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Blockchain Technology Model Towards Smart Agriculture: A Proposed Model

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Abstract: *The objective of this study is to examine the challenges created by blockchain technology to the agriculture stakeholders. Besides that, it is also noteworthy to understand that two important theories underlie the integration towards achieving the objectives of developing the blockchain technology for smart agriculture are the Grounded Theory and will conceptualise the Technology-Organisation-Environment (TOE) Theory. This study employs a qualitative approach because it can extract the complex description of the blockchain technology towards smart agriculture that involves various agriculture sector stakeholders. Semi-structured in-depth interviews will be conducted in six states: Perlis, Kedah, Selangor, Negeri Sembilan, Pahang and Sarawak as part of the research to get a more in-depth understanding of the profiles and better understanding on the challenges created by blockchain technology to the agriculture stakeholders. Drawing on the high value of smart agriculture principles, this study reconciles a comprehensive blockchain technology model and draw connections with the challenges faced by various stakeholders. This study expands knowledge on blockchain technology in supporting smart agriculture by looking into the blockchain technology attributes in terms of traceability, visibility, security and accessibility, as well as the challenges created by blockchain technology to the agriculture stakeholders. This study output will boost the modernisation process in the agriculture sector, managing the demand and supply of national food and agriculture supply. The underlying trend of agricultural research is discovered to be primarily embedded in scientific investigations from technologies' perspectives. Researching in smart agriculture is crucial but remains scanty due to the challenges facing at the different levels in the supply chain. As such, the novelty fits within this research model are unavailable to the researchers' best knowledge.*

Keywords: Blockchain, smart agriculture, Technology-Organisation-Environment (TOE) Theory, agricultural sector

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1. Introduction

Agriculture and food production are part of a dynamic and complex network that is reliant on technical advances such as new farming practises, better chemicals, and more advanced agricultural technology. New technologies introduced into the market via Industry 4.0 provide production and financial potential in a variety of industries for supply chain networks (Esmaeilian et al., 2020). As a result, conventional agricultural product and food supply chain methods may be insufficient. The world's population is projected to grow to nearly 10 billion by 2050, boosting agricultural demand in a scenario of modest economic growth (Food and Agriculture Organisation of the United Nations, 2017). In Malaysia, the population grew to 32.7 million people in 2020 which is in line with a steady positive global trend that has been forecast to continue growing to a projected population of 35.09 million in 2025 (Plecher, December 15, 2020). While the population increased many folds, such a large world population will demand more food in the future. The increasing demand for food reflects the increase in agricultural production. The agricultural sector is increasingly under pressure to meet the growing population's consumer demand. Therefore, proper management of agriculture activities and the environment must increase its capacity to produce foodstuff and enhance sustainable agriculture and plantation activities.

The agricultural economics activities and development in Malaysia have long gained attention. Malaysia believes that robust agricultural growth, modernisation and productivity increases are crucial to sustaining economic development. Despite this widely acknowledged role of agriculture in economic development, many academics, agencies and communities appear to have lost interest in the sector, often relegating its role to sunset status. The World Bank report revealed that Malaysia's agricultural productivity less than half (45%) than the high-income countries (The World Bank, December 17, 2020). This could be because the agricultural sector is dominated by smallholders who are still underexposed to the smart technology.

Notably, the agriculture sector will be critical in launching the Malaysian economy to the next level. Thus, the agriculture sector gets a boost under Malaysia's Shared Prosperity Vision 2030. Base on the Shared Prosperity Vision, Guiding Principle 15 - Sovereignty and Sustainability that emphasises promoting the use of technology in agricultural activities (Ministry of Economic Affairs, 2019, pg. 5-20). The Strategic Thrust 2 under Key Economic Growth Area (KEGA) 13 - Smart and High-Value Farming (Ministry of Economic Affairs, 2019, pg. 6-14) is developed with the Enabler 6 – Big Data (Ministry of Economic Affairs, 2019, pg. 7-14) to accomplish the Shared Prosperity Vision initiatives and achieve the main objectives - Development for all (Ministry of Economic Affairs, 2019, pg. 1-01). Figure 1 depicts the Shared Prosperity Vision 2030 framework to better understand this study's relevance with the Malaysia government's policy.

The agricultural sector has been thrust as a potential driver of sustainable long-term economy growth and shared prosperity concerning food security and supply amidst economic shutdowns containing the pandemic (The World Bank, December 17, 2020). This century pandemic caused by COVID-19 has significantly impacted countries across the globe, including Malaysia. These devastating impacts are also being felt by the agriculture sector, one of Malaysia's principal economic activities for poverty reduction and stability (Graticola, November 23, 2020). Hence, the Covid-19 pandemic has forced the government revisiting strategies on agriculture in the 12th Malaysia Plan to formulate the National Agro-Food Policy (2021-2030). The key approach includes modernising the agriculture sector and adopting smart farming to boost and advance the sector. This is also in line with Sustainable Development Goals (SDG 2 - Zero Hunger) which was introduced under the United Nation Development Program. According to Datuk Seri Mustapa Mohamed, the Minister in the Prime Minister's Department (Economy), the government wants the agriculture sector to continue to grow. Hence, smart farming will be an important focus (The World Bank, December 17, 2020).

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Although Malaysia's government has made efforts to transform the agriculture sector into a dynamic, sustainable, and competitive sector, the agricultural sector still faces daunting challenges. These challenges include the low level of automation, lack of industrialisation, poor managerial skills, inconsistent and fragmented information, and food safety issues caused the entire agriculture supply chain inefficient eventually. Among these issues, the agriculture sector's low productivity has been one of the government's major concerns. The productivity was reported to be stagnant since 2017 and increased very marginally in 2018. Further, agriculture only contributed 7.1 per cent of Malaysian 2019 Gross Domestic Product (GDP), far behind service and manufacturing. Base on the department statistics, GDP From Agriculture in Malaysia decreased from RM 27,848 million in the third quarter of 2020 to RM 24,399 million in the fourth quarter of 2020 (Figure 1).

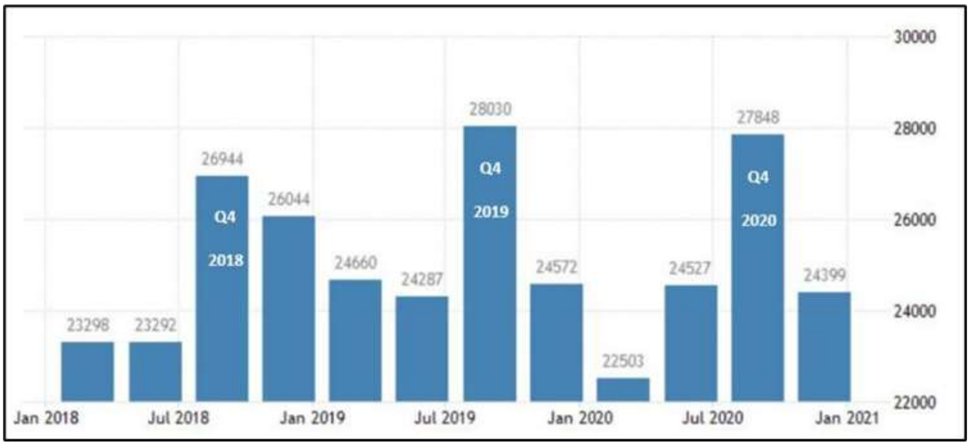

Figure 1: GDP from agriculture sector (Quarterly date of 2018-2021)
(Source: Tradingeconomics.com, Department of Statistics, Malaysia)

The abovementioned increased demand due to the growing population and contraction of GDP due to the COVID-19 pandemic has made it crucial to improve the efficiency, productivity and optimisation of agricultural techniques. However, agriculture in Malaysia is also facing great challenges. Among the notable challenges are the land area for agriculture activities is decreasing every year for housing development activities. Secondly, climate change has shifted the harvest season and reduce yields. Thirdly, most of the smallholders are less educated and refuse to adopt smart technologies. Thus, all these challenges require imperative technology solutions driven by blockchain to increase productivity, yields, and minimise risks (Tambi & Abu Dardak, November 2, 2020). The application of blockchain technology will help to identify the demand of the consumer (market) and the supply of agricultural products by farmers. The application of blockchain technology in the agriculture supply chain includes sensors, devices, and machines and information technologies involving the entire stakeholders from farmers, agribusiness, distributors and consumer market, will lead agriculture to be more efficient, productive and profitable. By leveraging blockchain technology, traditional agriculture will be transformed into smart agriculture in which reduce labour dependency, increase process efficiency and improve cost-effectiveness.

Henceforth, smart agriculture in Malaysia is viewed to enhance the agricultural sector and improve the supply chain in the region overall. To boost the productivity growth in the agriculture sector, the Malaysia government has launched Agriculture 4.0 as one of the strategies to increase its productivity, efficiency and competitiveness (Tambi & Abu Dardak, November 2, 2020). The modern agricultural supply chain works in a multi-tiered ecosystem of stakeholders, from farming to agribusiness, distributor and the market. Interestingly, blockchain technology has the potential to revolutionise the agricultural business. This is due to increased consumer demand for food traceability and visibility. Stakeholders may utilise the blockchain technology to get access to data from the food supply chain, from the farm to the store and consumer (Xu et al., 2020). It is difficult to achieve traceability and visibility in the complicated agricultural supply chains. However, it is thought that it can be done using blockchain technology since it provides a continuous means to maintain security and access data while also reporting the effect to customers (Tan, November 2, 2020).

While the agriculture sector worldwide is undergoing a transformation driven by blockchain technologies, the application of blockchain technology in Malaysia is still under-researched, particularly in the agriculture sector. With respect to the COVID-19 pandemic impact, there have been massive changes in Malaysia's economic landscape. The 12th Malaysia Plan would have to be realistic in looking into various smart farming approaches to achieve the aspiration of Shared Prosperity Vision 2030 in realising the high value of smart agriculture. Besides, the developing blockchain technology for agriculture can increase yield and reduce the dependence on the foreign workers in the agricultural sector, while at the same time create high technology-driven job opportunities for Malaysians in the agriculture sector. Hence, research in merging blockchain technology into the agriculture sector is urgently needed in Malaysia. Against this backdrop, the aim of this study is to examine the challenges created by blockchain technology to the agriculture stakeholders. Besides that, it is also noteworthy to understand that two important theories underlie the integration towards achieving the objectives of developing the blockchain technology for smart agriculture are the Grounded Theory and will conceptualise the Technology-Organisation-Environment (TOE) Theory by DePietro et al. (1990).

2. Literature Review

2.1 Underlying Theories

In this study, two important theories underlie the integration towards achieving the objectives of developing the blockchain technology for smart agriculture towards the supply chain are the Grounded Theory and Technology-Organisation-Environment (TOE). The Grounded Theory will be developed from the findings blockchain technologies model for smart agriculture toward the supply chain by "selecting coding". Grounded Theory is set out to discover or construct theory from data richness and diversity of human experience, identify repeated ideas, and categorise the concepts with codes as they become apparent. These codes can then be grouped into different concepts. Grounded Theory application could increase awareness of the business and related circumstances to prepare and improve the quality of interventions. Henceforth, Grounded Theory is particularly useful in providing a blockchain technologies model for smart agriculture toward the supply chain.

Next, this study will conceptualise the Technology-Organisation-Environment (TOE) Theory by DePietro et al. (1990). The TOE theory has been chosen as the model that provides a more comprehensive examination of the elements influencing adoption. It has also been acknowledged as a useful model for examining the value generation and adoption of innovation (Chittipaka et al., 2022). Previous studies used the TOE theory to try to match the characteristics of technology with those of the organisation's internal and external environments to explain how new technology is used (Chatterjee et al., 2021; Chau et al., 2020). The TOE framework is now utilised by electronic data interchange and open systems (Kuan & Chau, 2001), knowledge management systems (Lee et al., 2009), e-commerce (Liu, 2008), Internet websites (Oliveira & Martins, 2011), E-business (Oliveira & Martins, 2011), enterprise resource planning (Pan & Jang, 2008), and Business-to-business (B2B) (Teo et al., 2006). The TOE Theory demonstrates that a decision should be made to implement technological advancement by focusing on the influences in the operational and environmental environments and the characteristics of the technology itself.

2.2 Research Model

This study proposes the research model (Figure 2) of TOE theory for using blockchain technology for the smart agricultural supply chain. The TOE theory can be used in various industries, countries, and cultures to explain how new technologies work. In this instance, the technology context discusses all current technologies and emerging innovations that will apply to the organisation. Additionally, this technology context also focuses on the applicability as well as the advantages against the challenges of adopting new technologies. So, the debate over whether technology affects society or society affects technology doesn't give a complete picture of how technology changes and the main forces that drive it (Salazar & Holbrook 2008). If new technologies are made, the TOE theory is used for empirical research to figure out how organisations adopt new ideas and how organisations adopt new ideas from other organisations (Baker 2011). Within the context of smart agriculture, the technology context refers to the blockchain technologies acting as vital driving forces in the agriculture sector. Next, the context of the organisation includes measures that describe the organisation's stakeholders, such as farmers, owners of agribusinesses, distributors, retailers, and consumers, in terms of how decisions are made and how processes are formalised. Besides, when evaluating new technologies adoption, the term organisation also includes evaluating their unique characteristics and all available resources, such as the size of the organisation or farm, management structure, and organisational culture. Environment factors in the TOE refer to the external elements, such as whether or not blockchain technology would benefit the organisation's business operations in terms of their competitiveness and overall efficiency. Indeed, this study refers to the effectiveness and efficiency of the agriculture sector's supply chain upon applying or adopting blockchain technology.

In summary, the TOE model underpinned the study based on some factors. TOE framework absorbs the limitations of dominant technological viewpoints and acts as a valuable analytical tool for distinguishing the causes and inherent features of innovation capabilities and other environmental factors of the adopting business. Also, the TOE is a more solid theoretical foundation (Alshamaila et al., 2013) that may help figure out the usage of blockchain technology in supporting smart agriculture as well as the challenges for agriculture stakeholders.

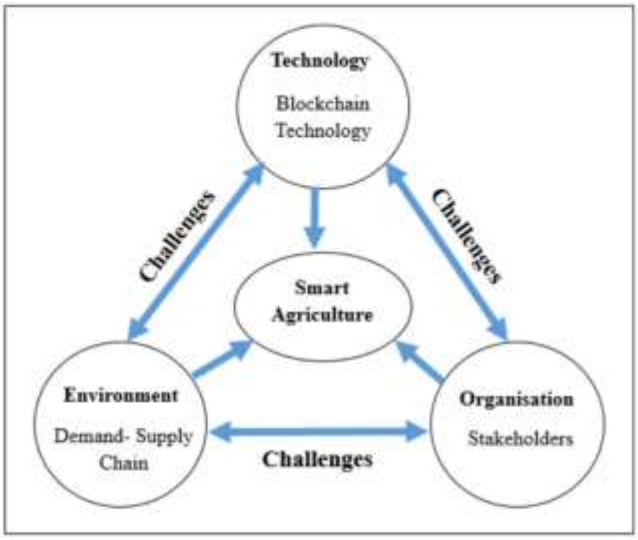

Figure 2: Proposed research model Technology-Organisation-Environment (TOE) for smart agriculture

2.3 Blockchain for Agriculture

The world faces immense problems regarding supplying food for such a rising population. As for Malaysia, the food component continued to be the third-highest contributor with 13.8% (Tan & Yeo, 2020). Needless to say, the government has been proactively planning and monitoring the Sustainable Development Goals (SDG) and ensuring the SDGs are aligned with the 12th Malaysia Plan. One of the SDGs' important aims is to combat hunger (SDG 2 – Zero Hunger). The SDGs stress the value of agriculture and the need to re-energise farming by helping the agriculture stakeholders with new production models and enhancing information sharing. Sylvester (2019) asserted that innovation in food and agriculture processes is required to overcome some of these challenges and, more importantly, make agriculture both exciting and lucrative for all stakeholders, especially smallholder farmers engaged in feeding the world. Blockchain technology is one of the most influential technology revolutions in the food and agriculture sector.

This developing technology, known as blockchain, has the potential to fill the inadequacies in the system referred to above. Blockchain has acquired immense popularity in the banking and finance sector, but its use in agriculture is on the rise. Blockchain technology is increasingly capturing the interest of agricultural firms (Gurtu & Johny, 2019). A growing number of businesses are beginning to recognise how better data management competency from expanding technology contributes to supply chain knowledge and diminishes transactional bottlenecks (van Hoek, 2019). Reduce transaction costs, enhance logistics, boost traceability and improve food safety measures in the agriculture sector by using technology (Erol et al., 2020).

The application of blockchain technology has the potential to revolutionise the agricultural sector in a number of key areas, including the facilitation of peer-to-peer agricultural transactions, the creation of a smart contract platform to simplify the complex transaction process, and the establishment of transparent digital agricultural supply chains. As depicted by Queiroz et al. (2020), blockchain is regarded as a superior and highly disruptive technology that contributes to remodelling traditional business models and creating new opportunities across the supply chain. Blockchain is a potential digital technology that may enhance agricultural supply chain operations. More development of blockchain-based supply chain technologies is required to alleviate concerns during the crisis (van Remko, 2020). In parallel, Paliwal et al. (2020) reviewed the role of blockchain technology in the sustainable management of supply chains. They demonstrated the incredible strength and function of blockchain technology-based information systems. Since 2014, it has been widely known that blockchain technologies can be used in many other sectors. The emergence of blockchain technology in the agriculture supply chain represents an exciting opportunity to improve transactional efficiency, reduce resistance, and promote traceability internationally (Kamilaris et al., 2019). In agriculture, the use of blockchain technology will continue to rise. As the agriculture sector remains fragmented, riddled with data silos, low transparency, and archaic manual processes, blockchain technology within the supply chain can enable this revolution toward smart agriculture. Therefore, in lieu of this, developing blockchain technologies for smart agriculture supply chains is vital in Malaysia. Hence, blockchain technology is further divided into four attributes: traceability, visibility, security and accessibility.

2.4 Traceability

The advancement of blockchain technologies has enabled traceability via the availability and verification of upstream information in the food supply chain regarding suppliers and materials (Kittipanya-Ngam & Tan, 2020). Traceability is the system's ability to verify product components throughout the supply chain process (Xu et al., 2021). The root cause of the traceability problem is the centralised information management systems and databases used to store and manage data, which introduced a central point of failure. In the worst-case scenario, they are disparate and stand-alone. This single-point storage will leave the whole system vulnerable to error, hacking, corruption, or attack, as the infiltrators or hackers only need one successful trespass to alter or manipulate the data (Saberi et al., 2019). Tian (2017) developed an agricultural supply chain monitoring system using blockchain and the Internet of Things. Awwad et al. (2018) stated that blockchain technologies in the supply chain could bring cost savings, transparency, consistency, and improved service delivery speed. Additionally, Kros et al. (2019) stressed that traceability helps ensure responsive coordination between the supply chain participants. Therefore, it is crucial to ensure the monitor and control can be correctly executed, and this efficiency is likely to bring down the operation costs.

2.5 Visibility

Blockchain visibility is conceptualised as the model through which an organisation communicates and reports its action to its liaisons across its supply chain network to support its visibility at all levels. It enables a clear view of the upstream and downstream inventories as well as demand and supply status. Hence, data availability in a timely and accurate manner is essential to supply chain effectiveness. Blockchain visibility can improve supply chain partnerships (Kshetri, 2018). This study argued from the angle that supply chain visibility must have data readily available, accurate, timely and in a format that communicates necessary information (Pettit, 2008). Blockchain visibility has a similar feature. Using blockchain technologies in the Agri-Food supply chain, all node activities on the network are visible, and all information documented is based on consensus among network participants (Kamble et al., 2020). Kittipanya-Ngam and Tan (2020) posit that digital transformation in the food supply chain has gained by all means, including enhancing information transparency increases in the consistency of food product safety and quality.

2.6 Security

The goal of ending hunger (SDG2) highlights the importance of ensuring food security in the country. Security is an emerging area within the supply chain risk management field, and it has gained increased scholarly interest over the last decade. Blockchain technology offers security, preserves a temper proof record, eliminates the need for a third-party middleman in transactions, helps to lower total transaction costs, and increases product quality. Little academic work has been undertaken to resolve the security issues in the food industry (Liu et al., 2021). Smart agriculture is the new method mainly focusing on farming practices that increase productivity in distribution and security. Blockchain technology was developed to track data on agricultural products using double-chain storage management to overcome storage and delivery issues (Niknejadet al., 2021).

2.7 Accessibility

As technical innovations become available, the increasingly competitive customers and consumers' situation in downstream chains are the current challenges in agriculture supply chains. With blockchain technology, consumers can place demands on food supply chain traceability, safety, and sustainability on all agriculture producers. Kittipanya-Ngam and Tan (2020) indicated that the opportunity for the blockchain technology of agriculture supply chain is the e-market channel accessibility. This e-market channel has allowed the agriculture supplier to access many target markets quickly. Hence, with the rapid technological advancement, consumers' online purchase (smart purchase) behaviour has spiralled upwards as consumers begin to realise that the power of the e-market is just a click away (Yeo et al., 2021).

2.8 Research Gaps

Based on the research by Xiong et al. (2020), the conceptualisation of blockchain technology in agriculture is based on reviewing past research without involving any field study. Besides, this study has a different focus where it looks explicitly into the application and rationale of utilising blockchain technology in the agriculture sector based on the previous studies. Several limitations have been highlighted in this research that provides the opportunity for future research to be carried out. One notable limitation in Xiong et al. (2020) study is the barrier/challenges in adopting blockchain technology in the agriculture sector. Thus, this proposed research would like to investigate the challenges created by blockchain technology to the agriculture stakeholders.

Correspondingly, research by Mirabelli and Solina (2020) gathered the data from the appropriate keyword to detect the current research trends and possible future challenges in blockchain and agricultural supply chains topics. Most papers reviewed from the Scopus database focus on too general concepts and are not strictly related to a specific real agricultural supply chain in blockchain technology. Additionally, this research also revealed that United States, China, India and some of the European countries are the most active continents in the application of blockchain in the agricultural sector from the point of view of scientific research. This has provided a vacuum for the currently proposed research to be carried out in Malaysia's agriculture sector, which is one of the important contributors to the country's economy.

From the review of literature, the majority of the published articles emphasise on traceability which is one of the blockchain technology attributes, such as Patelli and Mandrioli (2020), Demestichas et al. (2020), Kamble et al. (2020), Prashar et al. (2020), and Thume et al. (2021). Many other blockchain attributes seem to be omitted and under-researched. Hence, this research bridges the gaps in crafting a comprehensive blockchain technology model. In conclusion, we conquer the claim by Xiong et al. (2020) and Mirabelli and Solina (2020) that the current blockchain technology in the food supply chain is still in the early stages of development. Therefore, this research needs to be conducted to fill the gaps in these immature areas.

3. Method

The qualitative method will be employed in this study as it provides more in-depth information about this proposed research. Sample size guidelines suggest a range between 20 and 30 interviews be adequate in the qualitative method to reach saturation (Creswell, 2013). The researchers for the interview guide will develop open and semi-structured questions. In-person interviews will be done at the owners' residences, and audio recordings will be made only with the consent of all participants. Each interview will last between 45 and 60 minutes. Thematic analysis approaches will be used to transcribe and code the data collected during the interviews using ATLAS.ti version 8.0. (Braun et al., 2018).

These semi-structured interviews and naturalistic inquiry will be conducted in six states: Perlis, Kedah, Selangor, Negeri Sembilan, Pahang and Sarawak. These states have recently been identified as the distribution economic regions with a smart and high-value agriculture hub by Shared Prosperity Vision 2030. The study samples will draw from a group of agriculture stakeholders comprising seven participants from the six states. Before the researchers' kick start the data collection phase, an application for full ethical approval will be submitted to the Jawatankuasa Etika Penyelidikan Manusia (JEPeM) of USM. This application process will take approximately two months till the ethics approval letter is issued. Upon receiving the ethical approval from the Jawatankuasa Etika Penyelidikan Manusia (JEPeM) of USM, a letter of permission to conduct the research will be addressed to stakeholders in the six states, Perlis, Kedah, Selangor, Negeri Sembilan, Pahang and Sarawak with attachment ethical approval letter from JEPeM. To begin with, the researchers will solicit participation from agricultural farms and conduct interviews with the owner and two farmers from each farm involved. Additionally, the researchers will also seek help from the farmland owner to link the researchers to the agribusiness business that receives the farm's supply. The interview will then be conducted with the agribusiness owner. Next, the agribusiness owner will link the researchers to the distributor for the interview process. The subsequent interview will then be carried out with retailers and consumers. Finally, the interview process would be complete if all stakeholders in the supply chain were interviewed.

4. Conclusion

The underlying trend of agricultural research is discovered to be primarily embedded in scientific investigations from technologies' perspectives. The findings of this research will spur the agriculture industry to use blockchain technology. By developing the blockchain technology model in smart agriculture, the Technology-Organization-Environment (TOE) theory will be expanded into new advanced technology and emerging innovation area. The research findings will bring a significant contribution to society, academia, government, industry and environment. This study will increase research growth in blockchain implementation for agricultural supply chains, which is something that would be beneficial from a scientific point of view. In conclusion, this study expands knowledge on blockchain technology in supporting smart agriculture by looking into the blockchain technology attributes in terms of traceability, visibility, security and accessibility, as well as the challenges created by blockchain technology to the agriculture stakeholders.

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