems, such as the trade, logistics, delivery, warehousing information etc.; another is that generated from IoT devices, such as the air temperature, air humidity, soil pH, soil nutrition, ground moisture

data etc. After hashing and digital signing, those data will be sent to the entire nodes of blockchain system directly or through the IoT gateways, where they will be verified, added into transaction pool, and stored into blockchain.
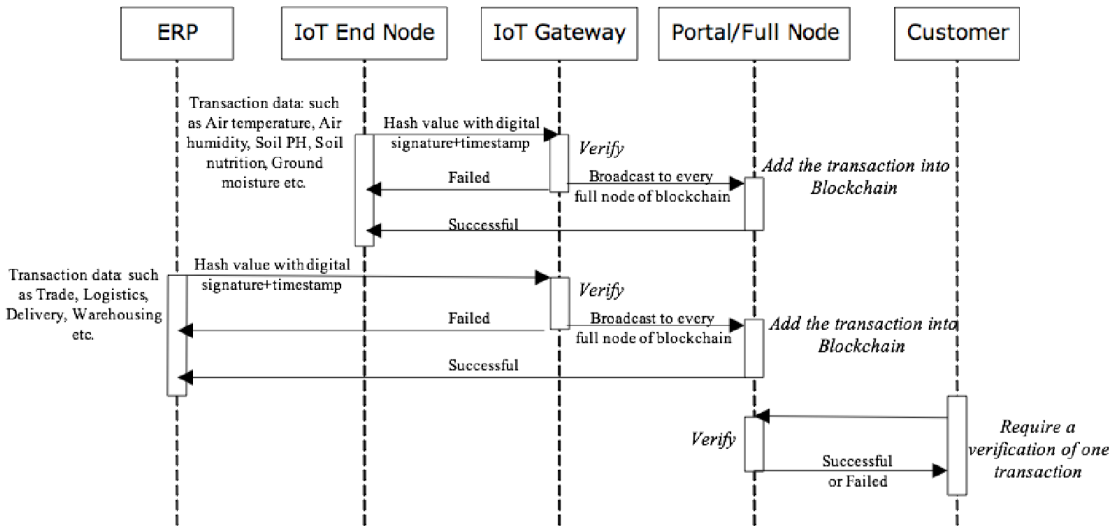
FIGURE 3 *Flow of the transaction data process*

End consumers can use their computers or mobile phones to retrieve all transaction data and verify them. For example, one buys a box of milk from a supermarket, and then he/she can use a smart phone to scan the 2-D barcode to retrieve all transaction data related to it, including which farm the milk was produced from, on which day and time it was produced, the ID of cow in the farm, the ID of the staff who collected the milk, collecting device information, packaging information, all the temperature and other environment data for the milk's production, process, logistics, storage etc. All those information can be verified by the blockchain system without the human intervention. Figure 4 shows a sample of the blockchain data structure.

FIGURE 4 *Sample of blockchain data*

4.5 Conclusion

In summary, blockchain and IoT technologies can help us to build a trusted, self-organized, open and ecological smart agriculture system, which involves all parties in the ecosy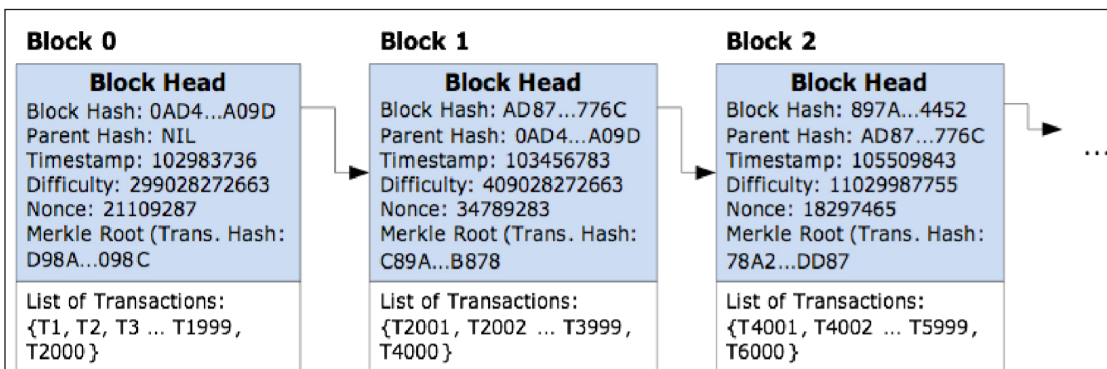stem, even they may not trust each other. To the best of our knowledge, this is the first work on applying blockchain technology and IoT technology on traditional smart agriculture ecosystem to solve the food safety issues. The proposed method tries to use IoT devices instead of manual recording and verification, which reduces the human intervention to the system effectively. In the future, we will explore how to use the smart contract script technology to define a set of automated warning code in the system, to help law-executors to find problems automatically and process them timely.

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Blockchain Technology for Inclusive Development of Agrarian Rural Economy

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5.1 BACKGROUND

Farming systems, especially the smallholder and family farming systems, in developing and less developed countries, are burdened with many challenges and are vulnerable to various risks and shocks. While climate change and natural resource scarcity are the two most widely known challenges for the agriculture sector, there are many other serious impediments, such as lack of income stability and resilience that affects the smallholders. Moreover, smallholders are mostly deprived of access to finance and market, making farming an unprofitable and economically unrewarding activity for many of them.

Agriculture research and development has so far been mostly concerned with increasing farm productivity, which, however is not of much help for the smallholders. With their small landholdings and frugal resources, it is not possible for many of them to achieve economies of scale to compete fairly in the market. Therefore, it is nearly impossible for smallholders to make decent profit, which is sufficient for their livelihood. This is a key reason why many smallholders continue doing farming primarily for their own consumption, only occasionally selling their surplus produce; that also to intermediaries who pay pittance compared to the commodity price in organised agriculture markets.

With these handicaps, there is a bleak possibility that smallholders would ever be able to get out of the vicious cycle of poverty and debt. Hence, to change this situation, infusion of capital in form of farm loans and introduction of safety nets such as insurance have been much emphasized. It is interesting to note that smallholders also constitute the largest share of unbanked population in the world, which is why access to institutional finance and other services such as insurance is lowest among them.

Blockchain and distributed ledger technologies can potentially help in changing this state of affairs. Blockchain can bring in trust and veracity, especially in identity management and audit trail, which is a critical prerequisite for the financial institutions to extend credit. Therefore, blockchain can not only make it possible for financial institutions to include

more people under its service net, but also, combined with other digital technologies such as artificial intelligence and big data analytics, can reduce (or possibly eliminate) the role of intermediaries in agriculture value chains, making it leaner, more efficient and digitally inclusive, especially for the smallholders.

Although blockchain is an emerging technology that yet to have many successful evidences in the domain of food and agriculture systems, there are still many potential use cases that can possibly disrupt the farming systems by removing or resolving many of the handicaps that smallholders are burdened with today.

5.2 SMALLHOLDERS AND THEIR IMPORTANCE IN FOOD SYSTEMS

Smallholders are defined as small-scale farmers, pastoralists, forest keepers, fishers who manage farm holdings varying from less than one hectare to 2 hectares. Their farming objectives are family-focused motives such as favouring the stability of the farm household system, using mainly family labour for production and using part of the produce for family consumption (FAO, 2012).

Smallholders are critical for food and nutrition security in the developing world. Since last half a century, average farmland size has steadily been decreasing in most regions of the world (Lowder, Skoet, & Raney, 2016), resulting in food systems getting increasingly dependent on smallholders. Today, 500 million small farms account for around 80 percent of global food production (Dalgleish *et al.*, 2011). Women comprises about 40 per cent of the agriculture labour force in these farms, making smallholder based farming systems also critical for gender inclusivity (FAO, 2012).

In poor, labour-abundant economies, not only the small farms account for primary vocation for a large section of the rural poor, but they also generate informal employments at village level, which is why small farm development can be a 'win-win' proposition for growth and poverty reduction (Riesgo *et al.*, 2016).

In summary, smallholders are and will continue to be critical for food production as well as health and nutrition security and poverty alleviation. Indeed, both urban and rural consumers in developing countries count heavily on the efficiency of their local smallholder farmers to satisfy their food needs. Also, women, being a substantial majority of the smallholders, produce most of the food that is consumed locally. Smallholders, as gross domestic food and nutrient providers, have therefore a special role to play in the global efforts to improve food and nutrition security (Dioula, Deret, Morel, & Kiaya, 2013).

5.3 CHALLENGES IN THE SMALLHOLDER FARMING SYSTEMS

Smallholder farming systems are plagued with many challenges and constraints. Unlike bigger commercial farming systems, smallholders are more susceptible to shocks such as market price volatility, extreme climatic conditions as well as vulnerability to anthropogenic impacts such as water scarcity and contamination, land and forest degradation and atmospheric emissions etc. The fragility and lack of resilience of the smallholder farming systems affect achievement of some of the key Sustainable Development Goals (UNSDG) such as SDG 1, 2, 5, 6, 12, 13 and 14.

However, these anthropogenic and environmental impacts are not the only impediments to smallholder farming systems. Lack of access to capital, absence of safety nets such as insurance, exclusion from banking systems and poor land tenure management are some of the other key problems that smallholders across the world struggle with. Unlike the environmental and anthropogenic impacts, these challenges are more complex; as they not only involve agriculture sector but also other sectors such as banking, insurance etc. and calls for many legislative and policy level interventions in order to solve them. Hopefully, digital technologies could possibly play a bigger and more fundamental role in solving some of these challenges, as these technologies are cross-sectorial in nature and the impact of innovation in one sector is generally permeated across multiple sectors and society as a whole.

5.4 HOW BLOCKCHAIN CAN SOLVE SOME OF THE PROBLEMS OF SMALLHOLDER FARMING SYSTEMS

Technology innovations in agriculture, commonly known as Agtech, are widely believed to bring in solutions for many of the challenges that are affecting the food and agriculture systems. Digital technologies, such as Blockchain, Internet of Things (IoT), Artificial Intelligence and Robotics are considered to disrupt the way we produce and consume food and smallholder farmers could benefit as much from technology disruptions as large commercial farms.

Blockchain or distributed ledger technology in general, is a promising and potentially disrupting technology that can solve many of the problems of the smallholders as discussed in the previous section. Although most of the blockchain applications in agriculture so far have been focused around the problems of traceability and better supply chain management, blockchain technology could be an equally effective solution for many other problems in the food and agriculture systems. In the subsequent chapters, some of such high potential use cases are discussed.

5.5 How Blockchain can solve the Problems of Digital Inclusion through Digital Identity Management and KYC[1] Compliance

Financial inclusion of rural population is a humongous developmental challenge that most of the developing economies are burdened with. It is estimated that only 4.7 per cent of adults in rural areas in developing countries have access to loan from a formal financial institution and only 5.9 per cent of these population got a bank account (International Finance Corporation, 2014). Lack of access to finance is one of the key reasons for the perpetual dependence of smallholders on moneylenders, pushing them into a vicious cycle of debt and poverty.

Lack of identity is one key reason for financial exclusion of rural poor. Globally 1 billion people do not have an official proof of identity and one in every two women in low-income countries does not have an ID, limiting their access to critical services and participation in political and economic life (World Bank, 2019). Lack of identity results in inability to fulfil KYC requirements, which is a fundamental prerequisite for banking and financial services.

Digital technologies such as blockchain can offer plausible solution to this problem. This is because proliferation of mobile phones (both smart and feature phones) is widespread among the unbanked; about 1.1 billion unbanked adults – roughly two-thirds of all those without an account – have a mobile phone (World Bank, 2017a), which makes them digitally connected. Therefore, blockchain technology can provide a viable, economic and scalable solution for complying with KYC requirement using mobile phones and digital identity (also known as eKYC). In fact, it is estimated that mobile and blockchain technologies together can generate additional revenue of USD 380 billion from the emerging markets from the unbanked population alone (Pani, 2016).

Traditionally, KYC procedure involves physical verification of identity documents, such as passport etc. by the concerned agency. Sometimes KYC documents are also compared with various databases (e.g. crime records) for additional historical information. However, traditional processes are resource intensive and time consuming. It is estimated that the average cost incurred by the financial institutions to meet KYC obligations is about USD 60 million but some are even spending up to USD 500 million each year on KYC compliance alone (Thomson Reuters, 2016).

Higher cost and time requirement are not the only inefficiencies in traditional KYC process. Financial institutions generally do not share verification data among themselves,

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[1] KYC: Know Your Customer: It is process of a business verifying the identity of its clients and assessing their suitability, along with the potential risks of illegal intentions towards the business relationship.

resulting in KYC process being replicated multiple times by different organizations for the same customers or even by the same organization to offer different services to the same customer.

Blockchain technology allows collection of identity information about individuals from various service providers and store them into a single cryptographically secure and unchanging database without the need for a third party to verify the authenticity of the information. Due to this, it is possible to create a system where the user will only need to go through the KYC procedure once and then use this platform to confirm her/his identity for all future requirements. This is a huge improvement in terms of cost and infrastructure requirement that blockchain based KYC platforms can bring in. With this system, a rural farmer can be profiled once and then the collected data can be accessed remotely by a plethora of financial service providers for KYC purpose. Therefore, this system will not only reduce the cost and complications of KYC process but will make it possible for the rural farmers to avail services which were not available earlier because of KYC compliance requirements.
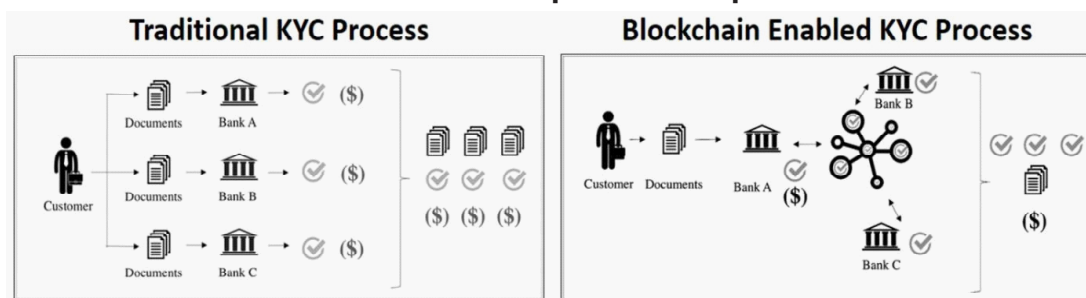
How blockchain improves KYC process

FIGURE 1: *Comparison between Traditional and Blockchain Enabled KYC Process.*
(*Source: Parra Moyano & Ross, 2017*)

Although blockchain enabled digital KYC (e-KYC) systems have many significant advantages over traditional systems, these are not without their own share of challenges and preconditions. The main challenge with blockchain-based e-KYC systems are the policy level changes that are required in order to make such systems widely accepted and available. It is also important to have a strong legal backing in place, as well as robust governance and oversight procedures together with data security and privacy laws to facilitate the use of decentralised system such as blockchain.

Blockchain, being still an emerging technology, needs favourable policies, such as permitting banks and mobile money providers to experiment with proofs-of-concept and pilot projects. In addition, suitable amendments or new legislations in data sharing and

Examples of blockchain applications in Digital Identity Management & KYC
1. In India, BankChain, which is a community of 27 banks, are developing blockchain enabled KYC protocols, which State Bank of India, a large public sector bank, will use for easy and secure customer onboarding, for example, for rural banking.
2. Indian start-up Signzy offers a digital on-boarding solution for banks, NBFCs and other financial institutions that uses a combination of artificial intelligence and blockchain to ensure that digital compliance is convenient but secure.
3. Jocata Financial Advisory & Technology Services Private Ltd. based in India, provides sophisticated Know Your Customer (KYC) and Anti-Money Laundering (AML) software as service (SaaS) that not only meets regulatory expectations and reduces the cost of compliance but also aims to drive business growth by creating a high-quality, standardized and reusable data asset.
4. Another Indian company Veri5Digital has built a suite of Identification products that use Video-Selfie and Govt. issued ID (PAN, Passport etc) to offer a KYC service.
5. Blockpass, based in China offers shared regulatory compliance services for humans, companies, objects and devices. As an identity system, that supports verification of humans (KYC), objects (KYO) and connected devices (KYD) through their software as service (SaaS) product suits.
6. The RegTech or regulatory technology division of IBM in 2018 successfully completed a "Proof-ofConcept of Blockchain-based Shared KYC" in collaboration with leading financial institutions such as Deutsche Bank and HSBC. Banks can in future use this technology to onboard rural unbanked population, such as farmers.

privacy laws that might affect the legal viability of blockchain-based solutions are needed for such solutions to function and flourish. Finally, they should encourage coordination among different stakeholders with a view towards ensuring interoperability between different institutions and blockchain arrangements, so that they can integrate as initiatives are scaled up (GSMA, 2019b).

5.6 How Blockchain can Help Smallholders' Access to Capital and Insurance

Access to capital is a key requirement for farm productivity and profitability. Capital availability can significantly increase the ability of households to meet their financial needs for agricultural inputs and productive investments. The resource poor farming households, in the absence of farm credit are more often unable to purchase inputs as needed and consequently limit their production and consumption choices (Lin, Wang, Gan, & Nguyen, 2019). Evidence from China suggests that one additional Yuan of credit can yield 0.235 Yuan of additional gross value of output (Feder, Lau, Lin, & Luo, 1990) and study in rural Peru reveals that credit constrain could account for as high as 27 per cent loss of agricultural output (Guirkinger & Boucher, 2008).

Lack of verifiable identification, credit history and risk assessment, difficulties in contract enforcement and the high cost of serving geographically dispersed customers are

some of the key obstacles to financial inclusion of farmers (Mattern, 2018). Blockchain technology has the potential to solve many of these problems.

Blockchain can help in collateralization assets, otherwise difficult to be mortgaged, by creating digital identities or records that are immutable and tamperproof, thus minimizing possibilities of fraud and corruption. Blockchain's inherent features such as transparency, shared control and disintermediation (using smart contracts to automate the transfer of ownership of assets in the event of default without the intervention of a third-party), makes such digital assets secure and amenable to the financial institutions. Hence, blockchain opens up new opportunities for both lenders and borrowers to use digital collaterals for lending, which could potentially be a game changer for small farmers by making them eligible for institutional credit, even in the absence of conventional collaterals.

Along with digital collateralization of assets, blockchain technology has opened up completely new ways of financing. Popularly known as micro-lending or peer-to-peer financing, these processes have unlocked huge capital available with individual small and micro investors that can potentially disrupt the traditional lending process by banks and other financial institutions. One of the biggest problems of financial institutions in lending to poor is lack of credit history and undefinable creditworthiness. Micro-lending systems has taken up this challenge in a completely different way. By using technology, it is possible to record many financial transactions such as credit availed by farmers from commodity traders and agro-dealers, which could be used as an index to infer individual creditworthiness. Furthermore, the smart-contract and distributed ledger of blockchain technology makes lending process more secure, trustworthy and transparent, making it possible for the hitherto ineligible borrowers to get loans from these micro-lending institutions.
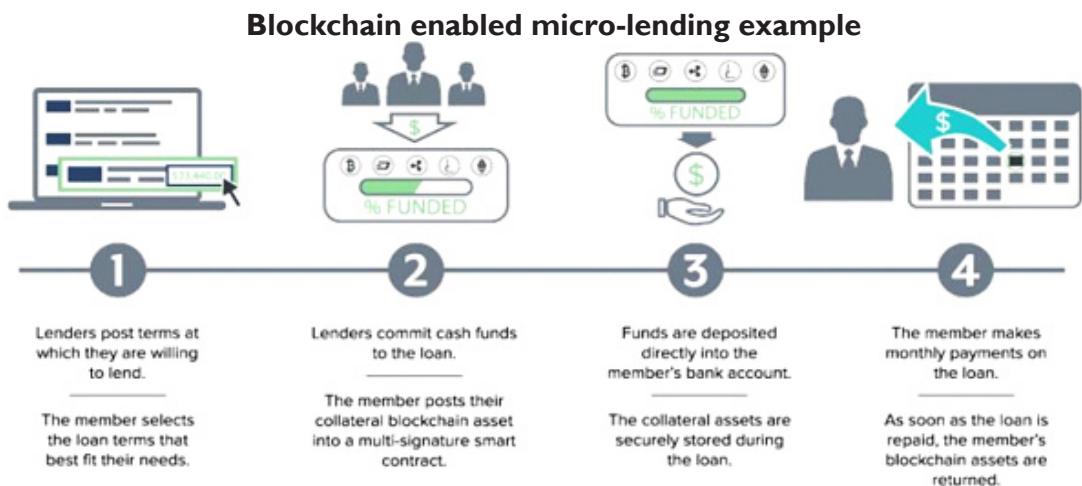
Blockchain enabled micro-lending example

1	2	3	4
Lenders post terms at which they are willing to lend.	Lenders commit cash funds to the loan.	Funds are deposited directly into the member's bank account.	The member makes monthly payments on the loan.
The member selects the loan terms that best fit their needs.	The member posts their collateral blockchain asset into a multi-signature smart contract.	The collateral assets are securely stored during the loan.	As soon as the loan is repaid, the member's blockchain assets are returned.

FIGURE 2: *Example Workflow of Blockchain Enabled Micro Lending.* (*Source: Wood, 2018*)

Smallholders and agro-commodity buyers both face problems in terms of enforcement of contractual obligations. While for buyers, enforcing contract with many small farms that are widely dispersed, is operationally difficult and not cost worthy. On the other hand for the smallholders, there exists huge lack of trust for selling their produce to unknown buyers, since in case of default of payment; they do not have sufficient resource to recover it through legal means. Blockchain can offer possible solution to this problem. Using a blockchain platform and 'smart contracts' for contractual agreements, all buyers and sellers in a value chain can participate and mitigate problems in enforcing obligation on the part of the sellers and payment on part of the buyers. This may also allow smallholders to use the agreements as a guarantee of repayment when applying for credit from formal financial institutions.

Along with access to capital, insurance coverage among smallholders is severely low; out of 1.5 billion individual smallholders in developing countries, only about 198 million have some form of agricultural insurance coverage (Hess & Hazell, 2016). Lack of insurance coverage is a major reason for the lack of resilience of the smallholders' leaving their already fragile livelihood exposed and vulnerable.

Index based agriculture insurance has long been considered as the most viable and optimally effective solution to logistical problems that limit smallholders' access to insurance. Studies show that, in addition to providing a safety net, farmers' adoption of insurance products have a positive impact on investments, efficiency, nutrition and income (Castillo *et al.*, 2016). It is estimated that even if only 200–300 million farmers would have been covered under agriculture insurance, an additional 40–150 million tons of food and USD 15–70 billion of farming income can be generated by 2030, along with indirect benefits such improved nutrition and health (World Economic Forum & McKinsey, 2018).

Blockchain together with other digital technologies such as remote sensing, Internet of Things and big data analytics, can provide viable and scalable insurance solutions for the farmers. Crop insurance policies are plugged into smart contracts on a blockchain platform and indexed to local weather, which is monitored for aberrations. During an extreme weather event, pay out can be automatically triggered, which facilitates fair, transparent and timely settlement of insurance claim without any need of human mediation. On the supply side, such platforms can give a sandbox to the insurance service providers to experiment and create bespoke insurance products enabling them to innovate and scale.
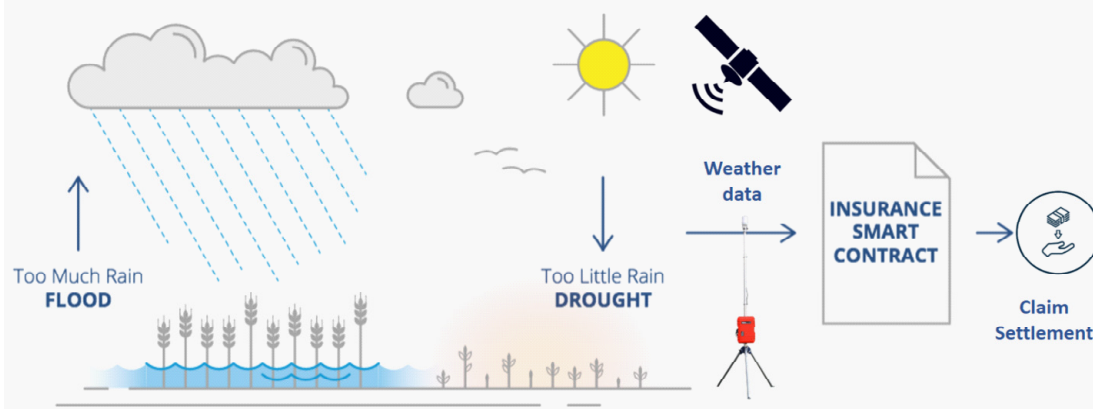
Blockchain enabled Index-based insurance process

FIGURE 3: *Workflow Diagram of Blockchain Enabled Index based Crop Insurance.*
(Source: Author. (Adapted from The Crypto Oracle, 2019))

Examples of blockchain applications in Insurance & Micro-finance
1.   IBISA is a blockchain start-up that offers financial protection from crop loss to smallholder farmers. In India IBISA and its local partner, DHAN started the first pilot in March 2018. Now it is scaling in Tamil Nadu to 1000 farmers. DHAN works with 1.8 million poor families across 15 states in India since 1997.
2.   Oxfam in Sri Lanka (OiSL), Etherisc, AON Plc. together with Sanasa Insurance, have launched blockchain platforms for weather index insurance. Blockchain technology helps automate the insurance products, thereby simplifying the claims process. Farmers are able to insure their crops against the amount of rainfall. An independent third party sets the levels of rainfall and estimated payouts. Levels are set for both droughts and floods, with payouts starting at the minimum threshold and increasing according to the severity. Following a disaster, the payment process starts automatically, and payouts are distributed within 2– 4 weeks. Recipients are thereby able to re-engage in their livelihoods in the aftermath of a natural disaster. As per senior officials from Oxfam, Sri Lanka, currently there are 5000 direct beneficiaries and around 29,000 indirect beneficiaries (through private insurance company's network) who are availing this insurance.
3.   Blockchain Climate Risk Crop Insurance is a digital platform for standardized crop insurance for smallholder farmers in Africa and Asia, which increases their resilience to climate change by enabling transparent, timely, and fair payouts in extreme weather events. It is a digital platform wherein crop insurance policies are plugged into smart contracts on a blockchain and indexed to local weather. During an extreme weather event, the policies are automatically triggered, which facilitates fair, transparent and timely payouts. The farmer registers for insurance through a scratch-card attached to a bag of seeds by paying a premium via mobile money. The system has been developed by a company named Sprout Insure, in partnership with ACRE Africa; a recognized intermediary for index insurance across subSaharan Africa and Etherisc, a smart contract technology developer for different types of index insurance products.
4.   Bank of Hodlers is an Indian start up that provides crypto currency-backed loans, crypto credit cards, and insurance policies against theft of digital assets.

Examples of blockchain applications in Insurance & Micro-finance
5. ChitMonks, an Indian company has created India's largest blockchain network for Savings and Borrowings. By synergizing Chit Fund Companies ("Chit" is a financial arrangement wherein a certain number of persons/subscribers enter into an agreement that subscribes to a certain sum of money by way of instalments over a definite period of time. Each subscriber shall in his turn, be entitled to a prize amount as determined by the lot, or tender or auction or in such other manner as specified in the chit agreement) Regulators, Subscribers, Banks, Service providers, and ecosystem enablers, they have successfully built a large trusted network of savers and borrowers in their platform, which currently serves about 17,000 chit fund groups, 700,000 subscribers and generated about USD 2.5 billion worth of business.
6. Alchemy Coin is a blockchain-based P2P lending marketplace that facilitates instant and direct lending between borrowers and lenders by leveraging blockchain and smart contracts
7. HARA is a global & open blockchain-based data exchange enabling everyone to make better data-driven decisions. HARA has successfully helped digitize loan administration and disbursement process of several financial institutions in Indonesia. It has so far disbursed USD 759,000 worth of micro-loans to 28,000 farmers.
8. Indonesia based Blossom Finance has introduced Smart Sukuk (Sukuk is the Arabic name for financial certificates, also commonly referred to as "sharia compliant" bonds) that combines proven models for Islamic financing with the efficiency of blockchain digitization and tradability. The fund raised through this instrument is used for supporting local Islamic microfinance cooperatives called 'BMT'. (BMT is a model that combines a for-profit motive ('Bait-ul-Tamwil') with a social-benefit motive ('Bait-ul-Maal'). 'BMT'-s provide core banking facilities to marginalized communities where traditional banks don't operate or charge fees beyond what the community can afford. Blossom Finance, using smart 'Sukuks', provides important savings and financing services to marginalized communities to help reduce poverty.

However, in spite of many success stories of blockchain in development finance, it is still not widespread around the world. Lack of awareness (both at service providers' as well as customers' ends), literacy and gender gaps, digital infrastructure and clarity on regulatory policies are some of the key hindrances for mass proliferation of blockchain in rural insurance and microfinance sector.

For example, in Bangladesh, it was found in one survey, that most micro-finance institutions are not even aware of the concept, functionality and use of blockchain (UNCDF, 2019).

Low penetration of mobile Internet, together with inconsistent mobile broadband network coverage in rural areas, is a major impediment for rural people to use digital applications, such as blockchain. Rural mobile internet gap in south Asia is estimated to be 45 per cent (GSMA, 2019a), which means more than half of the rural population cannot use mobile apps, therefore are devoid of benefits from digital applications. The gender gap in mobile usage is also significant; women in most of the low and middle-income countries, especially in south Asia, are 23 per cent less likely than men to use mobile Internet (GSMA, 2019a). Lack of literacy also plays a role in slow and limited penetration of blockchain-

enabled solutions among the rural poor. Literacy gap in south Asia is about 49 per cent (Trendov, Varas, & Zeng, 2019), which is why many rural people are either not aware or even if they are, they cannot use digital applications which needs basic literacy and familiarity of using digital devices.

There is also lot of skepticism and resistance among the regulators regarding blockchain, probably because of its close association with Bitcoin. The Reserve Bank of India in 2018 initiated a major crackdown on the trade and purchase of crypto-currencies such as Bitcoin.

However, it is also to be noted that many banks do recognize that blockchain technology has many potential benefits for financial inclusion and enhancing the efficiency of the financial system and they emphasized that they should be encouraged to be exploited beneficially for the economy (Reserve Bank of India, 2018).

5.7 How Blockchain can Build Resilience by Making Humanitarian Aid Process More Efficient and Transparent

Humanitarian aid is critical for saving life, livelihood, and building resilience in vulnerable communities in face of natural disasters or other social problems such as conflicts or famine etc.

It is estimated that globally about 201 million people in 134 countries needed international humanitarian assistance in 2017 and USD 27.3 billion was allocated as aid and assistance in response (Global Humanitarian Assistance, 2018). Many times, management of such humongous aid money is plagued with lack of transparency and commitment among various actors such as government agencies, NGOs, etc. Information asymmetries at different stages of aid distribution also results in undermining effectiveness of humanitarian aids (Chamberlain, 2019). Blockchain technology could possibly be a viable solution in this context. Using the feature of 'smart contracts', it can strengthen the accountability and credibility of different actors involved in humanitarian relief works. For example, 'smart contracts' between donors and grantees can automatically ensure compliance to aid conditionality without any need for human intervention, thus saving managerial cost and operational time. Furthermore, blockchain technology increase transparency of disbursement process by creating verifiable audit trail of transactional information related to the real-world events along the entire aid delivery chain (Reinsberg, 2019).

Donor support is also critical for NGOS and other philanthropy organizations for their survival and ability to deliver social good. A report by Accenture Labs in 2017

identified 4 key challenges that social development organizations face in delivering their missions (Accenture, 2017), these are:

1. Affordability: Organizations must operate at high level of fiscal and operational efficiency to keep transactional and operational cost minimal so that they can deliver services affordably.

2. Accountability: Organizations must be able to establish transparent and verifiable trail of funds; from where it comes to where it goes, in order to instil trust and confidence among donors.

3. Reliability/Sustainability: Organizations must ensure continuous flow of grant-in-aid or donor funding to deliver their mission and services sustainably and over long period to create better and greater impact with their work.

4. Marketability: The above three factors eventually decide the attractiveness of the development organization as a preferred partner or grantee for the donors, which is critical for long term survival of the organization and the viability and impact potential of its missions.

Using blockchain technology, development organizations could successfully manage these challenges and enhance transparency, increasing efficiency, promoting sustainability and achieving scalability.

The table below summarizes how the inherent attributes of blockchain technology such as transparency, auditability etc. can help development organizations to better streamline their operation and overcome the challenges as mentioned earlier.

Table 1: How blockchain technology can help insolving organizational challenges of development agencies. (*Source: Author (adapted from Accenture, 2017)*)

Organizational Challenges / Blockchain Attributes	Transparency	Efficiency	Auditability	Scalability	Sustainability
Affordability	Reduced monitoring	Reduced transaction cost	Reduced audit cost	Better fund utilization	Lower cost of service delivery
Accountability	Immutable data ownership	Less pilferage	Verifiable transaction trail	Better fiscal management	Better financial strength (fund availability)
Reliability	Increased trust	Increased dependability	Reduced human error/ corruption	Higher replicability reliability	Lesser management/ Operational cost
Marketability	Better organizational governance	Better return on investment	Better ethical compliance	Wider impact	Better brand image/ value

Because of these inherent advantages of using blockchain in humanitarian aid, a number of innovative blockchain-based solutions have been piloted in many parts of the word with demonstrable success.

Examples of blockchain applications in Humanitarian aid
1. World Food Programme (WFP) has successfully piloted a blockchain enabled direct cash transfer system called "Building Blocks", which facilitates cash transfers while protecting beneficiary data, controlling financial risks, and allowing for greater collaboration. First piloted in Sindh province of Pakistan for authenticating and registering beneficiary transactions, the system since then have been implemented successfully in two refugee camps in Jordan for over 100,000 people helping them to purchase groceries by scanning at checkout. Cash value from WFP or other partners is stored in a beneficiary 'account' maintained on the blockchain, but the cash that beneficiaries receive or spend on goods and services is paid to the beneficiaries or to the retailers in conventional currencies through a commercial financial service provider. Built on a private blockchain platform and integrated with UNHCR's existing biometric authentication technology—WFP has a record of every transaction. This not only saves financial transaction fees but also ensures greater security and privacy for Syrian refugees. As of 2018, WFP distributed cash transfers of USD 1.76 billion through this system
2. The Start Network is a global network of 42 leading aid agencies working together to change the humanitarian system through a range of innovative aid programmes. Start Network has been developing new forms of aid finance and experimenting use of blockchain for direct cash transfer. In 2017, collaborating with a social enterprise named Disberse; Start Network successfully piloted a blockchain enabled aid management system in Rwanda through NGO Dorcus, which successfully transferred EUR 50,000 funds through blockchain-enabled platform bypassing conventional banking route. Since then similar experiments were piloted in Albania and Ukraine.
3. In October 2019, UNICEF launched UNICEF Cryptocurrency Fund. This was the first time any United Nations organization used cryptocurrencies to fund technology development pilots that could benefit children and young people around the world.
4. Kenya Red Cross (KRCS), in collaboration with International Centre for Humanitarian Affairs (ICHA) and private sector partners, Safaricom (telecom operator) and Red Rose Silicon Limited piloted a blockchain-enabled cash transfer programming (CTP) that benefitted over 2000 beneficiaries.
5. Hypergive uses blockchain technology to make donations to the poor and hungry more efficiently by creating a cashless and secure donation system that is immune to pilferage and racketeering. Communities can purchase CareCards, which are blockchain-based prepaid cash cards, in form of donation. Each card is linked with a 'smart contract', holding the prepaid balance on the card, management functions for the partner organization, and the cardholder's picture so they can be validated at the time of the transaction. These cards are distributed to the needy people, who can use these cards instead of cash at partner merchant outlet. The smart contract that each CareCard is based-on, has measures to protect the integrity of the system and allow it to be managed at the community level, including daily spending limits, de-activation and value recovery if it is lost or stolen. Because of the in-built audit train and trust many registered charities prefer to work with this system, which provides additional benefit to the donors in form of tax receipt.
6. The Akshaya Patra Foundation, a charitable social organization (also the world's largest provider of cooked meals for schoolchildren), piloted a blockchain-based technology platform that makes use of artificial intelligence technology and the Internet of Things for monitoring and managing entire supply chain of school meal. Initial results suggest implementing the solution in 15 kitchens yielded an operational savings of INR 30 million (approximately USD 500,000) in 2017 (Accenture, 2017).

Although most of these innovations are at a very early stage of implementation and are yet to be mainstreamed or scaled up; nevertheless, these experiments do show evidence that blockchain could be a very important technology to overcome many of the challenges in the field of humanitarian aid.

5.8 HOW BLOCKCHAIN CAN HELP MINIMIZINGE PRODUCTIVITY AND ECONOMIC LOSS BECAUSE OF COUNTERFEIT AGRO-INPUTS

Counterfeiting is a growing problem for all industries; as per report from OECD and European Union's Intellectual Property Office. Trading volume of counterfeit and pirated goods has risen steadily in the last few years. It is estimated that in 2016, the volume of counterfeit trade was of USD 509 billion globally, which is about 3 per cent of total global trade (OECD/EUIPO, 2019).

Counterfeiting of agriculture inputs is a multifaceted menace that the farmers across the world face. Spurious chemicals are not effective in controlling pests or providing plant nutrition. Hence, when farmers use these fake inputs, they experience lesser crop yield and are unable to control crop pest, resulting in crop loss. The chemicals in counterfeit agro-inputs also pollute environment and damage ecosystems around farmlands. Furthermore, counterfeit agriculture inputs can also affect transboundary trade of agro-commodities; any products with traces of any banned chemicals, are straightaway rejected by the importing country. According to a study by the Federation of Indian Chambers of Commerce & Industry in 2015 (FICCI, 2015), total volume of non-genuine / illegal pesticides traded in Indian domestic market was about INR 3,200 crores (about USD 525 million) in 2013, which was found to be growing at about 20 per cent per year in value. However, this direct revenue loss of the agrochemical industry is only the tip of the iceberg, as the associated indirect economic impact due to crop loss and export rejections were much more; estimated to be about USD 27 billion per year (FICCI, 2015).

Blockchain technology can help fight counterfeiting in two ways; firstly, blockchain can create an immutable trail of transactional records as products move from production to consumer. This makes it easy for the consumers (or any other actor in supply chain) to authenticate either the branding (e.g. misbranding/look-alike) or the legitimacy of use (e.g. whether the product is approved for use in a particular country or location) or the authenticity of the ingredients (e.g. bio or organic farm inputs). Secondly it is possible to embed sensors and other Internet of Things (IoT) devices into the product packaging and connecting them to blockchain-based system. By doing so, not only the traceability of the product is established, but also various other parameters, such as ambient storage condition, incidence of tampering or adulteration, legitimacy of products etc. can be monitored and

managed. Thus, manufacturers of products that are perishable (such as vaccines) or of controlled manufacturing and distribution rights (e.g. products of geographical indication or G.I.) can gain much benefits from blockchain based systems.
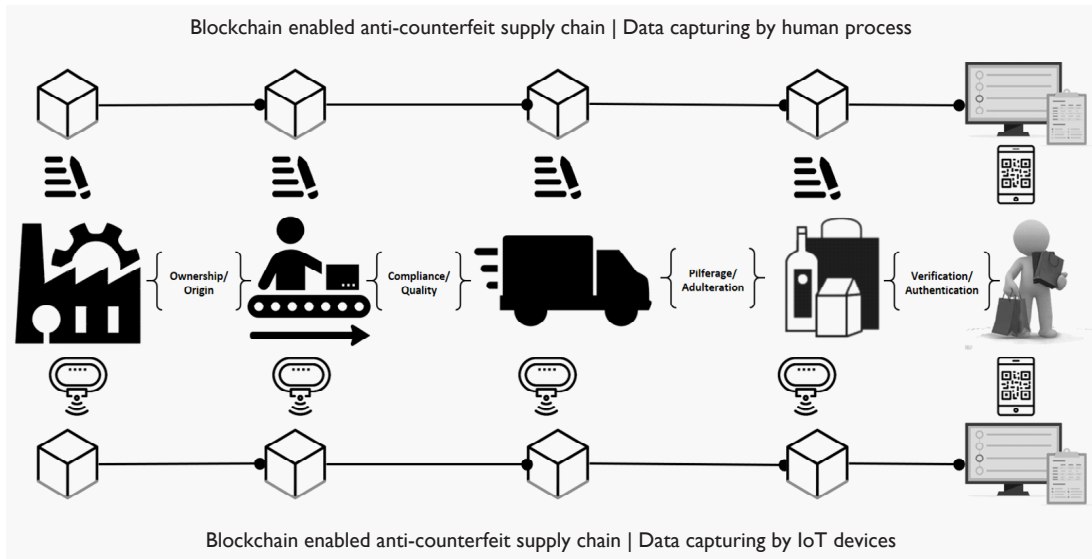

FIGURE 4: *How Blockchain Ttechnology helps in Anti-counterfeit. (Source: Author)*

The effectiveness of blockchain technology in fighting counterfeit has caught interest of technology developers. A number of applications and early prototypes that offer such solutions have already been piloted in many countries. Although most of the current prototypes are designed for high-value products such as pharmaceuticals or fashion industries, the underpinning blockchain technology-based systems are suitable for other applications, for example, agriculture input markets and can prove to be a key to fight the menace of counterfeiting in agriculture.

Examples of blockchain technology applications in anti-counterfeit
I. IBM researchers have developed an anti-counterfeit solution named 'Crypto Anchor', which is a tamper-proof digital fingerprint in form of a microchip or optical code that can be embedded into products (for example as an edible shade of magnetic ink, which can be used to dye a malaria pill). Such code could become active and visible by a drop of water, thus letting the consumer know whether it is authentic and safe to consume), and linked to a blockchain based database for end-to-end anti-counterfeiting solution. Crypto Anchors can also be detected by mobile phones outfitted with a special optical device and a software program in the mobile phone can then identify hidden optical structures and features to certify certain objects. Although currently at research stage, the application is going to be commercially available soon and as IBM claims, the opportunities for the Crypto Anchor based verifiers are limitless and offer a viable way to protect and validate all kinds of physical substances bringing new levels of trust to business transactions.

Examples of blockchain technology applications in anti-counterfeit
2. UCOT, a start-up based in Australia, has developed a mobile application that fights counterfeiting by combining technologies such as Internet of Things (IoT) together with blockchain. A unique digital identification microchip-sensor is embedded into product packaging, which can transmit data using 5G mobile network that is stored in blockchain-enabled system. The company claims that consumers can easily obtain information such as the origin, batch number, production date, and product unit's journey by scanning UCOT's smart tag (NFC or QR Code) on the unit with a mobile phone using the company's proprietary application and the authenticity of the goods can be ascertained by consumers themselves at the point of purchase.
3. YPB is an Australian company which has developed an anti-counterfeit system named 'ProtectCode'. Using a tracer substance that is invisible to human eye (named 'MotifMicro tracer') and a uniquely designed serialised QR code, embedded in the product's packaging or surface; ProtectCode system makes it possible for customers to scan the code with their smartphone to verify authenticity. It also creates a link, which consumers can use to get further information about the product and manufacturers can establish better engagement with the consumers by communicating direct with them through this digital link.
4. US based technology company Quantum Materials Corporation has developed nanoscale semiconductor particles, named 'Quantum Dots' that can be programmed to emit predetermined wavelengths of light in both the visible and non-visible spectrums. This unique optical characteristic of these nanoparticles makes it possible to create billions of unique optical signatures, which can be very effective in detecting fake products. Quantum dots can be incorporated into almost any physical item at the time of manufacture and the quantum dot signature of a product can be authenticated by scanning (via a hand-held scanner or an app on a smartphone) allowing tracking of products and providing visibility and traceability of the entire supply chain – from manufacturer to customer. For example, a customer purchasing a product that has 'quantum dots' incorporated into it, can use their smartphone to scan the same to ascertain that the product is genuine. Simultaneously the manufacturer gets to know that the product's authenticity has been checked and it can then offer a warranty or loyalty program to the customer in order to establish an enduring brand/customer relationship. Recently Quantum Materials Corporation has expanded their operation in India, as the company sees it as a large market for such anti-counterfeit products.
5. Indian start-up company Statwig has developed a cloud platform that use blockchain and Internet of Things (IoT) to monitor and track products from the point of origin to the point of consumption throughout the supply chain. This company works with UNICEF in different countries under the UNICEF SMART CHILD initiative to securely track and trace the vaccines that UNICEF procure for this program.
6. London-based company Blockverify helps businesses worldwide in fighting counterfeit issues with the help of blockchain technology. A unique ID tag called 'Blockverify tag' is attached to the products which is used at all stages of the supply chain for recording the history of transfers, ownership, locations, etc. permanently on a blockchain platform. The end consumer finally validates the tag via a mobile app at the time of purchase, which verifies the products authenticity as well as full traceability along the supply chain.
7. Adent Technologies, a company based in France has teamed up with Microsoft for integrating blockchain technology and artificial intelligence (AI) into a product tracking platform, called 'Adents NovaTrack'. The blockchain-as-a-service approach offers greater traceability, transparency, and security throughout the supply chains, guarding against counterfeit items. Microsoft's machine learning and business intelligence services then help transform the collected data into actionable business insights.

Examples of blockchain technology applications in anti-counterfeit
8.   TE-FOOD is a farm-to-table fresh-food traceability solution that serves 6000+ business customers, and handles 400,000 business transactions each day. It provides complete solution in anti-counterfeiting starting from tamperproof labelling, QR code to data capture applications, blockchain-based data platform and data analytics services.
9.   Gebe Cert is a microchip & blockchain technology company that uses encrypted microchips, which can be effectively, securely and discretely incorporated with any physically manufactured product. Upon integration of the microchip, the product is paired with a digital database on the blockchain. Verification of authenticity is instantaneous with a simple tap or scan with any smartphone device. The anti-counterfeit system of Gebe Cert is being used by more than five hundred brands for thousands of their products in Asia and the Middle Eastern countries.

Although blockchain technology promises many foolproof solutions for anticounterfeiting, most of the use cases are in early stages of development and there are very few companies who have specialized product for the agriculture sector. Furthermore, the cost of blockchain technology implementation together with the associated investment required for upgrading the entire supply chains is a key factor why such technologies are having better acceptance in high-value products market, such as fashion and jewellery industries, and not so much in other industries. However, as this technology matures and new innovations happens, cost of technology is bound to decrease and then other sectors, especially the agro-input sector could benefit much from it.

5.9 HOW BLOCKCHAIN IS HELPING IN LAND RIGHTS OF SMALLHOLDERS

Land tenure is a complex social institution, which governs the relationship among people with regard to assets such as land, water bodies and forests. It regulates use, control and transfer rights of lands as well as determines the rights of individuals to make money from the land through agricultural, infrastructure or by selling it to another party (Ashley, 2016). Proper land tenure management is necessary for poverty alleviation and equitable development and its importance has been duly acknowledged by including land-tenure and land rights as an indicator in United Nations Sustainable Development Goals (SDG); under SDG 1 (Target 1.14) and SDG 5 (Target 5A) dealing with poverty alleviation and gender equity, respectively (UNDESA, 2019).

However, in spite of being of such critical importance, land tenure management systems in most parts of the world are archaic, complicated and in some cases do not exists at all. It is estimated that only 30 per cent of the global population has a legal title to their land (World Bank, 2017b).

Extreme poor people are often landless or have insecure tenure rights over land and other natural resources (Campos, A.P., Villani, Davis, & Takagi, 2018) and it is believed

that policy measures towards securing land tenure rights for the poor and vulnerable – including indigenous people, landless farmers, pastoralists, rural women and youth – could significantly contribute towards eradicating extreme poverty (FAO, 2018).

Blockchain or rather the underpinning distributed ledger technology that powers blockchain, could bring in transparency and efficiency in land tenure management, while reducing fraudulent transactions and illegitimate land ownership. By integrating the various actors in land registration and cadastre process with a blockchain-based land-tenure management system, it is possible to achieve significant reduction in time and cost and stop corrupt practices. This will also significantly reduce frauds and litigations; for example, a blockchain based land registry system will make it practically impossible for multiple parties claiming ownership or selling the same land parcel at the same time.
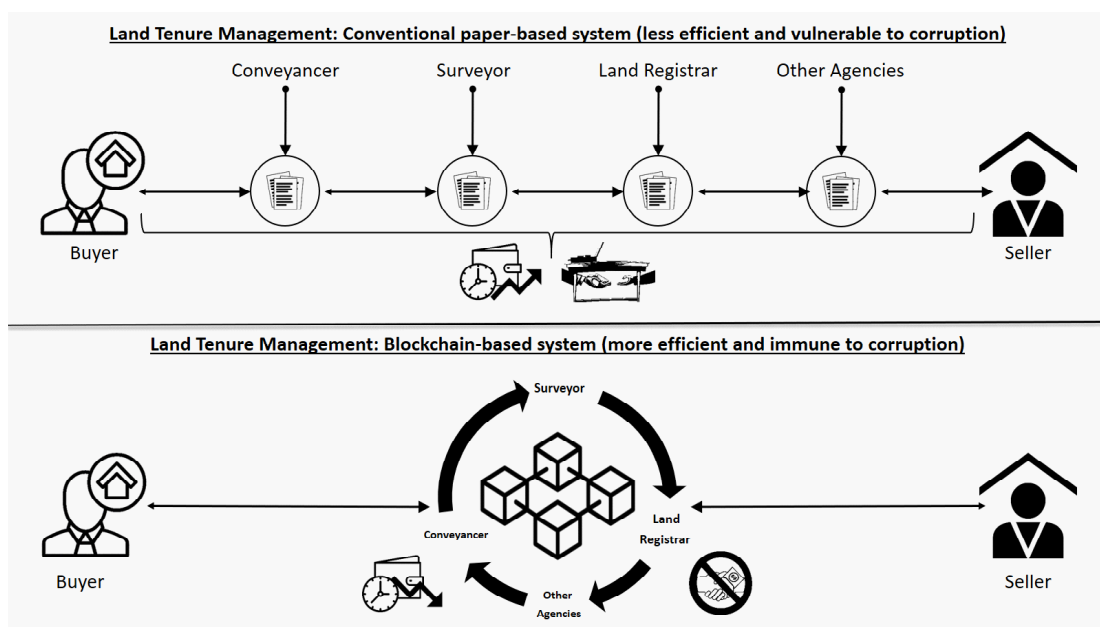

FIGURE 5: *Comparison between Conventional and Blockchain Enabled Systems for Land Tenure Management. (Source: Author)*

There are many innovative applications of blockchain technology in land tenure management; however, most of them are at an early stage of commercialization. In some countries, such as India and Bangladesh, government is also keen on experimenting with blockchain technologies for land tenure management.

Examples of blockchain technology applications in land-tenure management
1. Zebi Data, an Indian blockchain start up, has registered more than 100,000 land records since 2017 in the Indian state of Andhra Pradesh.
2. UNDP and Convergence.Tech, a Canadian technology company, has piloted blockchain technology for land registration in the Indian state of Haryana in 2017.
3. Digiland is an impact driven e-governance Company, based in Bangladesh. This company has digitized land titles and developed a blockchain-based app to provide a transparent, secure and convenient way to prove land title authenticity that has reduced time, costs and amount of human resources required for land registration as well as reduced legal disputes related to land titles, which is as high has 70 percent of all litigations in Bangladesh.
4. In 2017, the government of Bermuda decided to transfer its land registry system to a blockchain platform, developed by technology company Vaphr Inc.
5. Korean company BLOCKO has piloted a blockchain-based solution that will enable contract inquiry, registration, real estate information inquiry, and loan information registration through blockchain-based real estate smart contract platform in the Republic of Korea.
6. Bitland Global, a non-profit organization based in Ghana, is working to keep the land registration process accessible, transparent, and free from corruption.
7. US based technology start up Ubitquity has collaborated with *Cartório de Registro de Imóveis* (Real Estate Registry Office) in Brazil to create a pilot programme for the region's official land records. The pilot will create a parallel platform to replicate the existing legal structure of property ownership recording and transferring for two regions: Pelotas and Morro Redondo. Beyond the pilot, Ubitquity's platform will eventually replace the existing structure of property ownership recording and transferring, which is paper based, into a secure, digital platform underpinned by blockchain technology.
8. Indian technology company Tech Mahindra has partnered with the Department of Urban Planning and Municipalities (DPM) of the United Arab Emirates in 2019 to develop a blockchain-enabled land registry system, named SmartHub in Abu Dhabi, Al Ain, and Al Dhafra. The SmartHub blockchain service will store all property-related documents issued by the municipalities and verify tenancy contracts and it is expected to enhance traceability and transparency of records, boost security, and streamline data archiving, allowing for faster processing of land registry transactions.

5.10 KEY CHALLENGES FOR LARGE SCALE ADOPTION OF BLOCKCHAIN TECHNOLOGY

Lack of clarity of regulatory frameworks, high cost (real and perceived) of implementation (and corresponding overhaul of legacy or existing systems), high energy-intensive nature of the technology and lack of interoperability of data are some of the key challenges of large-scale blockchain technology adoption.

Ambiguities in terms of data protection legislation is a good example here. The General Data Protection Regulation (GDPR) in European Union has provided citizens the right to be forgotten, as the rule says; "*when an individual no longer wants her/his data to be processed, and provided that there are no legitimate grounds for retaining it, the data will be deleted*" (European Commission, 2019). However, this goes against the fundamental

architecture of blockchain, which is based on immutability of data; that is to say, when a record is created in blockchain, it can never be altered or deleted.

There are also other contractions in the regulations related to other aspects of blockchain technology. For example, 'smart contracts' are a very useful feature of blockchain that automates and guarantees interests of the transacting parties, and hence hailed as a viable solution for reducing lack of trust in business transactions and the associated costs of having third party guarantor, such as bank, to safeguard the interests of the transacting parties. However, legal validity of 'smart contracts' itself is not very well defined. For example, in December 2018, a report by the Swiss Federal Council on '*Legal Framework for blockchain and distributed ledger technologies in the financial sector*' states, in relation of 'smart contracts', that "*a party cannot enter into a legal relationship with the computer system as a counterparty, since such a system lacks any legal personality within the meaning of the Civil Code*" (MME, 2019). In case of India, there are numerous such anomalies and legal bottlenecks around validation of the smart contract. For example, the Indian IT Act, 2000 states that digital signatures (for validation of 'smart contracts') can only be obtained through a government designated certifying authority as per Section 35 of the act. This stands in complete variance with blockchain technology as it uses a hash-key for authorization instead of any individual identifier and authenticator agency. This disparity is also extended to the Indian Evidence Act, section 85B, which states that an electronic agreement would be considered valid only if it has been authenticated with a digital signature. These two legal anomalies pose challenges to the whole authentication process in blockchain through hash-key generation and may disallow its admissibility in the court as evidence (Khurana & Khurana- Advocates and IP Attorneys, 2018).

The world map (Figure 6) indicatively shows the regulatory outlook around blockchain technology around the world.

As evident from the map (Figure 6); cryptocurrencies (as well as blockchain as the underpinning technology) are having more supportive regulatory environment in Europe and North America, fueling lot of innovations and entrepreneurship around it. In Asia-Pacific region, apart from Japan, Thailand, Australia and New Zealand, the regulations are not mature and different countries treat blockchain technology with different degrees of caution and restriction. In Latin America and Africa, the technology is mostly evolving and regulatory framework is yet to evolve; apart from Brazil, Mexico and Nigeria, where the technology has been given legal status.

Implementation cost of blockchain is another major factor in its large-scale adoption. According to a 2019 report by ITU," *The cost of overhauling or replacing the legacy systems*
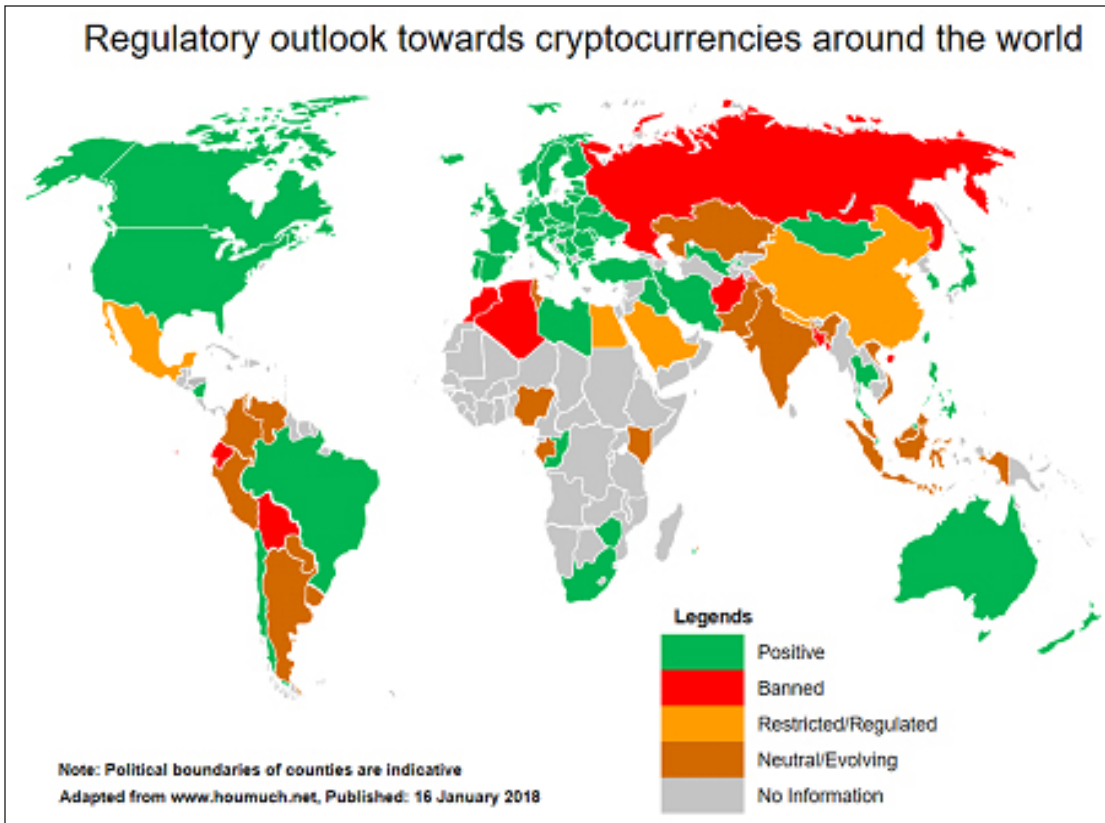
FIGURE 6: *Regulatory Outlook towards Cryptocurrencies and Blockchain Technology.*
(*Source: Author*)

currently used by large industries such as the financial, insurance and identity sectors is enormous. There is a significant investment of both time (education, training and tacit knowledge) and capital (equipment, software, affiliated applications, foundational technology itself and opportunity cost) to create a new infrastructure, train staff with the necessary skillsets and use it effectively throughout an organization" (ITU, 2019). According to a survey by Deloitte in 2019, 30 per cent of the respondents from various industries cited implementation cost, including the implicit cost of replacing or modifying legacy systems is a major barrier to the adoption of blockchain technology (Deloitte, 2019). According to estimates by Ernst & Young in 2019, the cost of development and maintenance of a private blockchain with capability of 1000 transactions per day is about USD 1.5 million over 5 years and cost of each transaction is about USD 0.85 (EY, 2019). Adding other associated cost of such as cost training people in using such systems and upgrade of existing systems etc. the real cost of implementation would be much higher. In addition, a very small system would be having only 1000 transaction per day; while in reality any mainstream commercial system would have much more transactional throughput, which means the cost would be even higher to that magnitude.

The blockchain technology inherently consumes massive amount of energy for its algorithmic consensus processes (or mining) that guarantees the trust and the validation of transactions. According to various studies, energy consumption of Bitcoin mining in 2019 was estimated to be 73 TWh (Digiconomist, 2019); more than the annual energy usage of some 180 countries in the world (Power Compare, 2018). Furthermore, the high energy-requirement for cryptocurrencies is also an obstacle for its mass adoption. Although technologies such as Ethereum (Casper), Hyperledger and Neo may consume much lesser energy, nevertheless it'll still be much more than conventional non-blockchain systems (Digiconomist, 2019).

As far as standards and interoperability requirements between various blockchain technology platforms and the networks that operate them are concerned, there is still no common global framework available (ITU, 2019). Although this gives lot of freedom and flexibility to the blockchain coders and developers to innovate, it also makes it difficult for different platforms to communicate among them. An analysis of more than 6,500 active blockchain projects in GitHub revealed that each of them used diverse platforms with multiple coding languages, protocols, consensus mechanisms, and privacy measures (Schatsky, Arora, & Dongre, 2018). Because of such multiple non-interoperable blockchain implementations, many fragmented blockchain applications and ecosystems have emerged which is also a major reason for the lack of widespread adoption of this technology (RAND Corp., 2017).

5.11 CONCLUSION

Blockchain technology could definitely be one of the most influential technologies of coming times. The biggest potential of blockchain (or the underlying distributed ledger technology) is that it is a very effective tool to ingrain trust, increase transactional efficiency and reduce cost of audit in applications involving data storage and exchange. With about 34 billion connected devices in 2025 (IoT Analytics, 2018), there will be enormous volume of data and effective data management will be the key to the success of applications and operations in every industry. Blockchain offers a clear advantage to data management, exchange and storage, compared to conventional databases. Its ability to combine secure data storage mechanism with in-built features of immutability of records and audit trails, together with monetary transaction capabilities, makes it an efficient tool in a multitude of applications, in many industries, especially in the agriculture sector.

Hence, it is important to think through and understand the industry-specific use cases where blockchain technology may offer a clear advantage for positive transformation. It is also important to understand the key value drivers of blockchain within a particular industry

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so that businesses not only assess what opportunities exist, but also foresee what threats may emerge and plan accordingly before jumping the gun.
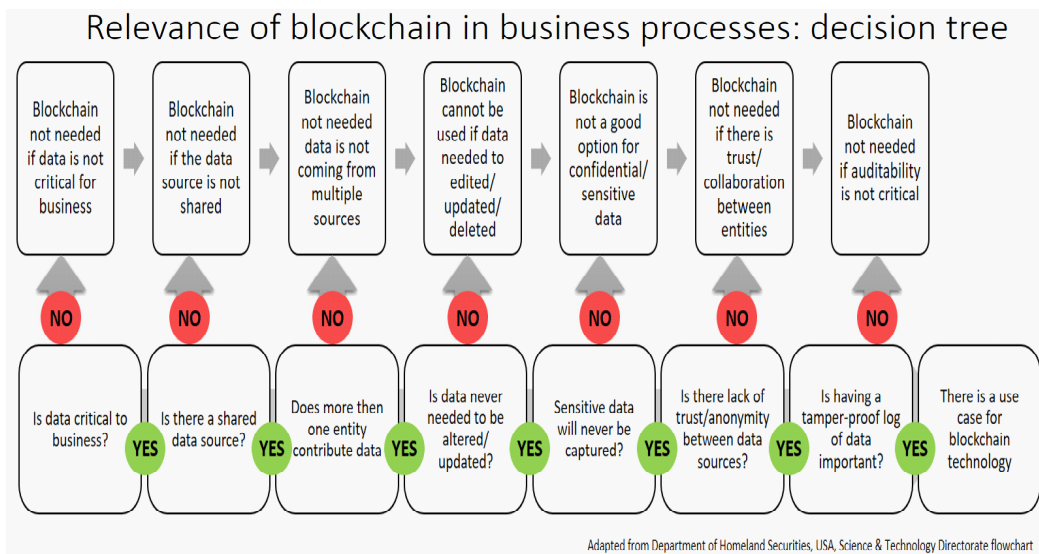
FIGURE 7: *Decision Tree for Evaluating Relevance of Blockchain Technology in Business Processes.* (*Source: Author*)

The decision tree above could help business and policy makers to undertake a quick litmus test to necessity and criticality of blockchain-based solutions over conventional databases.

However, in spite of the current limitations of blockchain technology, there exists tremendous potential for a growing number of use cases, outside cryptocurrencies and digital finance, where the attributes of blockchain can be used to a great extent. Agriculture sector, among others, offers such a fertile ground for innovations around blockchain technologies.

A study by Stanford Graduate School of Business in 2018, evaluated 193 organizations, initiatives, and projects that are leveraging blockchain to drive social impact and found that majority of them, about 74 per cent were at very early stage or just proof of concept projects. However, the study estimated that more than half of these projects and ventures could actually deliver social impact as soon as in two years period (Stanford Graduate School of Business, 2018). The implicit potential of blockchain has always made it favourable for venture capital investment; since 2013, USD 23.7 billion venture capital has been raised by about 4000 blockchain technology start-ups, and this is despite the fact that there was a massive rundown of cryptocurrency market in 2018 (John & Lundy, 2019).

It is quite evident from all these innovations, applications and case studies that beyond the hype and fad of cryptocurrencies, potentially transformative blockchain applications for social impact are already emerging. Blockchain technology can provide incremental or transformative solutions solving some of the world's toughest challenges. As more and more initiatives move from pilots to programs and technological and regulatory obstacles get resolved, blockchain technology will start delivering more value and move further away from hype into reality.

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