UNIVERSITY
OF TECHNOLOGY
SYDNEY

Blockchain Adoption for Agri-Products Supply Chain Traceability and Sustainability

by Anwara Akter Happy

Thesis submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy

under the supervision of
Associate Prof. Md Maruf Hossan Chowdhury
Senior Lecturer Dr Moira Scerri

University of Technology Sydney
Faculty of Business School

October 2025

CERTIFICATE OF ORIGINAL AUTHORSHIP

I, *Anwara Akter Happy*, declare that this thesis is submitted in fulfilment of the requirements for the award of *Doctor of Philosophy* in the *UTS Business School* at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution.

This research was supported by an Australian Government Research Training Program (RTP) Scholarship doi.org/10.82133/C42F-K220.

Signature:

Production Note:
Signature removed prior to publication.

Date: 21 October 2025

DEDICATION

I dedicate

To

My precious family
My beloved parents &
My husband, Saif

ACKNOWLEDGEMENTS

This journey has been intellectually rewarding and personally a special one. It is a challenging project that I have managed in my career where scholarly guidance, friendship, and self-determination become critically important. I am deeply indebted to my principal supervisor, Associate Professor Md Maruf Hossan Chowdhury, and my co-supervisor, Dr Moira Scerri, for their intellectual guidance, support and critical feedback, which shaped this thesis throughout the journey. A/Prof. Maruf is incredibly cooperative and easy-going and always had time for me whenever needed. I believe his supervision style was well-matched with the way I do things. I appreciate his contributions of time, intellectual guidance, valuable suggestions and critical feedback, which have made my PhD experience more interesting and stimulating. I would like to thank my co-supervisor, Dr Moira Scerri. Her critical feedback, supportive advice, and unique guidance always encouraged me to improve my thesis's quality. I appreciate her time contributions and intellectual support throughout my PhD journey. UTS Business School at the University of Technology has allowed me to broaden my knowledge in many ways. Its intellectual endeavours, research networks, publications, workshops for higher degree research and seminars have helped shape and transform my research ideas into research output. I also benefitted from the other department members during many formal and informal discussions with them. I want to extend my sincere gratitude to Prof. Bronwen Dalton, Prof. Carmel Foley, Prof. Rachel Wilson, Prof. Renu Agarwal, Prof. Kathy Walsh, A/Prof Bernhard Wieder, Dr Stephen Frawley, Dr Stephen Schweinsberg, A/Prof. Hyong-Hee Yu, Pro Simon Darcy, Dr Sonika Singh, Dr Helena Li, A/Prof Mohammad Alamgir, Hossain, Dr Zapan Barua, Dr Simon Faulkner, A/Prof. Sanjoy Paul, Dr Mihalla Gavin, Dr Celina McEwen, Dr Tracey Walmsley, Dr Rayan Merkbowi, Dr Stella Ng, Dr Ms

Ashleigh Hall, Dr Alan Skinner, Dr Shelley McGuire, and Dr Erica Ho. The members of UTS Business School were also very supportive throughout my PhD journey. They were always ready to extend their support to the students. I want to thank Ms Kristy O'Hare, Ms Nancy Chau, and Mr Fung Mak for their enormous support throughout the journey. During my studies, I have encountered several intellectually rich fellows in the school and across UTS. I immensely benefitted from academic discussions and informal meetings with them. I especially thank Mrs Nusrat Jusy Umme, Mr Iftekhar Ahmed Robin, Dr Shiyou Liu, Ms Leanne Sobel, Mr Robert Carroll, Dr Hina Mehreen, Ms Rachel Bertram, Ms Mingliang Wu, Ms Pranati Balijepalli, and Ms Deepa Subhadrammal for sharing their intellectual thoughts and being good friends. I am grateful to my parents, sisters, brothers and in-laws for their blessings and love, and especially for the limitless freedom in my life. I am deeply indebted to my mother, Mrs Razia Begum, who has showered me with endless blessings throughout my journey. I am deeply grateful to my late father; Md. Amin Uddin Khan has always been an inspiring teacher in my life. I want to express my cordial gratitude to my elder brother, Dr Shahadat Khan, and my youngest sister, Advocate Tahamina Akter Khanam, as they are my inspiration for all good deeds. Finally, I would like to extend my cordial thanks to my husband, Md. Saif Ahmed, for being supportive, compassionate and understanding during my PhD journey. His inspirations and support are unique; I feel proud of it. I also thank my well-wishers for their continuous encouragement and support in my work.

A professional writer and editor, namely Expert Editor, has edited this thesis. I want to extend my sincere thanks for their excellent work.

ABSTRACT

Traceability is essential in the Agri-product supply chain for many reasons, including quality assurance, consumer trust, regulatory compliance, risk management, and sustainability goals. Traceability ensures food safety, quality, and compliance by tracing and tracking Agri-products throughout the supply chain, providing transparency and enabling quick responses to contamination or recalls. It (traceability) builds consumer trust, meets regulatory requirements, and supports sustainability in the Agri-product supply chain.

Blockchain is a state-of-the-art technology that ensures traceability, leading to supply chain sustainability. The application of this technology for traceability within the supply chain is considered a developing research field in food supply chain management. However, this study highlights a lack of empirical research on the effect of blockchain adoption on traceability and sustainability of the supply chain. Traceability may enhance the sustainability of supply chains, but the literature needs to be investigated more. Thus, this study examines blockchain adoption for supply chain traceability and sustainability.

An initial model was proposed based on an extensive literature review. The literature review of this study was justified through the lens of the Dynamic Capability View (DCV) Transaction Cost Theory (TCT), and Institutional Theory (IT). The constructs were determined through an extensive literature review, and the validity and reliability were checked of these constructs. The hypotheses were tested, and the findings and results of this study were interpreted.

This study deployed a quantitative method approach within the positivist research paradigm. Survey data was collected from the global agri-products industries. A total of 294 usable survey responses were obtained from the global Agri-products (producers,

processors, transporters, wholesalers, and retailers) industries. The study used a partial least squares structural equation modelling (PLS-SEM) tool to analyse the research data. The data analysis followed a two-phase approach, which involved evaluating both the measurement model and the structural model.

The study used Dynamic Capability View (DCV), Transaction Cost Theory (TCT), and Institutional Theory (IT) as theoretical lenses for organisations to meet and match the specificities of internal and external business environmental contexts. There are drivers (e.g., stakeholder requirement, competitive pressure, market dynamics, regulatory support, etc.) and barriers (technological barriers, lack of infrastructure, lack of top management support) to blockchain adoption in SC. Organisations and their supply chains need to sense/identify the external and internal environmental factors that influence BC adoption and respond to the environmental factors. Arguably, blockchain adoption in a SC is a dynamic capability (DC) for organisations and their SCs to ensure SC traceability, which is an operational capability (OC) for organisations to track and trace the origin, characteristics, quality and other parameters for a product throughout the SC. For example, traceability helps to ensure transaction cost transparency, which may reduce the chance of opportunism in supply chain malpractices (illegal and unethical procurement and production practices, product lifecycle transparency). Also, traceability helps stakeholders to make rational decisions while addressing the limitations of bounded rationality.

The findings of this study confirm that there are significant impacts and positive relationships between business environmental drivers and blockchain adoption, along with direct, indirect and conditional effects of blockchain adoption on Agri-products supply chain traceability and sustainability, thereby making an important contribution to the literature on technology adoption in supply chain management. Further, the study posits that SC sustainability is an outcome of blockchain adoption and traceability. Thus, for the first time in the literature, this study investigates the role of dynamic capability (DC) in examining traceability in SC from a blockchain technology context. Further, the study investigates the role of DC and operational capability (OC) in examining sustainability in SC from a blockchain technology perspective.

The study's findings confirmed that nobody had tested the indirect effects of TRA between BCAD and sustainability before, which is a unique contribution. Therefore, this study claims traceability as a mediator role used for the first time in blockchain adoption for supply chain literature.

This study revealed that adopting blockchain in supply chains has significant impacts on supply chain traceability and sustainability. It is also ascertained that traceability ensures improvement in supply chain sustainability. In particular, the study's findings reiterate the importance of blockchain adoption for traceability in improving the Agri-products supply chain for sustainability (social, economic and environmental). In particular, a significant contribution was the empirical validation of a blockchain adoption model for Agri-products supply chain traceability and sustainability, using PLS-based SEM.

This research has both theoretical and practical implications. This study extends our understanding of blockchain literature for supply chain traceability and sustainability in general and the global Agri-products supply chain in particular. The study also expands the theoretical contribution of the Dynamic Capability Theory and Transaction Cost Theory about blockchain adoption within the Agri-products supply chain.

The comprehensive research model is unique. It integrates two core theories, Dynamic Capability View (DCV) and Transaction Cost Theory (TCT), to identify the applicable factors and their relationships in the blockchain adoption for supply chain traceability and sustainability model. The study also integrated both DCV and TCT to explain the outcome of sustainability. Thus, this study extended the outcome perspective of the DCV and TCT in the context of blockchain for the global Agri-products supply chain. Therefore, this study makes an insightful contribution to the existing literature.

In addition to the Dynamic Capability View (DCV) and Transaction Cost Theory (TCT), this study contributes to the Institutional Theory by highlighting how external institutional pressures shape blockchain adoption within global agri-product supply chains. The research demonstrates that coercive, normative, and mimetic forces influence firms' motivation to implement blockchain for traceability and sustainability compliance (Saberi et al., 2019; Scott et al., 2017). By incorporating Institutional Theory, the study extends the understanding of how organisational legitimacy and stakeholder expectations drive technological adoption beyond efficiency and capability perspectives. This theoretical integration strengthens the framework by showing that blockchain is not only a dynamic resource that enhances capabilities and reduces transaction costs but also a response to institutional expectations for transparency and accountability. Therefore, the study provides a multi-theoretical foundation, DCV, TCT, and Institutional Theory to comprehensively explain blockchain adoption and its sustainability outcomes in the agri-product supply chain context.

The model proposed may serve as a framework for managers addressing traceability and sustainability in supply chain management. The factors and variables obtained from this research will assist supply chain managers in identifying and measuring blockchain adoption for traceability and sustainability in the broader supply chain domain. This model will help managers develop the sustainability of goals. Overall, this study will inform managers that decentralised traceability in the Agri-products supply chain ensures improvement in sustainability. However, the study's implications are also significant for other industry contexts.

PUBLICATION FROM THIS DISSERTATION

Publication Type	References
1. Conference Paper	Happy, A., Chowdhury, M.M.H., Scerri, M.,2024. *Blockchain Applications in Global Agri-food Operations and Supply Chain: A systematic literature review.* Proceedings of the 21st ANZAM OSCSM Symposium, University of Canterbury, Business School, Christchurch, NZ.
2. Conference Paper	Happy, A., Chowdhury, M.M.H., Scerri, M., 2023. *Blockchain technology for Agri-food supply chain sustainability: A systematic literature review.* Proceeding of the 20th ANZAM Operations, Supply Chain and Services Management Symposium, University of Technology Sydney, UTS Business School, NSW.
3. Journal Article	Happy, A., Chowdhury, M.M.H., Scerri, M., Hossain, M.A. and Barua, Z., 2023. Antecedents and consequences of blockchain adoption in supply chains: a systematic literature review. *Journal of Enterprise Information Management,* 36(2), pp.629-654.
4. Book Chapter	Happy, A, Rahman, KW, Chowdhury, MMH, Chowdhury, M & Scerri, M 2021. Blockchain adoption challenges in supply chain. In: AGARWAL, R., BAJADA, C., GREEN, R. AND SKELLERN, K. (ed.) *The Routledge Companion to Global Value Chains: Reinterpreting Reimagining Megatrends in the World Economy.* Taylor & Francis Group, UK.
5. Conference Paper	Happy, A., Chowdhury, M.M.H., Scerri, M., 2020. *Blockchain Adoption in Supply Chain: A Systematic Literature Review.* Proceeding of the Australia and New Zealand International Business Academy (ANZIBA) conference, University of Technology Sydney, UTS Business School, NSW

DEFINITION OF KEY TERMS

Supply chain: A supply chain consists of a network of organisations interconnected through upstream and downstream relationships, integrating various business processes and activities to produce goods or services for the end customer (Christopher, 2016).

Blockchain: Blockchain is a type of distributed database or ledger, one of the top technologies in contemporary tech trends; it (Blockchain) ensures ***secure information sharing*** through computer terminal participants (nodes).

Traceability: Traceability means discovering information about the life cycle of products (Cambridge Dictionary). The European Union (EU) regulation 178/2002 defines traceability as tracing and following a food and food safety, nutrition, feed, food-producing animal health and welfare, or expected to be incorporated into a food or feed, through all stages of production, processing and distribution.

Sustainability: Sustainability means the development that meets the needs of the present generation without compromising the ability of future generations to meet their needs (Keeble and war, 1988).

Agri-Products: The term "agricultural product" or "Agri-Product" means any agricultural commodity or product, whether raw or processed, including any commodity or product derived from livestock marketed for human or livestock consumption. Examples are beef, wheat, barley, canola, cotton, sugarcane, fruits, and vegetables.

LIST OF ABBREVIATIONS

ABS	Australian Bureau of Statistics
AFSC	Agri-Food Supply Chain
BC	Blockchain
BCAD	Blockchain Adoption
CPR	Competitive Pressure
ENV	Environmental
ECO	Economic
MTurk	Amazon Mechanical Turk
MDY	Market Dynamics
RGS	Regulatory Support
SC	Supply Chain
SGV	Sustainability Governance
SCM	Supply Chain Management
SCS	Supply Chain Sustainability
SOC	Social
TRA	Traceability
TOR	Technology Orientation
UPS	Upper Management Support

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1:

1.1 INTRODUCTION

1.2 Overview

This chapter provides an overview of the background for the research by outlining the rationale, objectives, key questions, scope, and expected contributions of the study. This chapter also outlines the thesis organisation of the study.

1.2.1 Background to the research

Food quality and safety are critical to consumers in the globalised food supply chain. Food quality and safety are gaining attention in many countries around the globe due to the rising incidence of food contamination (Casino et al., 2020b). There are concerns about food quality and safety in Australia and the countries to which Australia exports agri-food. Most food poisonings occur due to mishandling food, keeping it at the wrong temperature, cross-contamination, and incorrect reheating (Golan et al., 2004). Inappropriate practices allow bacteria to survive or thrive (MLA, 2018). These poor practices lead to animal health and foodborne illness in the agri-food supply chain globally (Smith et al., 2005).

Due to the increasing occurrence of food contamination, global attention is shifting towards food quality, safety, and security (Sharma et al., 2020, Yadav and Singh, 2020b). Evidence shows that approximately seven million people (1% of the population) in Europe are affected yearly by foodborne illness (Saltini and Akkerman, 2012). In America, 47.8 million people (approximately 16.7% of the population) get sick each year with food-related illnesses (Resende-Filho and Hurley, 2012).

Each year, foodborne illness costs approximately 2.44 billion (90% uncertainty interval 1.65 – 3.68) in Australia (Glass et al., 2023). Moreover, the appropriate measures against food contamination and safety were pivotal during the COVID-19 outbreak (Sim and Wiwanitkit, 2021). In such an environment, most agri-food supply chain traceability depends on the traditional (centralised) information-gathering system (Jie et al., 2016a). It is also evidenced that the conventional supply chain merely procures, processes, and distributes agri-food to the consumer with relatively limited transparency and traceability mechanisms across the supply chain (Tao, 2018, Wu, 2017, Jie et al., 2016a). There are no exceptions in the context of the Agri-product supply chain (Jie et al., 2016b, Casino et al., 2020b).

Since agri-foods are highly perishable, appropriate temperature and humidity requirements in logistics are significant to maintain food quality and safety (Jie et al., 2016b). From this end, blockchain could ensure transparency and traceability in the agri-food supply chain by employing a real-time visibility system (Nikolakis, 2018, Tian, 2016c). Previous studies have considered using blockchain-based traceability mechanisms in agri-food supply chain management (Casino et al., 2020b). In most studies, researchers concentrated their reflections on the technical functions of blockchain technology and integrated applications with other technological functions. Such technologies include RFID (radio frequency identification), GPS (global positioning system), and GIS (geographical information system), among others (Costa et al., 2013, Tian, 2016b). Research indicates that beef producers could improve supply chain flexibility by enhancing customer relationships and quality practices using RFID and GPS technologies in the supply chains (Costa et al., 2013). However, little attention has been devoted to empirically investigating blockchain adoption (BCAD) for Agri-products supply chain traceability (SCT) and sustainability context (Tian, 2016b, Casino et al., 2020b, Islam and Cullen, 2021).

Traceability mechanism is becoming increasingly urgent for Agri-products to track the product or product attribute from paddock to plate in the supply chain (Min, 2019). The definition of traceability is inherently broad because it is a tool for achieving many objectives (Golan et al., 2004, Lin et al., 2019). According to the ISO 9001:2000 quality standard (Fotopoulos et al., 2010), traceability is "the ability to trace the history, application or location of an entity by means of the recorded definition." This definition is cited in Aung and Chang (2014). Saberi et al. (2019b) demonstrate the urgent need for SCT in pharmaceutical and medical products, banking and insurance, and high-value goods, including the AFSC. Adopting BC in the AFSC can track the agri-food product and product attributes to meet the urgent requirements of the traceability system.

The potential of blockchain adoption in the agri-food supply chain has increasingly received attention (Min, 2019, Salah et al., 2019, Behnke and Janssen, 2019). However, minimal research has been identified related to blockchain-based traceability and sustainability for the broader supply chain (Wilson and Clarke, 1998, Zhao et al., 2019). For example, the current traceability practice in the AFSC suffers from significant data fragmentation (Aung and Chang, 2014, Lin et al., 2019), where decentralised systems could secure the vulnerability of data management in supply chain practices (Behnke and Janssen, 2019). In addition, blockchain can improve agri-food value chain management; however, there is relatively limited empirical research in such areas of AFSC practices (Zhao et al., 2019). The evidence shows the need for further research on blockchain adoption for supply chain traceability and supply chain sustainability (SCT & SCS) in the Agri-products supply chain (see Appendix 2). Therefore, this research empirically examines the drivers (business environmental drivers) that influence blockchain adoption for supply chain traceability and sustainability in the global Agri-products context.

Although blockchain adoption has gained increasing attention in the SCM literature, there seems to be less emphasis on blockchain in food supply chains (Garcia-Torres et al., 2019, Cole et al., 2019, Wong et al., 2020a). Specifically, blockchain in the agri-food supply chain focusing on traceability and sustainability remains less researched in empirically supported areas (Hughes et al., 2019). Previous studies investigated blockchain for supply chain traceability and sustainability, yet most studies remain conceptually focused. For example, studies examined food SC traceability (Aung and Chang, 2014, Kamath, 2018, Lin et al., 2019), blockchain for agri-food value chain management (Zhao et al., 2019, Salah et al., 2019, Tian, 2016b), and blockchain for supply chain sustainability (Saberi et al., 2019b, Treiblmaier, 2019). However, very little empirical research was conducted in the context of the Agri-food supply chain (See Appendix 3). Thus, there is a significant gap in the literature.

Studies indicate that blockchain adoption for Agri-products supply chain traceability is rare. Also, blockchain in SCM has been researched on a range of topics, but most of the papers lack theoretical foundations (Kummer et al., 2020) (see Appendix 3). This is evident from existing studies on blockchain adoption in the broader supply chain that lack the application of established theories, specifically for supply chain traceability and sustainability in the Agri-food supply chain globally (Garcia-Torres et al., 2019, Kouhizadeh and Sarkis, 2018, Prashar et al., 2020) Moreover, relatively limited research has used established organisational theories in the context of the Agri-products supply chain. Thus, there is a need to empirically investigate the impact of blockchain on supply chain traceability and sustainability and use the established theories, specifically in the Agri-products supply chain context.

1.2.2 Problem Statement

In today's globalised food supply chain, ensuring food quality and safety has become a major concern for consumers and regulators alike. The rising incidences of food contamination and related illnesses have raised significant concerns globally, particularly among countries involved in the production and import of agri-products, such as Australia and its international trading partners (Casino et al., 2020a). Factors such as poor handling, inadequate storage temperatures, cross-contamination, and improper reheating contribute significantly to foodborne diseases, posing risks to both consumer health and animal welfare (Golan et al., 2004, Smith et al., 2005). These systemic failures within the agri-food supply chain highlight the urgent need for robust mechanisms that can guarantee food safety and traceability (Anastasiadis et al., 2025).

Despite growing awareness and the pressing need for transparency, traditional centralised systems used for managing agri-food supply chains often lack effective traceability mechanisms (Jie et al., 2016b, Wu et al., 2017a, Roy et al., 2023). These systems primarily focus on procurement, processing, and distribution without ensuring real-time visibility or accountability. The limitations of conventional approaches were especially apparent during critical periods such as the COVID-19 outbreak (Sim and Wiwanitkit, 2021). Blockchain technology offers a potential solution by enabling decentralised, transparent, and immutable records that enhance visibility across all nodes of the supply chain (Tian, 2016b, Nikolakis et al., 2018). However, most studies so far have primarily explored the technical features of blockchain, often in conjunction with other digital technologies such as RFID and GPS, without deeply examining its empirical adoption for traceability and sustainability in agri-food supply chains (Costa et al., 2013, Casino et al., 2020a, Islam and Cullen, 2021).

The concept of traceability—defined by ISO 9001:2000 as the ability to trace the history, application, or location of an entity—has become vital for tracking product attributes from farm to table (Fotopoulos et al., 2010, Aung and Chang, 2014). While blockchain technology can address challenges of fragmented data and improve supply chain resilience, there is minimal empirical evidence supporting its application specifically in agri-food contexts (Min, 2019, Lin et al., 2019, Behnke and Janssen, 2020a). Furthermore, existing studies are largely conceptual and have not sufficiently investigated the role of blockchain in ensuring both traceability and sustainability across global agri-product supply chains (Mohapatra et al., 2025, Zhao et al., 2019, Salah et al., 2019, Saberi et al., 2019b).

Although blockchain has been widely discussed within the broader supply chain management (SCM) literature, its specific application to the agri-food sector remains underexplored, especially from a theory-driven and empirically validated perspective (Garcia-Torres et al., 2019, Cole et al., 2019, Wong et al., 2020c, Cao et al., 2023). Most research lacks a robust theoretical foundation, failing to employ established organisational theories to understand blockchain adoption and its impacts (Kummer et al., 2020, Kouhizadeh and Sarkis, 2018, Prashar et al., 2020, Anastasiadis et al., 2025). Therefore, there is a need for empirical research that investigates the environmental and organisational drivers influencing blockchain adoption for improving supply chain traceability and sustainability. Addressing this gap is essential to developing a reliable, secure, and sustainable agri-food supply chain that meets the growing expectations of global consumers and regulators.

1.2.3 Research objectives and research questions

In light of the limitations of the extant literature, this study examines the influence of blockchain adoption drivers on supply chain traceability, resultant impact on sustainability

Based on the literature review and the theoretical lens of dynamic capability view (DCV) and transaction cost theory (TCT), this study aims to achieve the following overarching research objective:

- To investigate the impact of business environmental drivers of blockchain adoption, its consequences on the traceability and sustainability of the Agri-products supply chain and potential factors influencing such relationship dynamics.

The overarching research objective is broken down into two specific research objectives. Therefore, this study aims to achieve the following specific research objectives:

- To investigate the impacts of business environmental drivers on blockchain adoption in the Agri-products supply chain.
- To examine the direct, indirect and conditional effect of blockchain adoption on Agri-products supply chain traceability and sustainability.

1.3 Research questions

The research questions of this study explore blockchain adoption for supply chain traceability and sustainability. Furthermore, the research will examine blockchain adoption drivers for SC in general and the Agri-products SC in particular. Therefore, this research attempts to answer the following overarching research question:

- RQ: What factors influence blockchain adoption and to what extent does blockchain adoption influence Agri-products supply chain traceability and sustainability?

The central research question is broken down into two sub-research questions. Therefore, this research seeks to address the following sub-research questions (SRQ):

- **SRQ1:** How and to what extent business environmental drivers influence blockchain adoption in the Agri-products supply chain?
- **SRQ2:** How and to what extent does blockchain adoption influence Agri-products supply chain traceability and sustainability?

1.3.1 Scope of the research

The main scopes of the research are supply chain, supply chain management, blockchain adoption, blockchain adoption drivers (Business Environmental Drivers), supply chain traceability, sustainability, the possible role of mediators and moderators, and global Agri-products. In particular, from the various drivers identified through extensive literature review, this study will only focus on collecting and analysing research data for business environmental drivers (BED).

1.3.2 Research methodology

In this study, the researcher determined that the quantitative method best addresses the research questions within the positivist research paradigm. This choice is based on ontology (the belief in the nature of reality), epistemology (the theory of knowledge and the separation of researcher from what to be researched) and methodology (the way of investigating a phenomenon and producing knowledge) (Saunders et al., 2007, Creswell and Creswell, 2017). A research model and the survey instrument have been developed in light of the literature review and theoretical grounding. The research model has been validated through a pilot study. Research data from the global agri-products industry was collected using the MTurk online platform. Smart PLS Structural Equation Modeling (SEM) was deployed to analyse the quantitative data (Leavy, 2017) for this study.

1.3.3 Contribution of the research

This study is expected to make significant contributions theoretically and practically. The novel contribution of this study is summarised as follows:

1.3.3.1 Theoretical contributions

This study enhances the understanding of blockchain adoption in supply chains, particularly in terms of traceability and sustainability, by testing and validating the measurement constructs, making a key contribution to the research. It clarifies how blockchain adoption drivers relate to other elements in the model, including traceability, mediators, moderators, and outcomes. Notably, the research identifies specific drivers of blockchain adoption both within supply chains broadly and the agri-products supply chain specifically, which stands out as a distinctive contribution.

This study is grounded in three theoretical perspectives, the Dynamic Capability View (DCV), Transaction Cost Theory (TCT) and Institutional Theory (IT), to deepen insights into how blockchain influences supply chain operations management. Using these frameworks, the research offers important empirical findings that support the theoretical foundations. Consequently, it makes a meaningful contribution to the advancement of knowledge on blockchain adoption for enhancing traceability and sustainability in supply chains.

Contribution to Dynamic Capability View

This study makes a meaningful contribution to the Dynamic Capabilities View (DCV) by demonstrating how blockchain adoption strengthens firms' ability to sense, seize, and reconfigure resources in supply chain operations. The DCV emphasises that competitive advantage arises when firms effectively integrate and adapt internal and external resources to respond to market volatility (Teece et al., 1997). By investigating blockchain's role in enhancing traceability and sustainability, the study highlights how organisations develop new dynamic capabilities that improve transparency, trust, and responsiveness across supply chains. For example, blockchain-enabled traceability allows firms to identify sustainability risks and opportunities more efficiently, thereby reinforcing their sensing and seizing capabilities (Wamba & Queiroz, 2020). Moreover, the empirical findings provide evidence of how blockchain supports the transformation of traditional supply chain practices into innovation-driven, sustainable models. This contribution extends DCV literature by positioning blockchain not merely as a technological tool, but as an enabler of adaptive and reconfigurable supply chain strategies (Queiroz & Fosso Wamba, 2019).

Contribution to Transaction Cost Theory

In parallel, the study also advances the understanding of Transaction Cost Theory (TCT) by explaining how blockchain reduces inefficiencies and opportunistic behaviours in supply chain transactions. TCT suggests that firms seek governance structures that minimise transaction costs related to uncertainty, information asymmetry, and contractual enforcement (Williamson, 1985). The integration of blockchain enhances information sharing and verification, reducing the need for costly monitoring and third-party mediation (Saberi et al., 2019). By empirically showing the mediating role of traceability between blockchain adoption and sustainability, the research illustrates how blockchain lowers transaction costs while fostering collaborative and trust-based supply chain relationships. Additionally, the findings demonstrate that blockchain adoption mitigates opportunism and uncertainty, creating more predictable and cost-efficient exchanges. Thus, the study extends TCT by providing evidence of how digital technologies like blockchain reshape governance mechanisms to balance efficiency, trust, and sustainability (Min, Zacharia, & Smith, 2019).

Contribution to Institutional Theory

Institutional theory offers a robust theoretical justification for understanding blockchain adoption in agri-product supply chains as a response to institutional pressures for traceability, transparency, and sustainability. Coercive pressures from governments, regulators, and trade bodies compel organisations to adopt blockchain technologies that ensure verifiable and immutable records across production and distribution stages (Casino et al., 2019, Saberi et al., 2019a). By doing so, firms not only comply with food safety and traceability standards but also secure institutional legitimacy in competitive global markets (Scott et al., 2017, Treiblmaier, 2018). Furthermore, normative pressures from industry associations and consumer advocacy groups encourage blockchain integration to uphold ethical sourcing, environmental accountability, and fair labour practices (Queiroz et al., 2019b). Mimetic pressures also drive firms to emulate early adopters who gain reputational and operational advantages through blockchain-enabled transparency (Kouhizadeh et al., 2019, Hastig and Sodhi, 2020). Collectively, these institutional forces transform blockchain from a technological innovation into a mechanism for organisational legitimacy, sustainability assurance, and stakeholder trust (Francisco and Swanson, 2018, Hastig and Sodhi, 2020, Yawar and Kauppi, 2018) Hence, institutional theory underscores blockchain's contribution as both a compliance tool and a strategic enabler of legitimacy within agri-product supply chains.

This research explores traceability within global agri-product supply chains and introduces an empirically validated measurement for the multidimensional construct of supply chain traceability. It also establishes and confirms the mediating role of traceability (TRA) in the relationship between blockchain adoption and sustainability. The findings demonstrate that blockchain adoption has direct, indirect, and conditional impacts on both traceability and sustainability. Notably, this study is the first to examine the indirect effect of traceability on sustainability, mediated by blockchain adoption (BCAD), representing a novel contribution. It uniquely positions traceability as a mediating factor within the context of blockchain and supply chain research.

Furthermore, although existing literature suggests that blockchain-enabled traceability supports supply chain sustainability, no prior empirical studies have validated this relationship. This study fills that gap by identifying a positive link between supply chain traceability and the three dimensions of sustainability such as social, environmental, and economic and offering another original contribution.

1.3.3.2 Managerial significance

This research enriches existing knowledge and academic literature by offering a more in-depth understanding of blockchain adoption within the agri-products supply chain. It seeks to develop a blockchain adoption model aimed at improving supply chain traceability and sustainability. The proposed model can act as a practical guide for managers tackling supply chain challenges. Additionally, the study supports managerial decision-making related to traceability and sustainability across the broader supply chain domain. Its findings may also inform policymakers in crafting strategies for the accelerated adoption of blockchain technology, promoting food safety and a more sustainable global agri-product supply chain.

This study not only makes a significant theoretical contribution but also provides practical guidance for improving supply chain sustainability in the global market. By expanding current knowledge on blockchain adoption in the agri-products supply chain, the research introduces a comprehensive model that supports traceability and sustainability. This model can be a valuable tool for supply chain managers seeking greater transparency and visibility of information across the supply chain. It highlights how blockchain-based traceability can lower transaction costs by reducing reliance on intermediaries and promoting ethical sourcing and responsible procurement. These practices help prevent fraud and reduce opportunistic behaviours, benefiting both agri-food and broader supply chain management.

The study also encourages supply chain managers to adopt blockchain-enabled traceability over traditional methods to achieve social, economic, and environmental sustainability. Moreover, its findings can guide policymakers in formulating strategies to accelerate blockchain implementation, thereby supporting food safety and a more sustainable global agri-product supply chain. Additionally, the study supports managerial decision-making related to traceability and sustainability across the broader supply chain domain. Its findings may also inform policymakers in crafting strategies for the accelerated adoption of blockchain technology, promoting food safety and a more sustainable global agri-product supply chain.

1.3.4 Thesis organisation

This thesis is structured into seven interconnected chapters. Figure 1.1 illustrates the organisation of the thesis according to these chapters. Brief details of each chapter are provided below:

- **Chapter 1: Introduction** – This chapter outlines the study, highlighting key themes related to the broader research topic. It provides background information, explains the study's rationale, and introduces its scope and primary objectives. Additionally, it presents the research questions, objectives, contributions, and structure of the thesis.

- **Chapter 2: Review of Literature and Theoretical Framework** –An intensive review of literature on blockchain adoption (BCAD) drivers and supply chain traceability for sustainability is provided in this chapter. It further explores BCAD applications in supply chain management, with a specific focus on Agri-product supply chains. In particular, this section introduces the theoretical foundations of the study, including the justification for applying the dynamic capability view (DCV), transaction cost theory (TCT), and institutional theory (TI).

- **Chapter 3: Hypothesis Development for the Study**: This Chapter includes details the hypothesis development and relationships between the study constructs.

- **Chapter 4: Research Methodology** – This chapter focuses on selecting an appropriate research methodology and outlines the methods employed in the study. It justifies the research approach, covering aspects such as research paradigm, level and unit of analysis, sample selection, survey instrument, and data collection process. The principles of data analysis are also detailed.

- **Chapter 5: Quantitative Analysis of Data** –The analysis of survey data related to blockchain adoption for Agri-product supply chain traceability and sustainability in this chapter. A total of 294 valid responses were collected to examine the proposed research model. Smart PLS-SEM techniques were applied for data analysis.

- **Chapter 6: Discussion and Implications** – This chapter interprets the findings based on PLS results, aligning them with the study's research objectives. It discusses the dimensions of BCAD for traceability and sustainability and evaluates the hypothesised relationships among the study constructs. Theoretical and practical implications of the findings are also explored.

- **Chapter 7: Conclusion, Limitations, and Future Research Directions** – The final chapter summarises the study's key findings and contributions, both theoretical and practical. It also highlights the study's limitations and proposes potential future research directions.

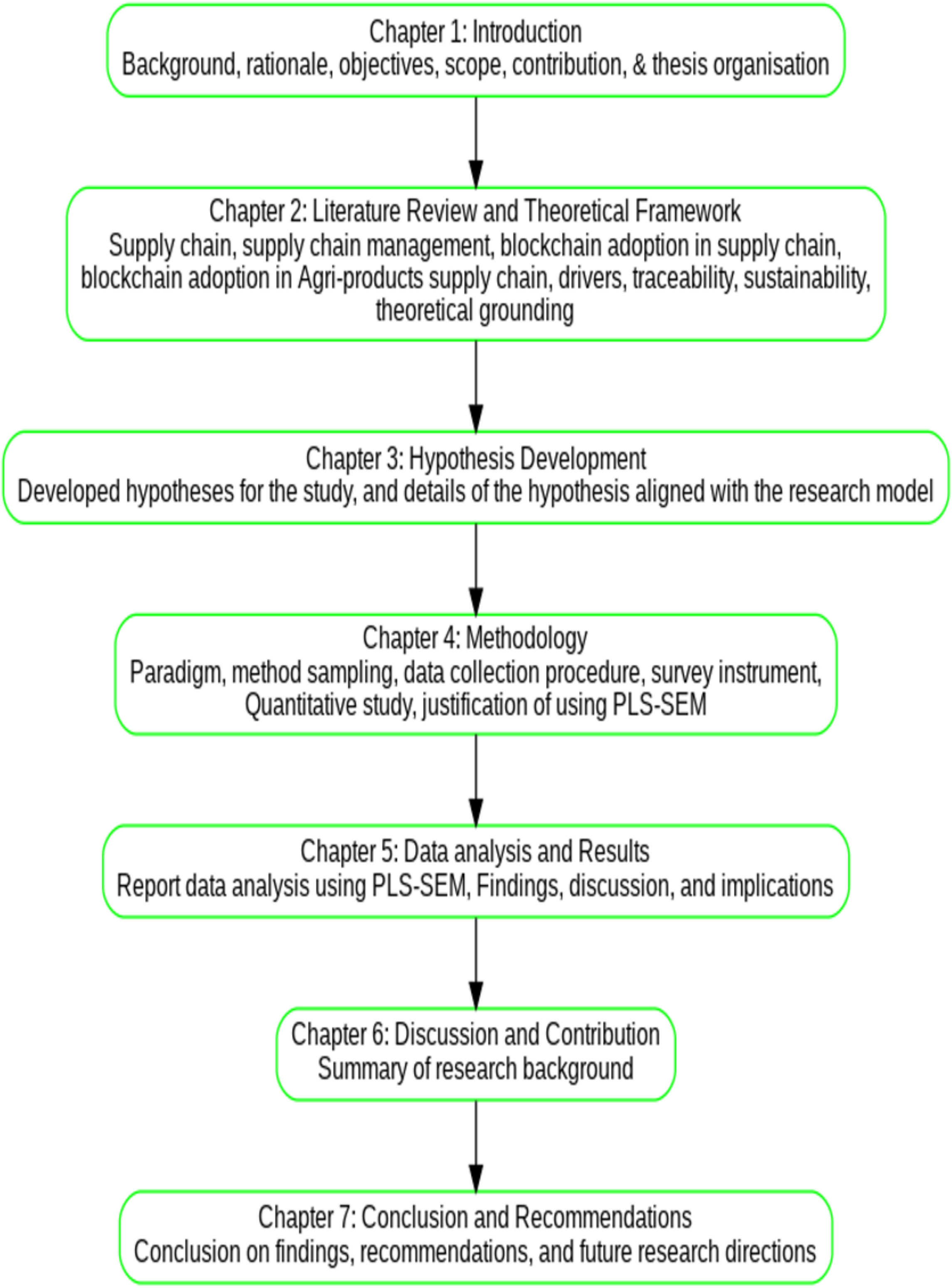

Figure 1.1 Thesis organisation

1.4 Summary:

The overview of the research is provided in this chapter and defines its scope. It highlights research problems, gaps in the existing literature and explains how they have been addressed in the study. Additionally, it reviews literature on blockchain adoption, supply chain traceability, and sustainability. The research questions and objectives are also outlined accordingly. It highlights the theoretical contributions and managerial significance of the study. Lastly, this chapter presents the thesis structure of the research.

CHAPTER 2:

2.1 LITERATURE REVIEW & THEORITICAL FRAMEWORK

2.2 Introduction

The previous chapter introduced the study. It outlined the underlying research background of this study. Chapter 2 critically reviews the literature on blockchain for supply chain traceability and sustainability in the Agri-products sector, and also outlines the theoretical framework of the study. The literature review outlines essential concepts such as the supply chain (SC), supply chain management (SCM), blockchain adoption (BCAD), BCAD in the supply chain, BCAD in the agri-food supply chain (AFSC), traceability, and sustainability. It also outlines the blockchain adoption drivers /constructs adopted for the study. Finally, it provides a model of the study followed by a theoretical framework of the study.

2.2.1 Supply chain (SC)

The ‘supply chain’ concept has been widely used since the 1990s. However, supply chains (SC) and their management, typically referred to as ‘supply chain management’ and the ‘supply chain’ concept, emerged in the field of management practitioners and academia in the 1980s (Harland, 1996). Many authors have defined the term, supply chain. According to Mentzer et al. (2001), a supply chain is a set of three or more entities, such as organisations or individuals, directly connected with upstream (i.e., supply) and downstream (i.e., distribution) flows of products, services, finances and information from source to the end customer. Christopher (2016) defined a supply chain as a network of organisations connected through upstream and downstream linkages, with different business processes and activities that produce products or services delivered to the ultimate customer. In addition, a SC consists of many partners, such as suppliers, manufacturers, wholesalers, distributors, retailers and customers. In particular, a supply chain is a network of multiple business connectivity and relationships. According to Lambert et al. (1998), a typical SC network of numerous businesses and relationships is represented in Figure 2.1. The diagram indicates how multiple supply chain partners work effectively and efficiently in a network (Lambert et al., 1998, p. 3). Furthermore, a supply chain is a key driver of business connectivity, connecting all business partners involved in the network.

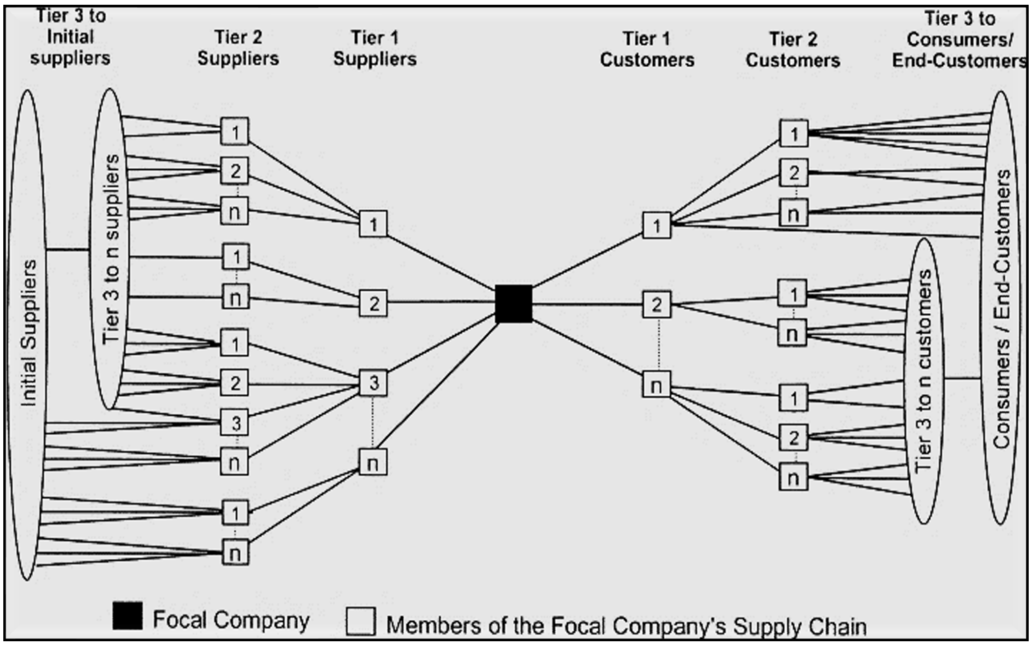

Figure 2.1 Supply chain network structure

Supply chain management (SCM)

SCM concept refers to managing business connectivity throughout the flow of products/processes and information from source to end customer (Lambert and Cooper, 2000). With the increasing popularity of the term SCM, there is considerable confusion about its appropriate definition in academia and practice (Mentzer et al., 2001). SCM is defined by Cooper et al. (1997) as "an integrative philosophy to manage the total flow of a distribution channel from supplier to the ultimate use." As for the operational terms consisting of the flow of materials and products, some argue that SCM is a management philosophy, while some claim that SCM is a type of management process (Lambert and Cooper, 2000, Cooper et al., 1997, Ho et al., 2002, Mentzer et al., 2001). In particular, SCM consists of three closely related elements. These elements are as follows:

i. The supply chain network structure (it consists of the member firms and the link between these firms),

ii. The supply chain business processes (purchasing, production, warehouse, sales and marketing, finance, research and development, human resource and information system) and

iii. The supply chain management components (the components by which business processes are managed, such as technologies).

Furthermore, SCM is the enabler of coordinating and integrating key business processes to provide goods and services that add value for customers and other stakeholders (Lambert et al., 1998). Fundamentally, the main focus of this coordination and integration among activities across the supply chain is to achieve a desired level of performance, thereby achieving a sustainable competitive advantage in the rapidly changing business environment (Gunasekaran et al., 2004; Lambert et al., 1998).

2.2.2 Blockchain adoption (BCAD)

Blockchain is an emerging technology based on cryptography, which uses unique codes to secure information within computer networks (Happy et al., 2021). It was introduced and popularised Nakamoto (2008) during the development of cryptocurrency (Bitcoin). Blockchain functions as a decentralised network of computer participants, known as "nodes," that are interconnected through a key access system. This interconnection enables direct peer-to-peer transactions without the need for intermediaries (Al-Jaroodi and Mohamed, 2019). A blockchain operates using a cryptographic hash function (Janssen et al., 2020, Tapscott and Tapscott, 2017), where each block is uniquely identified by a hash and is linked to the hash of the preceding block (Casado-Vara et al., 2018). This structure creates an immutable transactional ledger (Srivastava and Dashora, 2022). which serves as a record-keeping system in the form of a book or computer file (Letourneau and Whelan, 2017). Distributed ledger technology (DLT) is another name for a blockchain (Ramachandran and Rehermann, 2017).

The primary configuration of blockchain is structured around a distributed database, decentralised, immutable consensus mechanism, secured via cryptographic algorithms that control each block in the chain (Hughes et al., 2019). Thus, the characteristics of blockchains are that they are effectively a digital storage network; they contain independent data within each block. The key elements of blockchain are as follows (Drescher, 2020):

- **Immutable:** Recorded transactions in the blockchain platform cannot be altered.
- **Time-stamped:** All records are date and time-stamped, ensuring an audit trail for all additions to the network.
- **Append only:** Data can only be added to the blockchain in time-ordered sequential order.
- **Secure:** Secure algorithms govern all records to the blockchain using public-key encryption to reduce the risk of data corruption or fraud.
- **Open and transparent:** The nature of the blockchains' distributed ledger means that all network nodes share identical master records.

Blockchain offers an innovative, decentralised, distributed ledger that can record transactions from multiple entities across a network (Yiannas, 2018). Moreover, such records in a blockchain platform cannot be altered retroactively without the consensus of the whole network. In particular, blockchain executes its operations with a stack of technologies, including the internet as infrastructure, various applications such as smart contracts (Treiblmaier, 2018), Internet of Things (IoT) or industrial internet, and artificial intelligence (AI), among others (Cole et al., 2019). In particular, a smart contract is a software application that stores rules ('if this happens, then that occurs') to negotiate the terms of agreements between peer-to-peer arrangements, and smart contracts automatically verify the contract and execute the agreed terms on the blockchain platform (Hughes et al., 2019). Furthermore, IoT is an emerging new technology paradigm (Makhdoom et al., 2019) that incorporates the following five technologies (Qian, 2018): Radio Frequency Identification (RFID), Wireless Sensor Networks (WSN), Middleware, Cloud Computing, and IoT application software (Liao and Wang, 2018, Makhdoom et al., 2019).

Organisations tend to adopt blockchain for many reasons. First, blockchain adoption offers potential benefits to the organisation to achieve a competitive advantage in the rapidly changing business environment (Fosso et al., 2020, Kouhizadeh et al., 2019). For example, blockchain adoption in the organisation improves operational efficiency, enhances financial benefits, and improves performance in supply chains (Kshetri, 2018, Min, 2019). Meanwhile, organisations adopt blockchain technology in their business practices to achieve strategic goals (Wamba and Queiroz, 2020a).

Experts anticipated that BCT would shift how transactions are carried out in the AFSC by reducing the high number of intermediaries and transaction lead times throughout the SC (Kamble et al., 2020b). Therefore, blockchain adoption in the AFSC is essential for seizing and transforming opportunities in the rapidly changing technological environment (Teece et al., 1997, Teece, 2018, Kamble et al., 2020a). Furthermore, traceability is the most significant enabler for BCT implementation in AFSC, followed by suitability, immutability, and provenance (Kamble et al., 2020b, Casino et al., 2020b).

In the blockchain platform, smart contracts software automates complex multi-step processes per the contract's terms of organisations, ensuring transparent, secure, and traceable operational performance (Aung and Chang, 2014). Thus, organisations save time and reduce costs using automated processes in supply chain transactions, enhancing supply chain traceability and sustainability (Gatteschi et al., 2018, Garcia-Torres et al., 2019, Hastig et al., 2020). Furthermore, blockchain-enabled record-keeping ensures organisational transparency and treatability capability in internal and external transaction processes (Tian, 2016b). Therefore, blockchain adoption potentially influences supply chain activities to rapidly change through innovativeness (Kamble, 2018).

2.2.3 Blockchain adoption in supply chain

Blockchain adoption has received increasing attention in supply chain activities in recent times. For example, Wamba et al. (2020a) empirically examined the potential influence of blockchain on supply chain performance. They demonstrated fundamental insight into the dynamics of blockchain adoption determinates for supply chain performance (Wamba et al., 2020a). Blockchain adoption in the supply chain is expected to enhance traceability (Garcia-Torres et al., 2019, Hastig et al., 2020), transparency (Bai and Sarkis, 2020, Kshetri, 2018), trust (Kamble et al., 2019, Howson, 2020), and sustainability (Garcia-Torres et al., 2019, Kouhizadeh et al., 2019, Mahyuni et al., 2020). It is also expected to enable disintermediation (Saberi et al., 2019b). Influenced by the potential of adoption, practitioners and academic scholars seek to exploit and assess these potentials in supply chain practices (Kamble et al., 2020b, Queiroz et al., 2019a). However, experts predict that the widespread implementation of BCT will take a long time (Hughes et al., 2019, Di Vaio and Varriale, 2020). Hence, there is increasing interest in exploring the potential impact of adoption on supply chain practices, as demonstrated by numerous research agendas and recommendations for further research (Dolgui et al., 2020, Queiroz and Wamba, 2019).

Blockchain technology has gained increasing attention for its potential to revolutionise agri-food supply chains by enhancing transparency, traceability, and accountability. Tian (2016b) highlights that blockchain can significantly improve food safety by reducing information asymmetry and combating fraud throughout the supply chain. By creating a secure, immutable ledger, blockchain enhances trust among stakeholders, particularly in contexts where traceability is vital for quality assurance. Moreover, Francisco and Swanson (2018) propose a blockchain adoption framework specifically for agri-food systems, stressing the importance of institutional trust, regulatory clarity, and infrastructure readiness. Their work contributes to operationalising blockchain integration, though empirical validation in diverse agricultural contexts remains scarce.

A combination of technological, organisational, and environmental factors influences the adoption of blockchain in agri-food supply chains. Kamilaris et al. (2019) utilise the Technology-Organisation-Environment (TOE) framework to categorise these determinants, offering a structured lens through which blockchain adoption decisions can be assessed. This framework is useful in capturing the multi-dimensional nature of innovation adoption, but may require further contextualisation for the unique dynamics of smallholder-dominated agricultural systems.

Sustainability is another critical dimension in blockchain applications. Behnke and Janssen (2020a) argue that blockchain contributes to sustainable supply chains by reducing food loss, optimising logistics, and promoting ethically sourced products. However, while these claims are compelling, the literature often overlooks the resource intensity of blockchain infrastructure and its potential environmental impact, particularly in terms of energy consumption associated with certain consensus mechanisms.

In the context of developing nations, (Rejeb et al., 2020) examine both opportunities and challenges in blockchain deployment for agricultural use cases such as land tenure systems, direct farmer payments, and crop insurance. Their review underscores the transformative potential of blockchain for rural development, yet practical implementation remains limited due to infrastructural gaps, digital illiteracy, and lack of policy support. Casino et al. (2020a) extend the discussion by focusing on smart contracts, self-executing agreements embedded in blockchain systems, that can facilitate secure, automated transactions between farmers, processors, and retailers. This promises efficiency gains and cost reduction, but real-world application is still hindered by legal uncertainties and interoperability issues among different blockchain platforms.

While the existing literature presents a largely optimistic view of blockchain's potential in the agri-food sector, critical gaps remain. Many studies are conceptual or theoretical, lacking longitudinal empirical evidence of large-scale implementation. There is also an underrepresentation of research focusing on marginalised stakeholders, such as smallholder farmers, and on the socio-political implications of digitising agricultural transactions. Furthermore, issues such as data privacy, standardisation, and the environmental costs of blockchain remain underexplored. Future research should adopt an interdisciplinary, systems-level approach to evaluate not just the technical viability, but also the socio-economic equity and ecological sustainability of blockchain-based agri-food supply chains.

Given the potential of emerging blockchain technology adoption, it is receiving attention across diverse areas of SCM (Casino et al., 2019, Fosso et al., 2020, Kshetri, 2018, Kummer et al., 2020, Saberi et al., 2019a, Pournader et al., 2019, Shen and Pena-Mora, 2018, Wang et al., 2019b, Chang et al., 2019, Zhao et al., 2019). While SCM is the enabler for coordinating and integrating key business processes that add value to customers and other stakeholders (Lambert and Cooper, 2000), the main focus of SC integrations among the value-creation activities (source, make, and deliver) is to achieve the desired performance in SCs (Cooper et al., 1997, Gunasekaran and Kobu, 2007). Thus, this can sustain a competitive advantage in the changing business environment. From this end, blockchain capability can facilitate the integration of value-creation activity, enhance SCs transparency and traceability, and provide opportunities to achieve sustainable competitive advantage (Tian, 2016b, Yiannas, 2018, Wamba et al., 2020c). However, blockchain applications are in their infancy in SC practices (Kamble et al., 2020c). It is only the first step of a very long journey. The next-generation blockchain is expected to address many problems in the supply chain, including typical contracts of sale and security and loan arrangements or lease applications (Kamble et al., 2023).

Experts anticipate that a substantial change will occur across the supply chain globally due to the disruptive transformation of blockchain technology (Gatteschi et al., 2018). Furthermore, such transformation effects are expected to disrupt how supply chain processes are currently managed (Nowiński and Kozma, 2017) and profoundly impact the nature of value-creation activities in supply chains (Tapscott and Tapscott, 2017, Chang et al., 2020).

Blockchain is an immutable distributed ledger that enables more efficient and transparent transactions and reduces transaction costs in supply chain activities (Schmidt and Wagner, 2019). The nexus of blockchain provides opportunities for creating trust between all parties, with fewer or without intermediaries and associated costs. The intermediary costs and lack of trust always remain debated in traditional transaction processes across the supply chain (Chase Jr, 2016). However, the breakthrough of blockchain capability is advancing the paper ledger to the trusted electronic ledger. The electronic ledger allows buyers and sellers to communicate directly without the involvement of intermediaries. Consequently, supply chain actors can save intermediary costs in the transaction process (Schmidt and Wagner, 2019).

Blockchain ensures transparency between buyer and seller and provides higher security for real-time tracking of shipments. Many organisations, including Bosch, IBM, Microsoft, Samsung, Toyota and Visa, embraced the technological advancement of blockchain and developed and implemented new applications underpinned by this technology. For example, the Commonwealth Bank of Australia, Wells Fargo and Brighann Cotton successfully applied blockchain technology in a first trade transaction between two independent banks (Ramachandran and Rehermann, 2017). They used a combination of the IoT and smart contract applications on a blockchain platform to make this operation successful. As a result, they achieved a blockchain-enabled, cost-efficient, transparent, error and risk-free transaction process despite it occurring in a complex supply chain network (Ramachandran and Rehermann, 2017).

Furthermore, researchers investigate blockchain-related topics in logistics and SCM and argue that organisational theories provide a bridge for academic research in BCT application in the logistics and SCM context (Kummer et al., 2020). However, Kummer et al. (2020) also argue that many blockchain studies in SCM address various topics, but most papers lack theoretical foundations. Therefore, there is a need for research on blockchain in SCM to bridge the connection with established organisational theories to minimise such gaps (See Appendix 1 and 2).

Evidence shows that technologies like bitcoin, blockchain and fintech are evolving, and organisations embrace them to combat competitive challenges in their SC practices (Fosso et al., 2020). Helo and Hao (2019) reviewed BCT and outlined potential applications for immutable distributed ledgers in operations and SCM. Saberi et al. (2019b) explored BCT's main adoption barriers in achieving sustainable SCM goals. Casino et al. (2019) investigated a comprehensive classification of BCT applications across diverse sectors such as supply chain, business, healthcare, IoT, privacy, and data management. Min (2019) reviewed the BCT application that minimises risk and improves security in the SC. Queiroz et al. (2019a) analysed blockchain and SCM integration and indicated the significant disruptions and challenges in SCM due to blockchain adoption. Kshetri (2018) examined blockchain applications in SCM to achieve strategic SC objectives (cost, quality, speed, dependability, risk reduction, sustainability, and flexibility). However, the studies are primarily fragmented and partially focus on specific areas of the SC, such as applications in SCs, sustainable SCs, SC resilience, performance, and impact. In addition, using content analysis, Srivastava and Dashora (2022) explored the adoption of blockchain technology, the challenges, and the benefits to agri-food supply chain management. Deploying dynamic capability theory, Kamble et al. (2023)

demonstrated the relationship between blockchain technology adoption, supply chain integration, and sustainable supply chain performance using structural equation modelling in the context of the automotive industry. However, no empirical studies have examined blockchain adoption drivers for supply chain traceability and sustainability in the context of Agri-products. Though the literature on blockchain in SCs is emerging over time, the empirical research is relatively limited, and recommendations for further research are increasingly high (Hughes et al., 2019). This study attempts to minimise such limitations in SCM research by addressing the gaps in the literature. An overview of recently published literature on BCAD in the SC is given in Table 2. 1.

Table 2.1 Key findings of previous literature on blockchain in SC

TITLE	AUTHOR	KEY FINDINGS
Blockchain technology’s impact on supply chain integration and sustainable supply chain performance: Evidence from the automotive industry	Kamble et al. (2023)	The finding highlights that blockchain technologies, while valuable, act more as an enabler than a standalone driver of sustainable supply chain performance. The necessity of full mediation through supply chain integration implies that technology must be coupled with cohesive collaboration, process alignment, and information sharing to achieve sustainability goals. This underscores the strategic importance of integrating digital innovation with broader organisational and inter-organisational practices to unlock its full potential.
Application of blockchain technology for agrifood supply chain management: A systematic literature review on benefits and challenges	Srivastava and Dashora (2022)	The study indicates that blockchain technology promises transformative benefits in the agrifood sector, the gap between its theoretical potential and practical application exposes a significant risk of underperformance. Organizations implementing the technology without sufficient technical expertise may risk misalignment with operational requirements, potentially resulting in inefficiencies or the inability to achieve the intended objectives. This emphasises the need for capacity building, stakeholder education, and phased implementation to ensure blockchain’s benefits are fully realised.
Designing a blockchain-enabled supply chain	Wang et al. (2021)	This study suggests that incorporating a business model perspective provides an important strategic dimension to blockchain adoption. However, the research would be strengthened by a more comprehensive examination of the socio-technical challenges and implementation resistance, which constitute crucial determinants of the scalability of blockchain-enabled supply chains.
A Systematic Review of Blockchain Literature in Logistics and Supply Chain Management: Identifying Research Questions and Future Directions	Kummer et al. (2020)	The paper appropriately emphasises the insufficient theoretical grounding in blockchain-oriented logistics and supply chain management (LSCM) research. However, it overlooks the opportunity to critically examine the underlying reasons for the limited application of organisational theories and to identify the specific theoretical gaps that warrant immediate scholarly attention.

Dynamics between blockchain adoption determinants and supply chain performance: An empirical investigation	Wamba et al. (2020a)	Although the study successfully identifies key enablers of blockchain adoption and links them to improved supply chain performance, its reliance on survey data may limit the depth of contextual insights, particularly in understanding the complexities of implementation across diverse organisational environments.
Bitcoin, blockchain and fintech: a systematic review and case studies in the supply chain	Fosso et al. (2020)	The paper provides a meaningful historical synthesis of Bitcoin, Blockchain, and Fintech research between 2007 and 2017, contributing to an understanding of the field's early scholarly development. However, its retrospective scope reduces applicability to the present technological landscape, where accelerated innovation and evolving regulatory, economic, and technical conditions have likely transformed patterns of adoption.
When Blockchain Meets Supply Chain: A Systematic Literature Review on Current Development and Potential Applications	Chang and Chen (2020)	The recognition of critical issues such as traceability, integration, and stakeholder collaboration provides valuable insights into blockchain-enabled supply chain research. Nevertheless, the study would be enhanced by a critical analysis of how these challenges differ across industries and the contextual determinants that shape effective adoption outcomes.
Blockchain applications in supply chains, transport and logistics: a systematic review of the literature	Pournader et al. (2019)	The presentation of four thematic clusters—Technology, Trust, Trade, and Traceability/Transparency—provides a structured framework for examining blockchain research within supply chains. However, the paper would be strengthened by a more critical evaluation of how these themes intersect or generate tensions in practical implementation contexts.
Blockchains in operations and supply chains: A model and reference implementation	Helo and Hao (2019)	The study effectively demonstrates a reference implementation of a blockchain-based logistics monitoring system (BLMS), highlighting its potential application in supply chain contexts. Nonetheless, it falls short of providing a critical assessment of practical limitations, including scalability challenges, interoperability with established logistics infrastructures, and the financial implications of deploying platforms such as Ethereum.

Blockchain technology and its relationships to sustainable supply chain management	Saberi et al. (2019)	The categorisation of adoption barriers into four distinct groups offers a valuable conceptual framework for analysing blockchain implementation challenges. However, the paper would be enhanced by empirical validation or case-based inquiry to evaluate the relative significance of each barrier and to identify the strategies organisations have effectively employed to overcome them.
Blockchain technology for enhancing supply chain resilience	Min (2019)	The article depicts blockchain as a transformative tool for lowering intermediary-related risks, thus emphasising its disruptive potential in supply chain contexts. However, it presents an overly simplified portrayal of the technology by ignoring key emerging challenges, including regulatory uncertainty, energy inefficiency, and security flaws inherent in smart contract execution.
A systematic literature review of blockchain-based applications: current status, classification and open issues.	Casino et al. (2019)	While the review effectively highlights the cross-sectoral constraints of blockchain technology, its analysis would benefit from deeper critical examination. Specifically, it should distinguish whether these constraints arise intrinsically from the technology or are influenced by contextual factors, including regulatory environments, infrastructure maturity, and organisational resistance.
Blockchain and supply chain management integration: A systematic review of the literature	Queiroz et al. (2019a)	Although the paper advances the foundational understanding of blockchain and supply chain management integration, its dependence on a limited sample of 27 articles over ten years may restrict the breadth and generalisability of the findings. This limitation is particularly significant given the rapid evolution of blockchain technology.
Understanding blockchain technology for future supply chains: a systematic literature review and research agenda	Wang et al. (2019a)	The study acknowledges trust as a pivotal factor influencing blockchain adoption; however, it could benefit from a more rigorous examination of how trust is cultivated or compromised within decentralised systems. This consideration is particularly important in settings where stakeholders exhibit disparities in technological proficiency, regulatory engagement, or data governance standards

Blockchain technology in agri-food value chain management: A synthesis of applications, challenges and future research directions	Zhao et al. (2019)	The paper effectively underscores blockchain's capacity to improve traceability and transparency within agri-food value chains; however, it could further explore how socio-economic factors, such as smallholder digital exclusion or regional regulatory variations, might impede equitable adoption. Such an analysis would provide a more nuanced understanding of the technology's practical impact.
Blockchain's roles in meeting key supply chain management objectives.	Kshetri (2018)	The paper argues for blockchain's potential to advance critical supply chain objectives; however, its analysis could be enhanced by critically evaluating whether the benefits reported in early-stage case studies are scalable or transferable across diverse industries and operational contexts. Such an assessment would provide greater insight into the technology's broader applicability and limitations.
Blockchain for Cities - A Systematic Literature Review	Shen and Pena-Mora (2018)	The paper offers a thorough classification of blockchain applications for smart cities; however, it could benefit from a more critical evaluation of whether these proposed use cases genuinely tackle systemic urban challenges. This is particularly relevant in determining if the initiatives respond to real urban governance needs or primarily represent a technology-driven agenda.

The inherent complexity of the SCs involved a vast number of partners and many individual activities across the supply chain processes. In addition, SC also engaged in a series of related activities that include coordinating, planning, and controlling products and services from the source to the end customer (Kamble et al., 2020a). Such complexity and related activities (coordinating, planning, and controlling) lead to a lack of visibility and transparency in shipping or transporting goods in the supply chain. Therefore, traceability opportunities are minimal due to a lack of visibility and transparency in the current supply chain architecture (Kshetri, 2018). There is no exception for the AFSC, as it involves similar complexity and lack of traceability throughout the value chain (Prashar et al., 2020). The following are the identified gaps in the literature related to blockchain in the supply chain.

Gaps relating to BCT adoption in SC:

Gap 1: Though the literature on BCT adoption in SCs is emerging over time, the empirical research is relatively limited, and recommendations for further research are increasingly high (Hughes et al., 2019).

Gap 2: Many studies of blockchain in SCM have addressed a range of topics, but most papers lack theoretical foundations (Kummer et al., 2020).

Gap 3: The opportunity for traceability is minimal due to a lack of visibility and transparency in complex agri-food supply chains (Prashar et al., 2020).

2.2.4 Blockchain adoption in agri-food SC

The adoption of blockchain in the agri-food supply chain is regarded as a new benchmark for quality in the food industry (Casino et al., 2020b). Feng et al. (2020b) suggested that the agri-food supply chain must improve traceability and sustainability to ensure food quality and safety for consumers. Numerous food quality and safety issues have been reported globally in recent years. For instance, Europe is currently facing a meat adulteration scandal that raises concerns about food safety (Boyacı et al., 2014). Additionally, horsemeat has been used as a cheaper alternative to beef (Boyacı et al., 2014). In China, food safety scandals are more frequent and lead to serious issues (Tian, 2016b).

Similarly, ‘‘needle in Strawberry’’ made the headlines in Australia, and the needle scare spread nationwide (Howells, 2018). The impact of food quality and safety scandals slows the economy. It endangers health and safety. Blockchain adoption may help improve transparency and traceability to ensure quality and safety in the AFSC (MLA, 2018).

Although blockchain technology is still in its infancy, experts predict it will play an essential role in the agri-food supply chain in improving traceability (Tian, 2016a). Researchers indicate the adoption of blockchain in many areas of Agri-food supply chain practices. For example, Casado-Vara et al. (2018) argued that blockchain adoption is necessary for product traceability in the agricultural supply chain and demonstrated a circular economy model. Zhao et al. (2019) suggested that blockchain-based IoT technologies have been adopted to improve Agri-food value chain management by highlighting four main aspects: traceability, information security, manufacturing, and sustainable water management. In contrast, existing studies indicate a lack of traceability mechanisms, thus limiting supply chain sustainability in the AFSC (Prashar et al., 2020, Salah et al., 2019). Therefore, more research is needed from theoretical and empirical perspectives to check the effects of blockchain technology on Agri-food value chain management (Zhao et al., 2019). For example, the adoption of blockchain is relatively new in the Australian beef supply chain. Limited research is identified in this context, and its potential for value creation remains unclaimed (Kamble et al., 2019, Zhao et al., 2019). Nonetheless, the application of blockchain technology influences the supply chain to change rapidly, which is a unique innovation path. The possible adoption of blockchain has not yet been fully explored, as it is still in the innovation-triggered stage (Gatteschi et al., 2018).

Despite being at an early stage of development, blockchain is increasingly recognised as a transformative tool for enhancing traceability in agri-food supply chains. Recent studies demonstrate that blockchain adoption has expanded across various supply chain practices, supporting transparency, information integrity, and sustainability (Dey and Shekhawat, 2021, Bosona and Gebresenbet, 2023). For instance, research highlights that blockchain, when integrated with IoT, strengthens food value chain management by enabling secure data exchange, real-time monitoring, and sustainable resource utilisation (Yogarajan et al., 2023, Pakseresht et al., 2024). However, existing evidence points to persistent challenges, particularly the absence of robust traceability mechanisms in many agri-food contexts, which undermines supply chain resilience and sustainability (Pandey et al., 2022, Apeh and Nwulu, 2025). Scholars also emphasise that more empirical research is required to evaluate blockchain's tangible effects on supply chain efficiency and value creation (Chiaraluce et al., 2024). For example, studies in sectors such as the Australian beef industry indicate that blockchain remains underutilised, with limited deployment beyond pilot projects (Casati et al., 2024). Overall, blockchain adoption is still in its innovation-triggered phase but has the potential to drive a unique transformation path for agri-food supply chains (Vern et al., 2025).

Australia is the third-largest exporter of beef and one of the most efficient cattle producers in the world (Jie et al., 2016b, Casino et al., 2020b). According to the Australian Bureau of Statistics (ABS), the value of the red meat industry is around A$7.7 billion (ABS, 2014). However, due to food quality and safety issues and competitive pressure from technological change, globalisation, and the impact of the pandemic, Australia's red meat supply chain is rapidly changing (Jie et al., 2016a, Ding et al., 2014). In such an environment, adopting blockchain could dramatically influence the traceability and sustainability of Australia's beef supply chain.

Evidence shows that research has discussed various advantages of applying blockchain technology for multiple industries in the supply chain. However, relatively limited studies investigate blockchain adoption drivers on supply chain traceability and sustainability in agri-products supply chain management (Casino et al., 2020b). Furthermore, no study empirically investigates blockchain adoption drivers for supply chain traceability and sustainability, specifically in the context of the Agri-products supply chain (see Appendix 1). Therefore, this study will empirically examine blockchain adoption drivers (Business Environmental Drivers) for supply chain traceability and sustainability, specifically in the Agri-products context. This study is expected to analyse focal farms (Agri-products producer, processor, transporter, wholesaler, and retailer) through dynamic capability theory and transaction cost theory.

Existing literature reviews provide a thorough analysis of blockchain from various viewpoints (Aung and Chang, 2014, Chang et al., 2018, Choi, 2019b). These reviews have laid the foundation for applying blockchain across various industries of the supply chain (Hofmann and Rüsch, 2017, Manski, 2017, Kshetri, 2017). Several studies examine factors such as drivers, barriers, outcomes, and benefits (Gurtu and Johny, 2019a, Hughes et al., 2019). However, limited research empirically explores blockchain adoption drivers regarding the Agri-food supply chain (Aung and Chang, 2014, Salah et al., 2019, Behnke and Janssen, 2019). There is a lack of empirical studies focusing on the drivers of blockchain adoption for supply chain traceability and sustainability, particularly within the global Agri-products supply chain context. Therefore, this research makes a valuable contribution to the existing literature.

Gaps relating to BCT adoption in AFSC:

Gap 4: Limited empirical study exists on blockchain adoption in agri-food supply chain management (Aung and Chang, 2014, Salah et al., 2019, Behnke and Janssen, 2019).

Gap 5: Studies have indicated relatively limited traceability mechanisms in agri-food operations management and recommended further research (Casado-Vara et al., 2018).

Gap 6: Although the application of blockchain technology in the agri-food value chain is still in its infancy, it can be expected that various agri-food organisations will take more initiatives. Therefore, more research from theory and empirical perspectives needs to check the effects of blockchain technology on the agri-food value chain, mainly to study its impact on the international agri-food trade and formulate corresponding standards based on the research results (Zhao et al., 2019).

Gap 7: Evidence shows that research has discussed various advantages of applying blockchain technology for multiple industries in the supply chain (Caldarelli et al., 2021). However, relatively limited studies investigate blockchain adoption drivers for supply chain traceability and sustainability for agri-food supply chain management (Casino et al., 2020b).

Gap 8: Since the adoption of blockchain is relatively new in the Agri-products industry, there is limited research identified in this context, and most of its potential for value creation remains unclaimed (Büyüközkan and Göçer, 2018, Zhao et al., 2019).

Gap 9: Lack of empirical study examines blockchain adoption drivers for supply chain traceability and sustainability, specifically for the Agri-products context.

Although blockchain technology has been increasingly explored for improving traceability, transparency, and sustainability in agri-food supply chains, most studies remain at a conceptual or pilot stage. Recent research highlights persistent limitations: (i) a scarcity of **empirical evidence** on blockchain adoption across diverse agri-product contexts; (ii) underdeveloped **traceability mechanisms** that restrict sustainable operations; (iii) limited assessment of blockchain's role in **international agri-food trade** and the absence of harmonized standards; and (iv) insufficient investigation into the **drivers and barriers** influencing adoption for supply chain traceability and sustainability. Consequently, the **value creation potential** of blockchain in the agri-product industry remains largely untested, particularly regarding measurable impacts on performance, competitiveness, and compliance in global agri-food networks (Dey and Shekhawat, 2021, Chiaraluce et al., 2024, Terrizzi et al., 2024, Apeh and Nwulu, 2025).

2.3 Blockchain adoption drivers in the supply chain

Based on an extensive review of the literature, this study examines the key factors driving blockchain adoption, with a particular emphasis on business environmental influences that impact supply chain traceability and sustainability: considering the mediating role of *traceability*, the moderating role of *technology orientation, upper management support* and *sustainability governance* for the Agri-product supply chain context. The following section provides a snapshot of various drivers (technological drivers, organisational drivers, and social drivers) identified from the previous management literature. It specifically provides (in section 2.1.7.5) how business environmental drivers influence blockchain adoption in the supply chain, including associated measurement items used for this study.

2.3.1 Technological drivers

Technological drivers encompass both the internal and external technologies utilised by an organisation, as well as those technologies that are available and accessible in the current market (Baker, 2012). Technology readiness, relative advantage, compatibility, and trialability remain important measurement items of technological drivers. According to Oliveira et al. (2014), the technological readiness of organisations refers to the technological capabilities available for adopting new technology, including both structural aspects and specialised human resources. Relative advantage refers to "the degree to which an innovation is perceived as being better than the idea it supersedes" (Rogers, 2003, p. 229). Rogers et al. (2014) further noted that relative advantage is linked to the extent to which an innovation is seen as offering significant organisational benefits compared to the concept it replaces. Thus, relative advantage represents the perceived superiority of an innovation over existing practices (Venkatesh et al., 2003). Compatibility (COM) refers to "the degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters" (Rogers, 2003, p. 240). Compatibility reflects the alignment of an innovation with adopters' requirements, values, and prior experiences (Rogers et al., 2014). Trialability (TRI) refers to "the degree to which an innovation may be experimented with on a limited basis" (Rogers, 2003, p. 258), enabling organisations to test innovation in a controlled way before commitment, which serves as risk reduction and promotes "learning-by-doing" (Dobrovnik et al., 2018). More recent studies reinforce these constructs in the context of blockchain adoption in agri-food supply chains, highlighting that technology readiness and compatibility strongly influence adoption intentions, while trialability and perceived relative advantage enhance trust, traceability, and sustainability outcomes (Casino et al., 2020a, Apeh and Nwulu, 2025, Chiaraluce et al., 2024, Pandey et al., 2022, Terrizzi et al., 2024).

2.3.2 Organisational drivers

Organisational drivers encompass the existing internal resources and opportunities that facilitate technology adoption within organisations. As a result, they play a crucial role in the adoption of new technologies. Key factors for measuring organisational drivers include top management support, organisational readiness, and technological expertise.

Top Management Support (TMS) is the supreme authority comprising the board of directors responsible for formulating the mission and vision of the organisation (Nayak and Dhaigude, 2019). Top Management Support plays a strategic role in the adoption of new technology by organisations. Top management members are in a strategic decision-making role and are primarily responsible for designing and implementing the sustainability culture in the organisation to embrace change. Organisational readiness (OR) refers to the capability to adopt blockchain technology in the rapidly changing business environment. Overall organisational readiness includes know-how, capability to assess suitability/context of an application, skills shortage, knowledge gap, ability to engage others, capability doubt, adaptive organisational capability, expert knowledge requirement, familiarity, education, and leveraging existing company resources (Hastig et al., 2020). Technological knowledge refers to the readiness of technology and technical expertise relating to new technology, existing technology, and IT infrastructure to support blockchain technology adoption. The capability enables firms to obtain and effectively harness internal and external knowledge to adopt blockchain technology.

2.3.3 Individual drivers

Individual drivers relate to the influence of stakeholders on organisations in adopting new technology to fulfil their requirements in a dynamic business environment. Key factors for assessing individual drivers include technology awareness, a tendency for innovation, and anticipated benefits. Awareness of technology refers to new technology, and understanding its potential in the competitive business environment may encourage organisations to adopt blockchain. The possibility of blockchain capability ensures that organisations achieve a competitive advantage. To this end, awareness of technology plays an essential role in deciding on the adoption of new technology in the competitive business environment. Technological novelty seeking refers to concisely comparing a technology with existing technologies to identify the uniqueness in the changing technological business environment. Consumers may seek uniqueness or, relatively, the novelty of the technology, enabling new categories of blockchain over existing technologies (Verhoeven et al., 2018). Expectation refers to the potential benefits of blockchain capability over existing technology that could encourage organisations to adopt new technology in the changing business environment. For example, the expectation of blockchain-based traceability is a significant example of providing a journey of products instead of a centralised traceability system.

2.3.4 Social drivers

Social drivers encompass the influence of societal factors on an organisation's decision to adopt new technologies to meet stakeholders' social expectations in a rapidly changing business environment. Key social drivers include cultural and social influences. Cultural influence relates to the beliefs, values, symbols, and assumptions that shape a company's operations within a specific cultural framework in a dynamic market. Social influence involves adherence to ethical standards and social responsibilities, particularly in blockchain adoption within evolving business environments. Social issues cover a broad spectrum, including child labour, rural poverty, fair trade, local economic development, living standards, resource rights, corporate social responsibility (CSR) accountability, human rights violations, conflict resources, circular economy initiatives, and exploitation in developing nations (Hastig and Sodhi, 2020). In this context, social influence significantly impacts the adoption of blockchain technology in supply chains amid shifting business conditions.

2.3.5 Business environmental drivers

Business environmental drivers refer to the internal and external forces that push organisations to embrace new technologies in response to a shifting marketplace to address business challenges. Schuetz and Venkatesh (2020) advocate that environmental drivers provide insight into how blockchain adoption can overcome business challenges like high monetary and time costs. Business environmental drivers such as government support refer to support for relevant actions for adopting new technology. This involves first providing applicable laws. It also includes offering incentives, mainly economic, and adopting IT infrastructure. Research indicates that government support and incentives significantly affect organisations' decisions to embrace technology (Mohtaramzadeh et al., 2018). In addition, stakeholder influence refers to stakeholders' pressure to adopt blockchain technology to improve traceability and transparency for sourcing information about products or processes. As a result, organisations adopt new technology to meet needs of stakeholders, trading partners', or other entities such as governmental and non-governmental organisations or consumers. To this end, in adopting new technology, stakeholders' influence plays a significant role in the changing business environment. Following Wong et al. (2020a), the business environmental drivers considered in this study consist of three distinct factors: market dynamics, competitive pressure, and regulatory support. The following focuses on and investigates each.

Market dynamics (MDY) refers to the forces and factors that influence the behaviour, structure, and performance of a market in a rapidly changing business environment (Wong et al., 2020a). These dynamics include supply and demand fluctuations, competitive forces, technological advancements, regulatory changes, customer preferences, and economic trends (Chatterjee et al., 2023, Wamba et al., 2020a, Wong et al., 2020a). Increasingly, **ESG (environmental, social, and governance)** considerations have also become part of market dynamics, as stakeholders, policymakers, and consumers demand greater transparency, sustainability, and ethical practices across industries (Dey and Shekhawat, 2021, Terrizzi et al., 2024). ESG-driven market expectations, such as carbon footprint reporting, responsible sourcing, and social accountability, are pushing organisations to adopt technologies like blockchain to provide verifiable data and meet compliance and stakeholder needs (Apeh and Nwulu, 2025, Chiaraluce et al., 2024). Market dynamics may therefore influence organisations of all sizes to adopt blockchain technology to remain competitive and aligned with evolving ESG and regulatory requirements (Chatterjee et al., 2023, Wamba et al., 2020a). In particular, large organisations are more sensitive to these dynamics due to higher visibility and stakeholder scrutiny, whereas small and medium enterprises sometimes face challenges in technology adoption to meet ESG and market demands across end-to-end supply chains (Imamura et al., 2013, Wamba et al., 2020a).

Competitive pressure (CPR) refers to the extent of influence a company faces from its industry rivals (Oliveira and Martins, 2010). It has been recognised as a key factor affecting the adoption of information technology (IT) (Kaur Kapoor et al., 2014). Organisations are often required to stay competitive and adapt to changes in uncertain and increasingly dynamic markets. In this context, the adoption of blockchain as a change initiative can generate strategic advantages by enhancing efficiency, transparency, and trust across supply chains (Wong et al., 2020a). More recently, competitive pressure has also been influenced by ESG (environmental, social and governance) factors, as stakeholders, regulators, and consumers demand greater accountability, sustainability, and ethical practices (Dey and Shekhawat, 2021, Terrizzi et al., 2024). ESG-driven competition encourages firms to differentiate themselves by demonstrating responsible sourcing, reducing carbon footprints, and ensuring traceability, where blockchain can play a crucial enabling role (Apeh and Nwulu, 2025, Yogarajan et al., 2023). As a result, competitive pressure now encompasses not only market and technological factors but also ESG-related expectations, which heighten the need for innovative solutions such as blockchain to sustain industry relevance and stakeholder trust.

Regulatory support (RGS) pertains to the role of regulatory bodies in shaping policies and laws that directly or indirectly influence blockchain adoption by organisations within a rapidly evolving business environment. This includes government initiatives aimed at enhancing safety and compliance by encouraging or mandating blockchain-based systems, such as policies requiring end-to-end traceability to improve product journey visibility across supply chains. Increasingly, regulatory attention is also being guided by

ESG considerations, as environmental, social, and governance pressures prompt organisations to demonstrate responsible sourcing, ethical practices, and sustainability performance (Dey and Shekhawat, 2021, Terrizzi et al., 2024). For instance, ESG-driven traceability requirements now go beyond food safety to encompass carbon footprint disclosures, labour practices, and responsible resource utilisation, aligning with regulatory frameworks such as the EU Digital Product Passport and guidelines for sustainable finance (Apeh and Nwulu, 2024, Visconti et al., 2022). Previous research indicates a relative scarcity of studies focusing on business environment drivers—such as competitive pressure, market dynamics, regulatory support, and ESG expectations—concerning blockchain adoption within the supply chain context (Wong et al., 2020a). As a result, this study aims to examine these environmental drivers where regulatory support plays a critical role. Accordingly, the research framework encompasses business environmental and ESG-oriented drivers as defined by (Wong et al., 2020a) and extended by recent studies (Chiaraluce et al., 2024).

2.3.5.1 Justification of the business environment drivers (BED):

Business Environment Drivers (BED) enable firms to sense external opportunities and threats by scanning the competitive landscape, regulatory shifts, technological advancements, and consumer demands that shape supply chain dynamics (Teece, 2007). Through environmental sensing, organisations can identify inefficiencies, risks, and emerging trends such as sustainability regulations or digital disruptions that demand strategic responses (Jolink and Niesten, 2015). Seizing occurs when firms capitalise on these sensed opportunities by mobilising resources toward innovative solutions, for example, adopting blockchain or green logistics to enhance supply chain transparency and resilience (Queiroz and Wamba, 2019). This capability allows managers to translate environmental insights into actionable strategies that reduce transaction costs, improve trust, and align with sustainability goals (Hastig and Sodhi, 2020, Saberi et al., 2019b). Transformation follows when organisations reconfigure existing processes and resource bases to adapt to environmental change, such as transitioning from linear to circular supply chain models or embedding digital traceability technologies (Kouhizadeh and Sarkis, 2018, Wong et al., 2020a). By transforming their operational structures, firms can better withstand volatility, manage risks, and capture long-term competitive advantage in uncertain markets (Teece, 2018). In the agri-food sector, for instance, BED drives blockchain-enabled traceability systems that ensure food safety, enhance compliance, and meet increasing consumer demand for ethical sourcing (Rejeb et al., 2019, Salah et al., 2019). Furthermore, BED helps organisations align internal dynamic capabilities with external stakeholder expectations, reinforcing both strategic flexibility and innovation capacity (Jabbour et al., 2020). This holistic interplay of sensing, seizing, and transforming resources in light of environmental drivers allows firms to achieve supply chain sustainability and resilience (Hastig and Sodhi, 2020). Therefore, BED functions as a catalyst for aligning dynamic capabilities with environmental opportunities and threats, enabling firms to thrive in rapidly evolving business ecosystems (Teece, 2007, Wamba and Queiroz, 2020b, Rejeb et al., 2019).

2.4 The impact of BC adoption in SC

The adoption of blockchain in supply chains has numerous impacts, such as potential improvements in transparency, efficiency, trust, and security, including traceability and sustainability (Aung and Chang, 2014, Garcia-Torres et al., 2019, Kouhizadeh and Sarkis, 2018, Treiblmaier, 2018). Previous studies have shown that, among the many impacts, blockchain adoption increased supply chain traceability and sustainability in many ways. For example, BC adoption in SC enhanced product tracking by allowing immutable, time-stamped record-keeping opportunities for every transaction or movement in the supply chain. This process ensures tracking of the origin of products from source to end customer and provides visibility at every transaction stage in the supply chain (Bai and Sarkis, 2020, Garcia-Torres et al., 2019).

Blockchain-based traceability also reduces fraud and counterfeiting in the supply chain process. As evident in the literature, BC has the potential to verify authenticity, prevent counterfeit goods and ensure product integrity. For example, the pharmaceuticals, luxury goods, and food industries can benefit from adopting blockchain in their supply chain (Saberi et al., 2019a, Wamba and Queiroz, 2020a). In addition, blockchain can potentially increase compliance and provenance opportunities for organisations, allowing them to show their environmental, labour, and regulatory standards, which is increasingly important for customers and governments (Kamble et al., 2021).

Based on the above, it is evident that decentralised traceability improves supply chain sustainability. Overall, blockchain has the potential to significantly enhance supply chains by providing traceability and sustainability. As the technology matures, these benefits are expected to increase, further transforming how businesses manage supply chains globally.

This research explores blockchain adoption in the Agri-products supply chain, with a particular focus on traceability and sustainability. Consequently, sustainability plays a crucial role in the supply chain, while traceability acts as a key enabler to achieving it.

2.5 Traceability

2.5.1 Defining traceability

Traceability means discovering information about the life cycle of products (Cambridge Dictionary). Traceability is an objective-specific concept and a tool to achieve numerous objectives (Golan et al., 2004). For instance, the definition of traceability is fundamentally broad. There is no single definition that adequately defines the "traceability" concept. According to the ISO 9000:2000 guideline, traceability is the "ability to trace the history, application or location of which is under consideration" (ISO, 2000). Golan et al. (2004) said, "traceability is a series of recorded identification." Likewise, the United Nation's Global Compact described traceability through the lens of sustainability orientation. It defined traceability as: "the ability to identify and trace the history, distribution, location and application of products, parts and materials, to ensure the reliability of sustainability claims, in the areas of human rights, labour (including health and safety), the environment and anti-corruption" (Norton et al., 2014).

Defining traceability, the European Union (EU) regulation 178/2002 considers traceability for the food industry context as following food and food safety, nutrition, feed, food-producing animal health and welfare, or products expected to be incorporated into a food or feed through all stages of production, processing and distribution (EU, 2002). Wilson and Clarke (1998) defined food traceability as the information necessary to describe the production history of a food crop and any subsequent transformations or processes that the crop might be subject to on its journey from the grower to the consumer's plate. According to a comprehensive definition of traceability with holistic approaches provided by Bosona and Gebresenbet (2013b), food traceability is part of logistics management. Food traceability captures, stores, and transmits adequate information about food, feed, and production of the correct animal or substance at all stages in the food supply chain. To this end, the food product can be checked for safety and quality control, traced upward, and tracked downward at any time required (Bosona and Gebresenbet, 2013b). Furthermore, Aung and Chang (2014) limited the traceability definition by incorporating the essential three characteristics of (i) identification of units/batches of all ingredients and products, (ii) information on when and where they are moved and transformed, (iii) and a system linking these data.

2.5.2 Measuring traceability

Considering the broader aspects of traceability, Golan et al. (2004) argued that it does not specify standard measurement for “that which is under consideration” to measure. However, research indicates mandatory food traceability laws are being implemented in some European Union (EU) countries (Bosona and Gebresenbet, 2013b). For example, the EU has introduced the General Food Law (GFL) (Kher et al., 2010). In this regard, mandatory data for traceability measurement plays a key role (Folinas et al., 2006). Such mandatory data includes lot number, product ID, product description, supplier ID, quantity, unit of measure, and buyer ID necessary to measure food product traceability (Folinas et al., 2006). Considering the above for measuring traceability, the non-blockchain process involves manual verification and massive record-keeping (Kshetri, 2018). In contrast, blockchain can reduce the workload and ensure traceability by using smart contracts, IoT technologies, and automated processes in the food supply chain (Kshetri, 2018).

2.5.3 Blockchain-based traceability for FSC

The importance of traceability across the food supply chain is increasingly receiving attention due to growing concerns about food safety and contamination risk (Salah et al., 2019). In addition, the increasing problem of food quality and safety has gained attention, particularly following many food safety incidents due to the lack of appropriate traceability systems in the food supply chain (Aung and Chang, 2014). To this end, organisations can trace products' journeys on centralised traceability systems. They use technologies like Radio Frequency Identification Devices (RFID), barcode readers, isotopic technologies, and firm-specific traceability mechanisms. However, the limitation of the centralised traceability system is a single-point failure (Tian, 2016b, George et al., 2019, Saberi et al., 2019b). Also, a centralised traceability system provides relatively minimal opportunity for tracking and recording data for each supply chain segment, limiting supply chain sustainability (farmer, processor, distributor, retailer) (Yiannas, 2018, Saberi et al., 2019b). For instance, lack of traceability management and responsibility for investigating the journey of products are growing concerns in the current volatile business environment (Saberi et al., 2019b). In contrast, blockchain ensures decentralised traceability for securing food safety and quality in the agri-food supply chain (Saberi et al., 2019b, Tan et al., 2020). Consequently, supply chain members can obtain complete information about the food journey throughout the AFSC (Yiannas, 2018, Zhao et al., 2019).

Traceability is becoming increasingly urgent for the organisational supply chain to secure safe information about products and processes to achieve customer confidence (Cousins et al., 2019). There are many requirements for supply chain traceability for pharmaceutical and medical products, banking and insurance, and high-value goods, including the AFSC (Saberi et al., 2019b). Traceability is the most significant enabler of blockchain implementation in AFSC, followed by suitability, immutability, and provenance (Kamble et al., 2020b). Furthermore, concerning meat safety and quality, policymakers in many countries have proposed or adopted mandatory traceability systems to track animal feed to control the risk of animal disease (mad cow disease) and to improve meat safety (Golan et al., 2004). To this end, Golan et al. (2004) advocated a government initiative to increase safety by providing a mandatory traceability policy for increasing trackback capability for food systems. Evidence from previous studies shows that SC traceability significantly impacts blockchain adoption in the supply chain for sustainability (Sander et al., 2018).

Although traceability in supply chain management (SCM) is not a new concept, its criticality remains high, especially in today's globalised and highly regulated markets. Traditional traceability systems often rely on siloed databases, manual record-keeping, and intermediaries, which can create inefficiencies, errors, and vulnerabilities to fraud or data tampering (Behnke and Janssen, 2019). In contrast, blockchain-based traceability offers a decentralised and immutable ledger, enabling real-time, end-to-end visibility and secure data sharing among stakeholders (Casino et al., 2019, Aung and Chang, 2014). This is particularly important for agri-food and high-value product chains, where consumer demand for transparency, food safety, sustainability, and ESG compliance is growing rapidly (Apeh and Nwulu, 2025, Chiaraluce et al., 2024). By integrating blockchain, organisations can enhance trust, reduce risks, and meet evolving regulatory and market pressures more effectively than with conventional systems. Therefore, examining blockchain-enabled traceability is essential for overcoming current shortcomings, strengthening governance mechanisms, and enhancing value generation within contemporary supply chain management.

Traceability-related research gap:

Gap 10: The definition of traceability is fundamentally broad. Therefore, no single definition that adequately defines the “traceability” concept (Golan et al., 2004).

Gap 11: The increasing food quality and safety problem has gained attention, particularly following many food safety incidents due to the lack of appropriate traceability systems in the food supply chain (Aung and Chang, 2014).

Gap 12: The limitation of the centralised traceability system is a single-point failure (Tian, 2016b, George et al., 2019).

2.6 Sustainability

2.6.1 Defining sustainability

Sustainability refers to the degree to which decisions impact the natural environment’s future situation and the social and economic impact and viability of decisions (Krysiak, 2009). The term sustainability, which increasingly refers to integrating social, environmental, and economic responsibilities, has begun to appear in the literature of business disciplines such as management (SC, SCM), operations, and manufacturing, including agri-food supply chain management (Kamble et al., 2020a, Moktadir et al., 2018, Rainero and Modarelli, 2021).

Sustainability is defined by the World Commission on Environmental and Development as “development that meets the needs of the present generation without compromising the ability of future generations to meet their needs” (Keeble and war, 1988). The three dimensions of sustainability are known as the triple bottom line (TBL) sustainability. According to Elkington (1998), TBL is “the convergent area of three dimensions, economic, environmental and social, where none is compromised for the benefit of the others.” For example, in defining sustainability, many authors categorised three aspects of sustainability: economic, social, and environmental, as the scope of supply chain sustainability (Carter et al., 2008, Gómez-Luciano et al., 2018, Kamble et al., 2020a, Moktadir et al., 2018, Rainero and Modarelli, 2021, Hong et al., 2018b, Bai and Sarkis, 2020). In contrast, sustainability is a broader concept. Chowdhury and Quaddus (2021a) argued that supply chain sustainability is a multidimensional concept consisting of four dimensions: social, environmental, economic (financial), and economic (production). They defined sustainability as “managing the supply chain functions aligned with the stakeholders’ social, environmental, and economic sustainability requirements to reduce sustainability risks in the supply chain and improve market performance” (Chowdhury and Quaddus, 2021a).

Measuring sustainability

The multi-dimensional sustainability concepts and their measurement depend on a comprehensive measurement scale. For example, Gimenez and Sierra (2013) demonstrated the effects of sustainability governance mechanisms in measuring supply chain sustainability (SCS), which comprises the environmental dimension only. In supporting this view, some studies focus on social or environmental dimensions, such as green supply chains, to measure SCS (Morali and Searcy, 2013, Rahman et al., 2020, Tachizawa and Wong, 2015). However, the holistic view of SCS measurement for economic, environmental, and social sustainability is relatively limited. However, in grounding DCV, Chowdhury and Quaddus (2021a) developed, tested and validated a multidimensional (social, environmental, economic (financial), and economic (production) SCS measurement scale, covering four approaches in an integrative manner in the context of the apparel industry in a developing country. Such an approach brings a new turn in measuring SCS.

2.7 Blockchain and the three dimensions of SC sustainability (SCS)

2.7.1 Blockchain ensures the economic dimension of SCS

Blockchain adoption in the supply chain has the potential to generate a positive economic contribution to ensure SCS. Blockchain adoption may increase economic sustainability and focus on supply chain productivity or growth aspects, including trade, capital formation, and the fiscal and monetary balance of the economy, resulting from chain practices (Manupati et al., 2020, Nayak and Dhaigude, 2019). In addition, economic sustainability requires firms to optimise the utilisation of space and resources. To this end, incorporating blockchain into supply chains improves traceability, audibility, and verifiability at each stage of production, optimising resource utilisation and improving SCS (Bai and Sarkis, 2020). Queiroz and Wamba (2019) emphasised that blockchain adoption in the supply chain can enhance its security, information transparency, privacy, anonymity, traceability, accountability, integrity, robustness, trustworthiness, and authentication. As a result, organisations achieve long-term economic sustainability in their supply chain.

2.7.2 Blockchain ensures the environmental dimension of SCS

Studies indicate that blockchain ensures the sustainability of the environmental supply chain, promotes ecological balance, reduces carbon emissions and renewable energy use, increases energy efficiency and biodiversity, and reduces climate change (Kouhizadeh et al., 2019, Manupati et al., 2020). For example, Manupati et al. (2020) demonstrated that blockchain-based smart contracts optimise both carbon emission levels and operational costs within a multi-echelon supply chain. To this end, blockchain reduces lead time under carbon taxation policies in the multi-tier production-distribution supply chain system and provides environmental sustainability (Manupati et al., 2020). Thus, multi-echelon production-distribution supply chains on carbon emissions and lead-time considerations under carbon tax policy need further research (Fard and Hajaghaei-Keshteli, 2018).

2.7.3 Blockchain ensures the social dimension of SCS

Blockchain has the potential to support social supply chain sustainability, the equitable economic distribution of benefits in society (Bai and Sarkis, 2020), and address human rights, labour rights, the working environment, and other more localised social issues (Bai and Sarkis, 2020, Shen and Pena-Mora, 2018). For example, blockchain ensures immutable information, which provides social sustainability (Saberi et al., 2019b). To this end, blockchain's immutable information can prevent corrupt individuals, governments or organisations from seizing people's assets unfairly (Saberi et al., 2019b). Furthermore, blockchain-based traceability provides sustainability by ensuring human rights and fair and safe work practices (Saberi et al., 2019b). For instance, a clear record relating to the journey of a product helps buyers have confidence that the goods are from ethical sources (Hughes et al., 2019).

Gaps relating to SC sustainability:

Gap 13: The lack of study on emissions arising from raw materials and intermediate products relating to multi-echelon sustainable production-distribution supply chains with lead time considerations under a carbon tax policy and the need for further research (Fard and Hajaghaei-Keshteli, 2018).

Gap 14: There are relatively limited studies on blockchain adoption in the Australian beef supply chain focusing on sustainability.

2.8 Factors influencing the relationship between BC adoption, traceability and sustainability

Drawing on the existing literature and focusing on the research objectives, this study analysed the factors influencing the relationship between blockchain adoption, traceability and sustainability. The factors such as technology orientation (Yu et al., 2022), upper management support (Wong et al., 2020a), and sustainability governance (Chowdhury and Quaddus, 2021b) are considered to investigate accordingly. These factors (technology orientation, upper management support, and sustainability governance) have originated from previous innovation literature, represented in the following sections. For example, an extensive literature review on strategic orientation demonstrated that technology orientation contributes to developing big data capability (Yu et al., 2022). Halac (2015) argues technology orientation is used as a single-dimensional construct of strategic orientations. This study considers technology orientation to investigate the relationship between blockchain adoption and traceability.

Research indicates that upper management support (UMS) is a critical success factor in providing adequate resources to encourage a positive attitude in using information system research (Bueno and Gallego, 2017). The support from the upper management facilitates many operational decisions and strategic information technology management activities

(Ragu-Nathan et al., 2004). The alignment of UMS and organisational strategic goals contributes to the overall success of the new technology adoption processes in any organisation (Bueno and Gallego, 2017). To increase end-user acceptance and performance towards information systems, UMS is one of the main success factors many studies have indicated (Ragu-Nathan et al., 2004, Wong et al., 2020c, Bueno and Gallego, 2017). This research uses upper management support is used as a conditional effect between blockchain adoption and traceability to identify blockchain adoption in Agri-products supply chain traceability and sustainability.

Previous research indicates that sustainability governance is a profound need for organisations and their supply chain to comply with and achieve sustainable performance (Dauvergne and Lister, 2012). In particular, sustainability governance is essential in managing sustainability in the supply chain (Chowdhury and Quaddus, 2021b). To this end, the focal firm needs to establish appropriate governance mechanisms or activities to ensure sustainable development. This study uses the sustainability governance factor as a conditional effect to examine the relationship between blockchain adoption and traceability for sustainability. Thus, the following section provides technology orientation, upper management support and sustainability governance.

2.8.1 Technology orientation and blockchain adoption

Technology orientation refers to an organisation's strategic focus on developing, adopting, and integrating new technologies into its operations, products, and services (Gatignon and Xuereb, 1997). Technology orientation is the extent to which organisations are willing to introduce or use new digital technologies in their transformation process to sustain a competitive edge (Yu et al., 2022). It is a critical aspect of strategic management and innovation (Yu et al., 2022, Gatignon and Xuereb, 1997). Pan et al. (2021) have shown that technology orientation is one of the critical factors in the rapidly changing business environment to manage digital capabilities and new product development in emerging markets place. Researchers have found that technology orientation plays a critical role in utilising the firm's resources and capabilities to generate a competitive advantage in the emerging new technological business environment (Pan et al., 2021, Gatignon and Xuereb, 1997, Kapoor et al., 2014, Yu et al., 2022). Evidence shows that innovative firms are also strongly research and development (R&D)-oriented, and these firms proactively adopt new technologies and use emerging sophisticated digital technology in developing new products and processes in the supply chain accordingly (Workman Jr, 1993). Given the interest of the study, technology orientation is one of the important factors this study considered in investigating how it influences the relationship between blockchain adoption, supply chain traceability and sustainability.

2.8.2 Upper management support and blockchain adoption

Upper management support refers "to the degree to which upper management understands the importance of and is involved" in blockchain adoption in organisations (Ooi et al., 2018). Previous studies have identified that upper management support plays a significant role in successfully adopting technology in organisational business processes to enhance supply chain activities (Lin, 2014, Wong et al., 2020a). This supports explicit organisational strategic goals in many ways, among them vision and strategy alignment, resource allocation, culture and change management, communication and leadership, training and development, monitoring and evaluation, and risk management, which are significantly important (Nayak and Dhaigude, 2019). Specifically, the alignment of upper management support and organisational strategic goals contributes to the overall success of the new technology implementation processes. In contrast, the lack of such alignments has a major impact on the adoption decision in the organisation (Lin, 2014). For instance, upper management support is essential for adopting new technology in the organisation, as it provides a certain vision, the resources, and the essential leadership to drive initiatives forward (Ooi et al., 2018).

2.8.3 Sustainability governance and blockchain adoption

Sustainability Governance refers to organisations' framework, policies and processes to manage their sustainability strategy and practices. It encompasses how organisations, governments and related supply chain members integrate environmental, social and economic considerations into their decision-making processes in the supply chain activities to ensure sustainable development (Dauvergne and Lister, 2012, Chowdhury and Quaddus, 2021a). In particular, sustainability practices do not always ensure performance in supply chains unless focal firms establish appropriate governance mechanisms (Dauvergne and Lister, 2012). The importance of sustainability governance and practices is described by Chowdhury and Quaddus (2021a). Studies indicate ongoing pressure on manufacturing firms in developing countries to comply with social and environmental sustainability practices (Chowdhury et al., 2023). Moreover, sustainability governance is a profound need for organisations and their supply chain to comply and achieve sustainability goals. In particular, organisations with robust sustainability governance contribute to societal and environmental well-being; equally, they position themselves for long-term success in sustainability goals (Garcia-Torres et al., 2019).

2.9 Research Model

Based on an extensive literature review, this research developed a model focused on extending the TOE (technology, organisation and economics) model proposed by Wong et al. (2020a). The resulting framework differs from other frameworks developed recently on BCT adoption in SCM, such as the framework developed by Francisco and Swanson (2018). This framework is different as it focuses on the impact of blockchain adoption for business environmental drivers for supply chain traceability and sustainability through mediating (traceability) and moderating (technology orientation, upper management support and sustainability governance) roles (Happy et al., 2023). This framework comprehensively encapsulates all factors included in this research. The model of the study is presented in Figure 2.2:

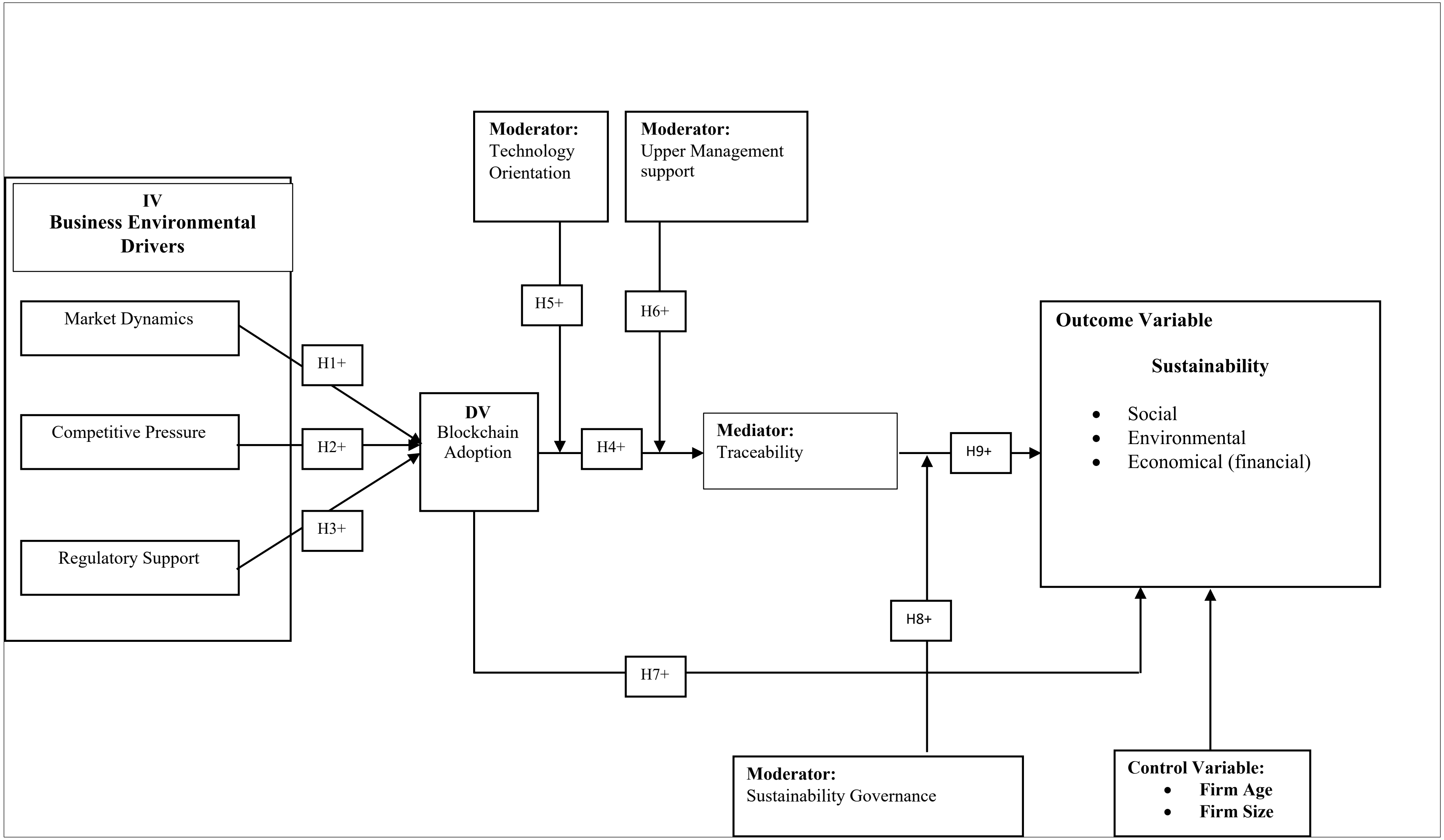

Figure 2.2 Blockchain for supply chain traceability and sustainability model

Blockchain for supply chain traceability and sustainability model

Based on previous studies, several drivers, such as market dynamics (MDY), competitive pressure (CPR), and regulatory support (RGS), have been identified (Wong et al., 2020a) and together constitute the concept of the business environmental drivers of the model for this study. The previous studies also identifies that blockchain adoption (BCAD) (Wamba et al., 2020a) significantly impacts traceability (TRA) in the supply chain (Hughes et al., 2019, Kamath, 2018). The review also identifies that BCAD enhances traceability (TRA) (Cousins et al., 2019) in many ways (Hughes et al., 2019, Kamath, 2018), and it (BCAD) directly and indirectly influences sustainability in supply chains. The studies identified that the concept of supply chain sustainability includes social (SOC), economic (ECO), and environmental (ENV), as shown in the model (Chowdhury and Quaddus, 2021a). Therefore, BCAD is modelled as an attribute of dynamic capability (DC), and the conditional effect of TRA extends the relationship between BCAD and sustainability.

Also, based on previous studies, factors such as technology orientation (TOR) (Yu et al., 2022) and upper management support (UMS) (Wong et al., 2020a) provide conditional effects between blockchain adoption and traceability. Also, sustainability governance (SGV) (Chowdhury and Quaddus, 2021a) provides conditional effects between traceability and sustainability in the model of the study. In addition, this study considered two control variables: firm age and firm size, as shown in the model (Chowdhury, 2014). Chapter 3, section 4.2.5 provides a detailed description of the drivers and constructs/attributes/variables adopted in the model of the study.

2.10 THEORETICAL FRAMEWORK

The previous section formulated this study's conceptual research model for blockchain adoption (BCAD) in the context of supply chain traceability and sustainability. This section outlines the theories that underpin this research, explaining how the relationship between the constructs is established. The research model is grounded in three theoretical lenses: the dynamic capability view (DCV), transaction cost theory (TCT) and institutional theory (IT).

2.10.1 Dynamic Capability View (DCV) and Supply Chain

Teece et al. (1997) introduced the concepts of DCV to understand firms' ability to use their resources to achieve competitive advantage in the uncertain and changing business environment. DCV is an extension of the resource-based view (RBV). RBV builds from the unique set of firms' resources, including all assets, capabilities, organisational processes, firm attributes, information and knowledge that firms control to achieve their strategic goal (Barney, 1991). However, the DCV can constantly adapt to change in the uncertain business environment. In contrast, the lack of change adoption capability in the uncertain business environment limits RBV. In particular, RBV focuses on exploiting firms' specific internal assets, which is the focus of the VIRN (valuable, rare, inimitable, and non-substitutable) perspective. To this end, a dynamic capability is different from ordinary capabilities because the prime focus of DCV is on rapid change adoption (internal and external) in the uncertain business environment (Wilden et al., 2019, Teece, 2007). Thus, the concept of capabilities refers to 'an organisationally embedded nontransferable firm resource whose purpose is to improve the productivity of the other resources proposed by the firm" (Makadok, 2001).

Dynamic capabilities are "the firm's ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments" (Teece et al., 1997). DCV is considered the primary source of competitive advantage in a firm's business (Teece et al., 1997). From the strategic management point of view, DCV fundamentally influences firms' innovation in their business model. Teece (2018) demonstrated how business model innovation and firms' dynamic capabilities are interrelated with the feasibility of their strategies. In particular, business models, dynamic capabilities, and strategy are interdependent (Teece, 2018). The dynamic capability (DC) framework consists of three key components: (1) identifying and responding to opportunities and threats, (2) taking advantage of those opportunities, and (3) converting these opportunities into innovations within an uncertain business context (Teece et al., 1997, Kale and Singh, 2007, Jolink and Niesten, 2015). To this end, blockchain adoption in supply chains is essentially a DC, capable of meeting and matching the specificities of internal and external business environmental contexts (Teece, 2007).

Blockchain-DVC and Supply Chain

In the context of blockchain-enabled supply chains, firms demonstrate their sensing capability by identifying critical inefficiencies, such as a lack of transparency, traceability issues, and vulnerability to fraud, and aligning these insights with emerging technological opportunities (Queiroz et al., 2019b). Seizing occurs when firms capitalise on blockchain's decentralised and immutable architecture to build trust, improve coordination among stakeholders, and reduce transaction costs, thereby converting sensed opportunities into competitive advantage (Saberi et al., 2019a). Transformation is achieved by reconfiguring existing supply chain processes and resource bases, such as transitioning from paper-based tracking systems to blockchain-led digital ecosystems, enabling real-time visibility and fostering resilience against disruptions (Kouhizadeh and Sarkis, 2018). Thus, the application of DCV in blockchain-driven supply chains illustrates how firms sense, seize, and transform resources to navigate uncertainty and strengthen strategic positioning in volatile markets.

Beyond efficiency gains, blockchain adoption also strengthens dynamic capabilities by enabling supply chains to respond proactively to regulatory and institutional pressures. For instance, governments and international organizations are increasingly mandating higher levels of sustainability reporting and product traceability, particularly in sectors such as food and pharmaceuticals (Pournader et al., 2020). By integrating blockchain, firms enhance compliance while simultaneously developing adaptive capabilities that allow them to respond swiftly to changing legal frameworks and customer demands for ethical sourcing (Casino et al., 2019). Moreover, blockchain's interoperability with other digital technologies, such as IoT and artificial intelligence, expands firms' sensing capabilities, allowing real-time data integration that enhances predictive insights into risks and opportunities (Queiroz et al., 2019b). In this way, blockchain serves as more than a technological tool; it acts as a strategic enabler of resilience and adaptability under DCV.

Furthermore, blockchain-enabled supply chains transform inter-organizational relationships by fostering collaborative ecosystems where trust and information sharing replace traditional transactional mechanisms. According to Treiblmaier (2019), blockchain reduces opportunistic behaviour by ensuring data immutability, thereby enhancing relational governance between supply chain partners. This collaborative dimension not only seizes market opportunities but also cultivates co-innovation and knowledge exchange, which are critical for long-term transformation (Kouhizadeh et al., 2019). Firms that embed blockchain into their supply chain strategies develop the capacity to reconfigure both tangible and intangible resources, enabling them to shift from transactional coordination to strategic partnerships (Wamba et al., 2020a). Such reconfigurations reflect the transformative nature of DCV, where blockchain facilitates not only technological integration but also organisational learning and continuous renewal. Thus, blockchain adoption extends dynamic capabilities by embedding adaptability, collaboration, and resilience within supply chain ecosystems.

The DC concept examines management strategies to adopt unexpected changes, risks and opportunities in the volatile market and determine and control such changes in uncertain business environments (Beske and management, 2012). An organisation needs DC to cope with the changing business environment, mitigate business risk factors, improve many operational aspects, gain opportunities in the uncertain business environment, or find some scope for improving business operations (Kyläheiko and Sandström, 2007, Warner and Wäger, 2019). The application of DCV has been researched in various fields, including marketing, the services sector, SCM, and other sectors. For example, DCV is commonly applied in supply chain management (SCM) to describe how supply chain participants utilize, adjust, and combine both internal and external resources to support value-creation processes within supply chains. Furthermore, the theory is generally used as a framework for supply chain resilience (Chowdhury and Quaddus, 2017), measuring supply chain sustainability (Chowdhury and Quaddus, 2021a), sustainable supply chain management (Hammervoll et al., 2012a) and many more perspectives. The DCV is one of the established theories among the many organisational theories widely used to improve supply chain operational efficiency/performance for achieving a competitive advantage in the rapidly changing business environment (Wamba et al., 2020c).

2.10.2 Transaction Cost Theory (TCT) and Supply Chain

TCT articulates and focuses on "transactions" or the unit of exchanges (Williamson, 1975). The basic principle of this theory is based on assumptions about human behaviour and uncertainty in transactions; this idea was coined by Koopmans (1959) and distinguished between primary and behavioural (or secondary) uncertainty. Fundamentally, TCT is based on the assumptions of bounded rationality and opportunism (Williamson, 1973). Simon (1957) first articulated the concept of bounded rationality. Bounded rationality refers to the capability of individuals to receive, store, and retrieve information without error; and opportunism relates to individuals' acts through a lack of openness or honesty in transactions (Williamson, 1973, Williamson, 1975). In particular, the assumption of bounded rationality and opportunism gives rise to transaction costs (Williamson, 1973, Grover and Malhotra, 2003). Thus, TCT emphasises boundary decisions, perhaps the central phenomenon of interest in the SCM (Williamson, 2008).

TCT is a well-established theoretical grounding for operations and supply chain management (Grover and Malhotra, 2003). Prior studies, for example, place emphasis on interpreting inter-organisational information sharing in the environmental and demand uncertainty (Yigitbasioglu and Management, 2010), explore outsourcing decisions and supply chain integration (Bals et al., 2017), and analyse the relational bonding in green supply chain practices (Li et al., 2017). To this end, utilising the TCT lens to understand transaction costs for supply chain traceability, sustainability, and emerging blockchain technology, is a significant issue.

TCT provides opportunities to investigate organisational structures, processes and resources, and inter-organisational relationships from various angles, including supply chain governance decisions (Roeck et al., 2020). For example, blockchain adoption reduces internal and external transaction costs and limits opportunistic behaviour in the supply chain (Schmidt and Wagner, 2019). Furthermore, a study indicates that adopting blockchain technology in the organisational supply chain potentially affects internal and external transaction cost reduction under the three enablers of transparency, trust, and disintermediation (Treiblmaier, 2018). Thus, from the lens of TCT, blockchain ensures cost reduction and cost avoidance in supply chain transaction processes (Roeck et al., 2020). Furthermore, TCT provides the unit of analysis of a transaction or exchange of information for goods or services between subsequent stages of a production process (Williamson, 1993). Williamson (2008) also demonstrated the applicability of TCT as a lens in analysing disintermediation and transactions in SCM.

Blockchain_TCT_Supply Chain

From the perspective of Transaction Cost Theory (TCT), blockchain-based supply chains reshape governance mechanisms by lowering transaction costs, curbing opportunism, and strengthening inter-organisational coordination (Williamson, 1993, Roeck et al., 2020). The immutable and decentralised nature of blockchain enhances transparency and trust among partners, thereby mitigating information asymmetries and reducing the need for extensive monitoring or enforcement mechanisms (Schmidt and Wagner, 2019, Warner and Wäger, 2019). Moreover, blockchain enables disintermediation by facilitating direct, verifiable transactions between parties, which lowers dependency on intermediaries and reduces associated costs (Treiblmaier, 2019). These efficiency gains translate into streamlined decision-making, lower contractual hazards, and stronger governance structures within the supply chain (Williamson, 2008). Thus, through the TCT lens, blockchain adoption represents a paradigm shift in supply chain management by enabling organisations to achieve cost reduction, improve relational governance, and mitigate risks in complex inter-firm exchanges.

In addition to reducing costs, blockchain technology transforms the governance of hybrid organisational forms that combine both market-based and hierarchical structures. Traditional alliances and joint ventures often encounter challenges of opportunism and contractual disputes; however, blockchain mitigates such risks by ensuring immutable, auditable records of all transactions and agreements (Grover and Malhotra, 2003). The deployment of smart contracts further enhances governance by automating enforcement mechanisms, thereby lowering ex-post monitoring and dispute resolution expenses (Wang et al., 2019a). This automation supports efficient coordination across supply chain actors and reduces reliance on third-party enforcement institutions, thereby diminishing contracting hazards (Schmidt and Wagner, 2019). By embedding trust in technological infrastructure, blockchain complements relational governance while simultaneously strengthening formal coordination structures (Roeck et al., 2020). Thus, blockchain adoption enhances hybrid governance arrangements and facilitates more efficient alignment of incentives in inter-firm relationships.

Furthermore, blockchain adoption redefines the theoretical boundaries of firms as conceptualised within TCT. Traditionally, make-or-buy decisions are driven by transaction cost considerations, with firms internalising activities when market exchanges become inefficient (Williamson, 1993). Blockchain alters this logic by significantly lowering coordination and information exchange costs across organisational boundaries, thereby enabling greater reliance on market mechanisms (Catalini and Gans, 2020). For example, blockchain platforms facilitate real-time data sharing and verification across supply chain partners, which reduces information asymmetry and opportunism in procurement and logistics processes(Catalini and Gans, 2020, Saberi et al., 2019a). Consequently, firms are able to outsource previously internalised functions, such as quality assurance and logistics tracking, without incurring higher governance costs (Queiroz et al., 2019b). In this way, blockchain extends the applicability of TCT by enabling modular and flexible supply chain designs that optimise both efficiency and resilience in increasingly volatile environments (Grover et al., 2018).

2.10.3 Institutional theory and supply chains

Institutional theory provides a critical framework for understanding organisational behaviour within broader social, cultural, and regulatory contexts. Rather than operating solely based of profit maximisation, firms seek legitimacy and social acceptance as vital resources for survival and long-term competitiveness (Mishra et al., 2025, Guo et al., 2024, Scott et al., 2017, Faundez, 2016). Legitimacy enables organisations to secure stakeholder trust, access external resources, and maintain societal approval, making it a central determinant of organisational endurance (Suchman, 1995). Within this theoretical lens, corporate behaviour is shaped by macro-level forces—including regulations, social norms, cultural traditions, and professional standards—that influence decision-making and strategic responses (Kostova et al., 2020).

A core concept within institutional theory is institutional isomorphism, which explains the convergence of practices across industries. DiMaggio and Powell (1983) identify three mechanisms of isomorphism: coercive, normative, and mimetic. Coercive isomorphism arises from formal rules, regulations, and stakeholder demands that compel compliance (Spanuth and Urbano, 2024, Kostova et al., 2020). Normative isomorphism stems from professionalisation processes, where industry associations, training, and certifications diffuse common standards and values (Faundez, 2016). Mimetic isomorphism occurs when firms imitate successful competitors to mitigate uncertainty and enhance their legitimacy in dynamic environments (Scott et al., 2017). Collectively, these forces reduce organisational diversity and embed institutional norms within corporate structures, leading firms in similar fields to adopt parallel practices (Mishra et al., 2025, Scott et al., 2017)

Within supply chain management (SCM), institutional theory explains how external pressures drive firms to adopt sustainability and socially responsible practices (Hartley et al., 2022). Coercive regulations, consumer expectations, and advocacy from civil society groups frequently push firms to strengthen ethical sourcing, environmental accountability, and labour standards (Meixell and Luoma, 2015, Hartley et al., 2022, Mohammed et al., 2024). Normative pressures from professional networks and global certification systems further reinforce sustainability commitments, while mimetic forces encourage firms to replicate the practices of industry leaders (Sauer and Seuring, 2019, Kauppi, 2013). Importantly, legitimacy-seeking behaviour may lead to decoupling, where firms symbolically conform to institutional expectations while maintaining practices that diverge from substantive change (Faundez, 2016, Kummer et al., 2020, Boxenbaum and Jonsson, 2017). This duality highlights legitimacy's dual role as both a strategic asset and a social construct that shapes corporate behaviour.

In the context of global supply chains, institutional theory highlights the significance of institutional distance, as regulatory and cultural variations across countries complicate firms' strategies for legitimacy (Kostova et al., 2020, Hartley et al., 2022). To navigate these differences, organisations balance efficiency objectives with legitimacy demands, often restructuring policies or aligning with international standards to secure broader acceptance (Faundez, 2016, Kauppi, 2013). This dynamic demonstrates that legitimacy is not static but evolves in response to changing expectations from regulators, consumers, and professional institutions. Consequently, institutional theory provides insights into how supply chain actors coordinate practices across diverse environments to secure stability and social approval (Deephouse and Suchman, 2008).

More recently, blockchain adoption in supply chain management has been increasingly analysed through an institutional theory perspective. While blockchain promises enhanced transparency, traceability, and accountability, its uptake is shaped by institutional pressures rather than solely by efficiency gains (Hartley et al., 2022, Treiblmaier, 2018). Coercive pressures stem from regulatory frameworks and global sustainability mandates, such as carbon accountability and ethical trade compliance (Casino et al., 2019). Normative forces arise through industry associations and professional bodies promoting blockchain as a standard for responsible supply chain management (Saberi et al., 2019b, Hughes et al., 2019). Mimetic pressures further accelerate adoption, as firms emulate competitors who have successfully implemented blockchain to enhance credibility and stakeholder trust (Queiroz and Wamba, 2019, Hughes et al., 2019). Thus, blockchain adoption illustrates how institutional forces influence not only organisational legitimacy but also the diffusion of emerging technologies in global supply chains.

Institutional theory highlights that blockchain adoption in supply chain management is often driven by regulatory pressures aimed at enforcing traceability and sustainability standards. Governments and international organisations are increasingly mandating digital traceability systems to ensure compliance with food safety, environmental, and ethical trade regulations (Hughes et al., 2019, Saberi et al., 2019a). Blockchain provides an immutable ledger that aligns with these coercive institutional demands by enabling regulators to verify compliance efficiently (Casado-Vara et al., 2018, Hughes et al., 2019). Firms that fail to meet these evolving regulatory expectations risk reputational damage, fines, and exclusion from global trade networks. Consequently, blockchain adoption becomes not merely a technological choice but a strategic response to institutionalised coercion. This illustrates how institutional theory offers a robust explanation for blockchain's diffusion under external pressures that transcend market logic (Treiblmaier, 2019).

From a stakeholder perspective, blockchain is increasingly recognised as a mechanism for meeting societal expectations of transparency and accountability across supply chains. Consumers, advocacy groups, and industry associations exert normative pressure on firms to disclose sourcing practices, carbon footprints, and labour standards (Queiroz & Fosso Wamba, 2019). Blockchain enables the verification of sustainability claims by providing real-time data on product origin and production processes (Francisco & Swanson, 2018). In this sense, legitimacy is achieved not only by regulatory compliance but also by demonstrating responsiveness to broader societal values (Yawar & Kauppi, 2018). Firms leveraging blockchain to meet stakeholder expectations can build reputational capital and strengthen brand trust. Hence, institutional theory underscores blockchain as a legitimacy-seeking tool shaped by normative pressures that demand ethical and sustainable business conduct.

Mimetic pressures also accelerate blockchain adoption in global supply chains, as organisations imitate competitors who integrate blockchain to enhance legitimacy and secure competitive advantage (Deephouse and Suchman, 2008, Suchman, 1995).

Firms often adopt blockchain not solely for efficiency gains but to avoid being perceived as lagging behind industry leaders (Kouhizadeh et al., 2021). For instance, leading agribusiness and retail corporations have embraced blockchain to comply with international traceability requirements, prompting others in the sector to follow suit (Hughes et al., 2019, Saberi et al., 2019b). This imitation reduces uncertainty in emerging markets, where institutional frameworks for blockchain remain fragmented. As more firms converge toward blockchain-based solutions, isomorphic pressures standardise practices across supply chains (Heugens and Lander, 2009, Kouhizadeh et al., 2021). Therefore, institutional theory explains blockchain diffusion as a product of interconnected regulatory, normative, and mimetic forces that reinforce its legitimacy within global commerce.

2.10.4 Justifying the theory's application

To efficiently address the research gaps, this study relied on the DCV (Teece et al., 1997, Teece, 2007), TCT (Williamson, 1973) and IT (Suchman, 1995) as the theoretical grounding. Existing studies used the dynamic capability theory to cope with the uncertain business environment, identify dynamic stakeholder requirements, and interpret those requirements to sustainability practice (Chowdhury and Quaddus, 2021a, Hammervoll et al., 2012b, Hong et al., 2018a). Furthermore, Wamba et al. (2020c) justified the DCV theory in supply chain digitalisation from the blockchain diffusion perspective.

This study considered DC theory for the internal and external aspects of blockchain adoption drivers. The drivers, including business environmental drivers (market dynamics, competitive pressure and regulatory support), influence organisations to adopt blockchain technology. In particular, the internal and external factors of drivers influence organisations to change their business practices. Such drivers and factors propel an organisation to change how it performs operations and uses technologies for its operations; in this way, organisations transform their business practices. To this end, blockchain adoption can be considered a dynamic capability perspective. In this study, the link between three business environmental drivers (H1, H2, H3) and blockchain adoption explains the relationship using DCV.

While the focus is on blockchain adoption in SC, traceability is one of the key constructs (mediator) of this research. Traceability ensures operational capability for organisations. Dynamic capability leads to operational capability. Therefore, traceability improves operational performance in the organisation in many ways (enabling provenance of the product, lowering distribution cost, reducing recall expenses, and improving sales revenue) (Golan et al., 2004). Furthermore, blockchain adoption influences supply chain activities to undergo rapid changes (Kamble, 2018). To this end, blockchain adoption in the SC is a dynamic capability (Teece, 2018) that facilitates the operational capability of improving traceability in the supply chain. In this study, DCV supports the link (H4) between blockchain adoption and traceability (mediator) to explain the relationship.

The conditional effect of technology orientation (TOR) and upper management support (UMS) are supporting factors of the study. TOR extends the relationship between blockchain and traceability. Similarly, UMS extends the relationship between blockchain and traceability. In addition, blockchain adoption is a DC in the supply chain that meets external and internal business environmental changes (Teece, 2018). Traceability as an operational capability improves operational efficiency. To this end, DCV supports the moderator link (H5) of technology orientation between blockchain adoption and traceability (Teece, 2007). DCV equally supports the moderator link (H6) of UMS between blockchain adoption and traceability.

Blockchain ensures sustainability. Blockchain adoption is a DC for organisations and their supply chain to meet changing business needs. Blockchain adoption in organisations provides sustainability in many ways. For example, blockchain adoption in organisations can enhance security, information transparency, privacy, anonymity, traceability, accountability, integrity, robustness, trustworthiness, and authentication while improving organisational SC sustainability (Bai and Sarkis, 2020). To this end, DCV supports the link (H7) between blockchain adoption and sustainability.

Sustainability governance improves sustainability by reducing sustainability risk in the organisation. Furthermore, blockchain-based traceability ensures transaction cost reduction for sustainability practices in supply chains and assists trading partners in exchanging rational information (Hastig et al., 2020). Moreover, traceability ensures the identification of illegal and unethical procurement and production practices, product lifecycle transparency, and improves sustainability in the SC (Hastig et al., 2020). To this end, a traceability system reduces transaction costs in organisations. To this end, TCT supports the link (H8) of the moderator role of sustainability governance (moderator) between traceability and sustainability (Williamson, 2008). Traceability ensures sustainability. Blockchain-based traceability is an operational capability in the organisation that improves operational efficiency in the changing business environment (Teece, 2018). To this end, blockchain-enabled traceability helps to curb illegal practices, improve operational performance, increase operational efficiency, enhance supply chain coordination, and improve sustainability by reducing transaction costs (Hastig et al., 2020, Aung and Chang, 2014). In particular, the traceability mechanism reduces transaction costs and enhances operational efficiency in organisations. Thus, TCT supports the link (H9) between traceability and sustainability.

Institutional theory provides a powerful lens to justify the adoption of blockchain technology in agri-product supply chains, particularly for enhancing traceability. Regulatory bodies, international trade organisations, and consumer protection agencies increasingly demand verifiable data on product origin, safety, and sustainability (Saberi et al., 2019b). These coercive pressures compel firms to implement blockchain systems, which create immutable records of agricultural production, processing, and distribution (Casino et al., 2019). By embedding transparency into the supply chain, blockchain helps firms secure legitimacy in highly regulated global markets. Moreover, as legitimacy is central to organisational survival, blockchain adoption enables agribusinesses to demonstrate compliance with food safety and sustainability regulations, thereby avoiding reputational and financial risks (Scott et al., 2017, Treiblmaier, 2018). Through this alignment with institutional expectations, blockchain becomes more than a technological innovation; it emerges as a legitimacy-enhancing mechanism within agri-product supply chains.

Beyond regulatory compliance, institutional theory also explains how normative and mimetic pressures drive blockchain adoption to strengthen sustainability practices in agri-product supply chains. Stakeholders such as consumers, NGOs, and industry associations increasingly expect firms to verify sustainability claims, including ethical sourcing, environmental stewardship, and fair labour practices (Queiroz et al., 2019b). Blockchain enables these disclosures by providing reliable, tamper-proof data that can be accessed across the supply chain network (Francisco and Swanson, 2018). Firms often emulate leading competitors who adopt blockchain to align with such expectations, thereby reflecting mimetic isomorphism in response to uncertainty and reputational concerns (Kouhizadeh et al., 2019). In this way, blockchain adoption fosters legitimacy not only by complying with formal regulations but also by addressing societal values linked to sustainability and ethics (Yawar and Kauppi, 2018). Consequently, blockchain contributes significantly to building institutional legitimacy in agri-product supply chains, reinforcing its role as both a compliance and strategic differentiation tool. The organisational theories (DCV, TCT and IT) used for the research model are presented in the following Table 2.2 and Table 2.3 accordingly:

Table 2.2 Theory used for the model

Criteria	**Dynamic Capability View (DCV)**	**Transaction Cost Theory (TCT)**
Sensing Opportunities	Identifying inefficiencies (e.g., lack of transparency, traceability gaps) and aligning blockchain adoption with market and technological trends (Queiroz & Wamba, 2019).	Reducing uncertainty in information exchange and preventing opportunism by enabling transparent and verifiable transactions (Schmidt & Wagner, 2019).
Seizing Opportunities	Leveraging blockchain's decentralised architecture to build trust, coordinate stakeholders, and reduce operational frictions (Saberi et al., 2019).	Minimising transaction costs by lowering dependence on intermediaries through disintermediation (Treiblmaier, 2018).
Transforming Resource Base	Reconfiguring supply chain processes by shifting from paper-based to blockchain-enabled digital ecosystems, improving resilience and adaptability (Kouhizadeh & Sarkis, 2018).	Establishing efficient governance structures and reducing contractual hazards in supply chain transactions (Williamson, 2008).
Resilience and Risk Mitigation	Dynamic capabilities enable firms to adapt blockchain to respond quickly to disruptions, enhancing supply chain resilience (Teece, 2007).	Blockchain reduces transaction risk by enforcing smart contracts and lowering the likelihood of opportunistic behaviour (Roeck et al., 2020)
Sustainability Integration	Blockchain supports traceability for sustainable sourcing, enabling firms to integrate sustainability goals into resource reconfiguration (Saberi et al., 2019).	Transparency lowers monitoring costs for sustainability compliance and reduces the risk of greenwashing (Treiblmaier, 2018).
Innovation in Governance Models	DCV emphasises continuous business model innovation, which blockchain facilitates by enabling new supply chain collaboration mechanisms (Teece, 2018).	TCT highlights blockchain's role in lowering governance costs by reducing the need for hierarchical oversight in inter-firm transactions (Williamson, 1993).

Table 2.3 IT for BCAD in the Agri-product supply chain

Institutional Pressure	Criteria	Institutional Theory Applications
Coercive Pressure	Compliance with regulatory and trade standards	Firms adopt blockchain to comply with food safety, quality assurance, and traceability regulations imposed by government and trade bodies (Saberi et al., 2019; Casino et al., 2019).
	Mandatory sustainability and certification requirements	Blockchain ensures verifiable documentation of sustainable and ethical practices demanded by international markets and certification agencies (Scott et al., 2017; Treiblmaier, 2018).
Normative Pressure	Stakeholder expectations for ethical and sustainable practices	Industry associations, NGOs, and consumers expect transparent supply chains reflecting environmental and social responsibility (Queiroz et al., 2019).
	Professional and industry standards	Adoption of blockchain aligns with professional norms and industry standards promoting data integrity and accountability (Francisco & Swanson, 2018).
Mimetic Pressure	Emulation of leading competitors	Organisations imitate early adopters of blockchain who have achieved operational and reputational benefits (Kouhizadeh et al., 2019).
	Response to market uncertainty and reputation management	Firms adopt blockchain to enhance credibility and competitiveness amid uncertain market conditions and reputational risks (Yawar & Kauppi, 2018).

2.10.5 Contribution relating to DCV, TCT and IT in this study:

The Dynamic Capabilities View (DCV) provides a lens to understand how firms reconfigure and adapt their resources to environmental turbulence, thereby strengthening the moderating role of capabilities such as flexibility, innovation, and resilience in blockchain adoption within supply chains (Teece, 2018, Teece, 2007). By enabling organisations to sense, seize, and transform opportunities, DCV explains how firms leverage blockchain to enhance transparency and adaptability, moderating the impact of market and technological uncertainty (Queiroz and Wamba, 2019, Humdan et al., 2023).

In parallel, Transaction Cost Theory (TCT) highlights the reduction of opportunism, coordination costs, and information asymmetry, which serves to moderate the relationship between blockchain adoption and supply chain efficiency (Williamson, 1993, Roeck et al., 2020).

TCT suggests that blockchain-enabled trust and disintermediation reinforce the moderating effects of governance structures on performance outcomes (Schmidt and Wagner, 2019, Treiblmaier, 2019, Warner and Wäger, 2019). Together, DCV and TCT justify the moderating mechanisms by showing that blockchain adoption not only depends on resource reconfiguration but also on cost-efficient governance structures to achieve sustainable competitive advantage.

The application of institutional theory provides valuable insights into how blockchain adoption in agri-product supply chains enhances traceability and sustainability by responding to coercive, normative, and mimetic pressures. Coercive pressures from governments and international regulators drive agribusiness firms to implement blockchain-based traceability systems that ensure compliance with sustainability, food safety, and ethical trade standards (Casado-Vara et al., 2018, Heugens and Lander, 2009). Normative pressures emerge from consumer expectations, advocacy networks, and industry associations that promote transparency and social accountability throughout the agri-food value chain (Queiroz and Wamba, 2019, Yadav et al., 2020, Yawar and Kauppi, 2018). These pressures encourage firms to use blockchain to disclose sourcing practices, reduce information asymmetry, and verify sustainability claims (Francisco and Swanson, 2018). Mimetic isomorphism further accelerates adoption as firms imitate early adopters that have successfully integrated blockchain to enhance legitimacy and gain stakeholder trust (Kouhizadeh et al., 2021, Saberi et al., 2019a).

Consequently, blockchain serves not merely as a technological innovation but as a legitimacy-seeking mechanism shaped by institutional forces that standardise responsible practices across agri-product supply chains (Deephouse and Suchman, 2008, Treiblmaier, 2018). By embedding transparency and traceability into supply chain governance, blockchain aligns firms with evolving sustainability mandates and societal expectations (Hartley et al., 2022). Thus, institutional theory explains how blockchain adoption in agri-product supply chains is institutionalised as a strategic response to external pressures that reinforce legitimacy, ethical compliance, and sustainable competitiveness (Mishra et al., 2025, Faundez, 2016).

Thus, DCV, TCT and IT theories contribute to clarifying how moderators influence the strength and direction of blockchain's impact on supply chain sustainability and performance. The organisational theories (DCV, TCT and IT) used for the research model are presented in Following Figure: 2.3:

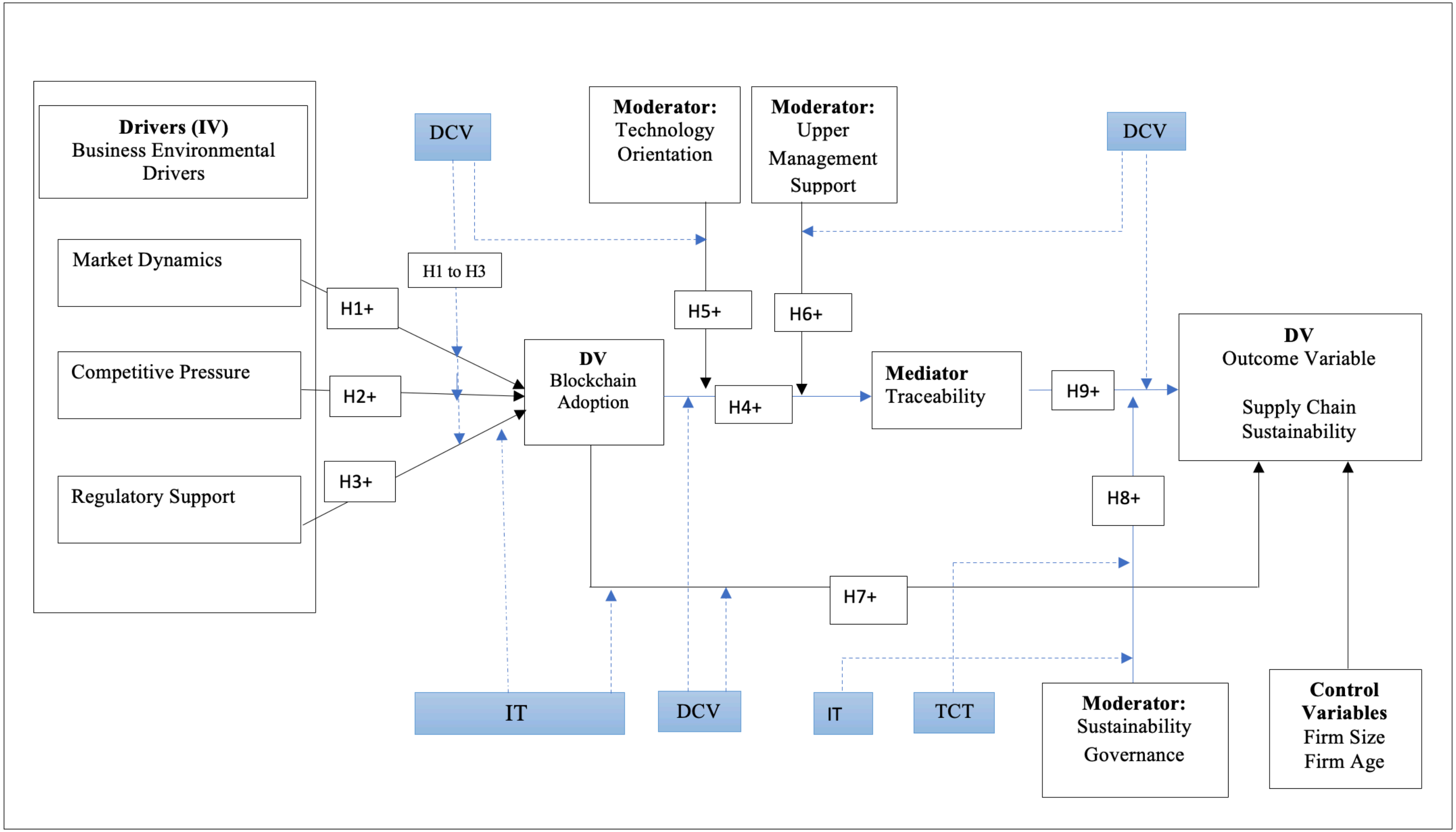

Figure 2.3 Theory application used in the research framework

2.11 Summary:

The chapter presented a literature review related to this research, offering a critical analysis of the literature on blockchain, supply chain traceability, and sustainability. The critical literature analysis identified gaps and addressed these in each section of the literature review. This chapter also addressed various blockchain adoption drivers, specifically business environmental drivers, which this study examined. Based on the literature review and focusing on the research objectives, an initial research model was presented in this chapter. A preliminary research model outlining the dimensions of constructs and their interrelationships concerning blockchain adoption for supply chain traceability and sustainability has been developed. Also, this chapter presented the theoretical grounding of this research. It addressed that theories such as the dynamic capability view, transaction cost theory and institutional theory provide a powerful lens to justify the adoption of blockchain technology in Agri-product supply chains, particularly for enhancing traceability for sustainability in various ways.

The theoretical grounding of this research addressed how the relationship between constructs is established. The model of the research is grounded in three theoretical lenses: the dynamic capability view (DCV) and transaction cost theory (TCT), and Institutional Theory (IT). It addressed the justification of the theory application of the research. Based on the justification of the theory integration and to fulfil the research objectives, the conceptual model is finalised with a set of hypotheses to test the direct, indirect and conditional effects among the variables involved in the study.

CHAPTER 3:

3.1 HYPOTHESIS DEVELOPMENT

3.1.1 Introduction

Based on the research framework in Figure 3.1 of Chapter 2, a set of research hypotheses on the relationships between blockchain adoption, blockchain adoption drivers, traceability, sustainability, technology orientation, upper management support, and sustainability governance is proposed. Nine potential research hypotheses have been formulated for empirical testing using the smart PLS Structural Equation Modelling (SEM) tool has formulated nine potential research hypotheses for empirical testing. A discussion relating to the inclusion of the control variable is then presented. The research hypotheses are discussed in the following section. To meet the study's objectives, this chapter also formulates and presents several hypotheses to examine the relationship between BCAD and other variables associated with supply chain traceability and sustainability.

3.1.2 Research hypotheses

A hypothesis is a proposition or statement about concepts created for empirical testing (Cavana et al., 2001). Research hypotheses establish a logical link between two (or more) research constructs, presented in a statement or line (Saunders et al., 2007, Sekaran, 2016). (By testing the hypothesis and either confirming or rejecting it, it is expected that a solution to the research problem can be found (Blumberg et al., 2014, Cavana et al., 2001).

3.1.3 Hypotheses regarding market dynamics to blockchain adoption

Market dynamics significantly affect the adoption of blockchain technology in organisations across various industries (Wong et al., 2020a, Wamba et al., 2020a, Wang et al., 2019a, Bag et al., 2023). Market dynamics refers to the forces and factors (demand fluctuation, competitive forces, technological advancements, globalisation, digital transformation, regulatory changes, customer preferences, and economic trends) that impact a market's behaviour, structure, and performance in the rapidly changing business environment (Wong et al., 2020a, Chittipaka et al., 2023). The effect of such forces and factors increasingly leads organisations to adopt new technologies, such as blockchain, to achieve a competitive advantage in the changing business environment (Bag et al., 2023, Chittipaka et al., 2023, Wamba et al., 2020a).

Previous studies indicate that the business environment is constantly evolving due to internal and external pressures (globalisation, digital transformation, consumer behaviour, environmental and social responsibility and disruptive events) (Mason, 2007). Also, stakeholders' cooperation and higher requirements on stakeholders' collaboration create pressure in the volatile market environment (Saberi et al., 2019a). In the current business environment, organisations are increasingly receiving attention to aligning with such internal and external pressure to achieve a competitive advantage (Hsing Wu et al., 2013, Nudurupati et al., 2021).

In light of the DCV, an organisation may need to adopt new technology because of business environmental pressure, influences of new technology, market pressure, and stakeholder pressure (Teece et al., 1997). For instance, firms must consider DC (dynamic capability) to mitigate such business environmental pressure to achieve a competitive advantage. Blockchain adoption for organisations is considered DC, as this technology can potentially enable transformational effects for organisations in many ways (Wamba et al., 2020a, Bai and Sarkis, 2020, Behnke and Janssen, 2020b).

At some stage, in response to dynamics capability, organisations need to change their strategic decisions and adopt new technologies, such as blockchain, because of stakeholders' pressure or demand fulfilment perspective in the volatile marketplace (Tian and Sarkis, 2020, Chittipaka et al., 2023, Bai and Sarkis, 2020, Chang et al., 2020, Kamble et al., 2019, Wamba et al., 2020b). To this end, dynamic capability profoundly affects in the changing business environment for organisations to stay competitive. Thus, organisations need dynamic capability by adopting new technologies, like blockchain, to respond to market dynamics. Based on the above, it is hypothesised that market dynamics positively influence blockchain adoption.

Hence, the research proposes the following hypotheses aligning with the dynamic capability view theory:

Hypothesis 1. *Market dynamics positively influence blockchain adoption in SC.*

3.1.4 Hypotheses regarding competitive pressure on blockchain adoption

Competitive pressure is one of the significant drivers influencing the adoption of blockchain technology across industries (Bag et al., 2023, Wong et al., 2020a). Competitive pressure is the external and internal pressure that drives organisations to adopt innovative technologies to gain a competitive edge in the changing business environment (Wong et al., 2020a, Oliveira et al., 2014, Kretschmer et al., 2012). It drives organisations to continuously improve their products, services, processes, and strategies to sustain their business and remain competitive (Kretschmer et al., 2012). In particular, competitive pressure also plays a significant role in adopting blockchain in the supply chain context (Wong et al., 2020a). To this end, blockchain adoption in the organisation is considered a dynamic capability (Wong et al., 2020a). Studies reveal that the DC drives organisations and is influenced by competitive pressure, which drives them to adopt new technologies, such as blockchain, to meet stakeholders' requirements in the changing business environment (Teece et al., 1997, Wamba and Queiroz, 2020b, Wong et al., 2020a, Shi and Yan, 2016). Therefore, organisations need the DC, the potential of blockchain capability, which encourages them to adopt blockchain to achieve a competitive advantage (Teece, 2007) in the volatile marketplace. For example, the expectation of blockchain-based traceability ensures a journey of products better than a centralised traceability system does (Hastig and Sodhi, 2020). To this end, competitive pressure may force them to make adoption decisions of blockchain for organisations. Studies indicate that competitive pressure between existing firms is essential in adopting blockchain in SCs to sustain a competitive advantage in the volatile business environment (Low et al., 2011, Nayak and Dhaigude, 2019). Organisations need dynamic capability by adopting new technologies such as blockchain to respond to competitive pressure. Hence, the research proposes the following hypotheses aligning with the dynamic capability view theory. Thus, based on the above, it is hypothesised that competitive pressure positively influences blockchain adoption.

Hypothesis 2. *Competitive pressure positively influences blockchain adoption in SC.*

3.1.5 Hypotheses regarding regulatory support for blockchain adoption

Evidence shows that rapid technological change and continuously changing business environment impact organisational business, where regulatory support plays an important role (Wong et al., 2020a, Shi and Yan, 2016). In the context of blockchain, regulatory support refers to the development and implementation of laws, rules, and guidelines designed to govern the use, adoption, and operation of blockchain technology across different industries, as with any new technology adoption (Wong et al., 2020a, Bag et al., 2023). With its decentralised nature, blockchain has the potential to disrupt many industries (from finance to healthcare), and it has both opportunities and challenges for regulators (Hughes et al., 2019, Helo and Hao, 2019). Ample regulatory support ensures quick adoption decisions of new technologies, such as blockchain, in supply chains (Safiullin et al., 2020). Hence, the research proposes the following hypotheses aligning with the dynamic capability view theory. Thus, based on the above, it is hypothesised that regulatory support positively influences blockchain adoption.

Hypothesis 3. *Regulatory support positively influences blockchain adoption in SC.*

3.1.6 Hypothesis regarding blockchain adoption to traceability

Organisations tend to adopt blockchain technology for many reasons. These include integrating technological changes, mitigating business risk factors, improving operational aspects, gaining opportunities in the uncertain business environment, or finding some scope for improving business operations. Blockchain adoption in the organisation is considered as a DC. Thus, organisations need DC (Teece, 2007, Wong et al., 2020a) to achieve a competitive advantage. Moreover, DC improves organisations' operational capability. To this end, traceability is an operational capability that improves operational performance in organisations in many ways. For example, a blockchain-based traceability mechanism enhances the operational performance of an organisation (Manupati et al., 2020). Therefore, organisations adopt blockchain to use traceability tools to identify the provenance of products and improve operational performance (Choi et al., 2020a). To this end, the underlying blockchain capability of traceability mechanism for sensing, seizing, and transforming opportunities depends on the organisation's dynamic capabilities (Teece, 2007, Wamba and Queiroz, 2020b). For instance, blockchain adoption in the organisation leads to a dynamic capability, which facilitates operational capability such as traceability in the supply chain (Garcia-Torres et al., 2019, Wamba et al., 2020a, Chowdhury and Quaddus, 2021a, Humdan et al., 2023). Therefore, organisations require decentralised traceability capability to control illegal practices, increase operational efficiency, improve sustainability, enhance supply-chain coordination, and sense market trends (Hughes et al., 2019, Hastig and Sodhi, 2020). Hence, the research proposes the following hypothesis aligning with the DCV theory. Thus, it is hypothesised that:

Hypothesis 4: *Blockchain adoption positively influences traceability.*

3.1.7 Conditional effect of TOR between BCAD and TRA

In blockchain adoption within the supply chain, technology orientation is critical in determining how effectively an organisation can integrate blockchain technology to improve transparency and operational efficiency, such as traceability (Halac, 2015, Pan et al., 2021). In this study, technology orientation (TOR) has a conditional effect on BCAD and TRA. TOR may extend the relationship between blockchain adoption and traceability as a supportive factor. Blockchain is a dynamic capability for organisations and their SC to meet and match the specificities of their business's internal and external environments. Specifically, BCAD leads to traceability, where organisations need technology orientation to adopt new technologies such as blockchain in their supply chain. In addition, the traceability (TRA) mechanism in the supply chain is an operational capability that improves operational efficiency. To this end, DC supports the moderating role of TOR between blockchain and traceability (Teece, 2018). Thus, it is hypothesised that:

Hence, the research proposes the following hypothesis, aligning with the DCV theory.

Hypothesis 5: *Technology orientation positively influences the relationship between blockchain adoption and traceability.*

3.1.8 Hypothesis regarding the conditional effect of UMS between BCAD and TRA

Blockchain adoption in an organisation needs a clear strategic vision to ensure its integration aligns with the firm's long-term goals, where upper management is responsible for setting this vision (Wamba et al., 2020b, Cole et al., 2019, Bueno and Gallego, 2017, Wong et al., 2020a). With strong leadership, blockchain adoption could become a strategic priority for an organisation rather than an experimental initiative (Low et al., 2011, Oliveira et al., 2014). Evidence shows that upper management support is one of the main success factors of originations for deciding to adopt new technologies, such as blockchain, as many studies have indicated (Bueno and Gallego, 2017, Ragu-Nathan et al., 2004, Wong et al., 2020a). In this study, upper management support is conditional between BCAD and TRA. As a supportive factor, UMS may extend the relationship between blockchain adoption and traceability. As shown above, in this study, blockchain is essentially a dynamic capability (DC) for organisations and their SC to meet and match the specificities of internal and external business environmental contexts. In addition, SC traceability is an operational capability that improves operational efficiency. To this end, DC supports the moderating role of UMS between blockchain and traceability (Teece, 2018). Thus, it is hypothesised that:

Hence, the research proposes the following hypothesis aligning with the DCV theory.

Hypothesis 6: *Upper management support positively influences the relationship between blockchain adoption and traceability.*

3.1.9 Hypotheses regarding blockchain adoption to SC sustainability

Organisations need blockchain technology to improve supply chain sustainability. Blockchain offers potential benefits for increasing operational efficiency, enhancing supply chain management, and sensing market forces to achieve a competitive advantage (Hughes et al., 2019, Wamba et al., 2020b, Wong et al., 2020a). Previous studies indicate that blockchain has the potential to transform supply chains by enhancing transparency, traceability, and accountability as a result, ensuring sustainability (Wong et al., 2020a, Garcia-Torres et al., 2019). In the context of supply chains, sustainability incorporates environmental, social, and economic factors, and blockchain can address each of these dimensions innovatively (Saberi et al., 2019b). Thus, blockchain can support sustainability in many ways in supply chain activities. For example, blockchain provides the creation of an immutable, transparent distributed ledger where the end-to-end supply chain transaction (from raw materials to final products) enables it to be recorded and visible to all members of the supply chain (Tönnissen and Teuteberg, 2020, Garcia-Torres et al., 2019). This transparency ensures that goods are sourced, produced, and distributed responsibly, aligning with the sustainability goals of the firm (Wamba and Queiroz, 2020a). Such visibility and transparency in the decentralised platform allow for ethical sourcing and combating unethical labour practices within a supply chain to prevent child labour, ensure fair wages, and guarantee safe working conditions (Hughes et al., 2019, Saberi et al., 2019b). Such practices in the supply chain allow recording contracts, certifications, and compliance data on an immutable blockchain ledger and adhere to support social sustainability (Saberi et al., 2019b, Kamble et al., 2019). In terms of sustainable sourcing and provenance, blockchain enables businesses to verify the sustainability credentials of the materials they source, reducing waste and increasing efficiency (Di Vaio and Varriale, 2020, Bai and Sarkis, 2020). Blockchain enables the ensuring of a circular economy and product lifecycle management by tracking products through each stage of the product lifecycle; blockchain ensures that materials are reclaimed and reused effectively, creating closed-loop systems. Businesses can leverage blockchain as a transformative solution to drive supply chain sustainability.

By improving transparency, traceability, efficiency, and accountability—through better tracking of materials, reducing waste, removing intermediaries, ensuring ethical sourcing, and optimising logistics—blockchain can help businesses meet their sustainability goals (Bai and Sarkis, 2020, Helo and Hao, 2019). However, there are challenges involved in the widespread adoption of blockchain technology, including cost, scalability, and data privacy (Queiroz and Wamba, 2019). Despite these challenges, blockchain has significant benefits of blockchain in creating supply chain sustainability, and as the technology matures, its impact on supply chain sustainability will likely grow (Treiblmaier, 2018). Therefore, blockchain as a dynamic capability (DC) offers to adopt change for a firm in a changing business environment (Teece, 2018). To this end, the link between blockchain adoption and sustainability (Teece, 2018, Kshetri, 2018, Min, 2019) aligns with DCV theory. Blockchain technology ensures operational efficiency, enhances financial benefits and improves supply chain sustainability (Kshetri, 2018, Min, 2019, Cole et al., 2019). Thus, combining all reasoning and arguments, it was hypothesised that:

Hence, the research proposes the following hypothesis aligning with the DCV theory.

***Hypothesis** 7: Blockchain adoption positively influences sustainability.*

3.1.10 Hypothesis regarding the conditional effect of SGV between TRA and sustainability

Sustainability governance and its practices are important for organisations. Organisations need sustainability governance to improve social, environmental and economic sustainability goals (Dauvergne and Lister, 2012, Chowdhury and Quaddus, 2021a). In this study, the conditional effects of SGV extend the relationship between TRA and sustainability. As a supportive factor, sustainability governance and its practice may improve traceability and supply chain sustainability. Organisations need traceability to comply with sustainability governance to achieve supply chain sustainability goals. Thus, from the lens of TCT, sustainability governance and its practices in the organisation improve traceability, reduce transaction costs and cost avoidance, minimise opportunistic behaviours in the supply chain practices, and improve sustainability (Hastig et al., 2020, Kamble et al., 2020b). To this end, TCT supports the role of sustainability governance between traceability and sustainability. Thus, it is hypothesised that:

Hence, the research proposes the following hypothesis aligning with the TCT theory.

Hypothesis 8: *Sustainability governance moderates the relationship between traceability and sustainability.*

3.1.11 Traceability ensures supply chain sustainability (SCS)

Traceability ensures supply chain sustainability. Traceability plays a significant role in ensuring supply chain sustainability by improving transparency, accountability, and efficiency of the operational activities of organisations and their supply chain (Treiblmaier, 2018, Manupati et al., 2020). Organisations adopt blockchain to improve operational performance in the rapidly changing business environment (Kamble et al., 2020b). The potential of blockchain is to support decentralised traceability and to improve operational performance in the organisation (Gurtu and Johny, 2019b, Wang et al., 2019b). Blockchain ensures dynamic capability (DC). Therefore, organisations need dynamic capabilities such as decentralised traceability to adopt change and achieve a competitive advantage (Teece et al., 1997, Saberi et al., 2019b). Traceability is a powerful tool for ensuring sustainability, from sourcing to manufacturing, distribution, and disposal in the end-to-end supply chain (Hastig and Sodhi, 2020, Bai and Sarkis, 2020).

Furthermore, traceability makes it possible to curb illegal practices, improve operational performance, increase operational efficiency, enhance supply chain coordination, improve sustainability and reduce transaction costs (Hastig et al., 2020, Roeck et al., 2020). To this end, TCT supports the link between traceability and sustainability. Thus, it is hypothesised that:

Hence, the research proposes the following hypothesis aligning with the DCV theory.

Hypothesis 9: *Traceability positively influences sustainability.*

3.1.12 Hypothesis related to the indirect effect of traceability

The indirect effect of traceability (TRA) (Cousins et al., 2019) between blockchain (BCAD) and sustainability is apparent in the model of the study. This indirect effect is not explicitly mentioned in the literature; however, based on the previous literature (Happy et al., 2023, Chowdhury et al., 2024), this study developed a hypothesis of TRA between blockchain adoption (BCAD) and sustainability. Therefore, Hypothesis 10 (H10) was presented in this study.

Traceability is an important factor in improving Agri-product supply chain sustainability. It is argued that a centralised traceability system is relatively lacking in transparency or visibility compared to a decentralised traceability system in supply chain activities (Bai and Sarkis, 2020, Kamble et al., 2019, Queiroz and Wamba, 2019, Saberi et al., 2019b). Along with the many limitations of a centralised traceability system in the conventional supply chain, a single point of failure is one of the important lacking. Thus, the Agri-products supply chain needs a decentralised traceability mechanism to combat the lack of a centralised traceability system.

In this study, blockchain adoption (BCAD) focuses on identifying and managing decentralised traceability (track and trace) mechanisms in the Agri-products supply chain (Kouhizadeh and Sarkis, 2018, Salah et al., 2019). Blockchain adoption in the supply chain ensures a decentralised traceability mechanism and provides transparency and visibility for tracing and tracking the Agri-products supply chain with an immutable information-sharing architecture (Hastig and Sodhi, 2020, Kamilaris et al., 2019). Evidence shows that traceability ensures sustainability (Kamble et al., 2023, Wong et al., 2020a, Cousins et al., 2019). In this study, the main objective of BCAD is to enhance traceability for sustainability. The model shows that traceability directly affects supply chain sustainability. Also, traceability indirectly affects sustainability through blockchain adoption. These effects positively influence Agri-products supply chain sustainability. Nobody has tested the indirect impact of TRA on BCAD and sustainability before. In this study, BCAD leads to traceability, traceability leads to sustainability, and BDAC leads to sustainability directly also, BCAD indirectly influences sustainability through traceability. Thus, we hypnotised that:

Hypothesis 10 (H10): *Traceability (TRA) mediates the relationship between blockchain (BCAD) and sustainability*.

3.1.13 Control Variable

This study considered two control variables: firm age and firm size, as shown in the model. A control variable is a variable that is held constant to analyse the relationship between other variables without interference (Bernerth and Aguinis, 2016).

Control variables help to clarify the relationships between other variables and eliminate confounding influences to ensure accurate precision of the model (Carlson and Wu, 2012). To achieve supply chain sustainability through blockchain adoption, organisational factors such as the size of the organisation have an impact. It is more likely that large organisations have the capability of implementing complex new technologies (e.g., BC), while small organisations are less likely to adopt complex technology. Therefore, this study uses firm age and firm size as a control variable following previous studies (Tabesh et al., 2024) to examine the robustness and reliability of the result and to identify whether any contextual factors influence blockchain adoption for traceability and sustainability model. With this consideration, the following hypotheses are presented.

CV 1: The size of the firm impacts blockchain adoption in the supply chain.

CV 2: The age of the firm impacts blockchain adoption in the supply chain.

3.1.14 Justification of the selection of control variables for the study:

The inclusion of **firm size** and **firm age** as control variables is theoretically and empirically justified in studies examining blockchain adoption in supply chains. **Firm size** often determines an organisation's financial resources, technological capability, and managerial readiness to adopt innovative systems such as blockchain (Maroufkhani et al., 2022). Larger firms generally possess greater capital and infrastructure to invest in emerging technologies and to manage the risks associated with implementation (Aboelmaged, 2014). Conversely, smaller firms may face constraints in terms of cost, expertise, and scalability, which may limit blockchain adoption. **Firm age**, on the other hand, reflects organisational experience, structural maturity, and openness to change (Burrell and Morgan, 2019, Hsu et al., 2014). Older firms may exhibit path dependency and resistance to adopting disruptive technologies, whereas younger firms tend to be more flexible and innovative in experimenting with blockchain solutions (Queiroz et al., 2019b). Therefore, controlling for firm size and age ensures that the analysis isolates the true effect of theoretical predictors on blockchain adoption, minimising bias from firm-specific characteristics.

3.1.15 Summary of the hypothesis

Based on the research objectives, ten hypotheses have been developed considering an extensive literature review of dynamic capability theory, transaction cost theory and Blockchain's role in supply chain traceability for sustainability. Hypotheses H1, H2, and H3 address the impact of business environmental drivers on blockchain adoption in organisational supply chain practices. Hypothesis H4 examines the relationship between blockchain adoption and traceability. A conditional effect of Hypothesis H5 extends the link between blockchain and traceability and plays a supportive role. Similarly, Hypothesis H6 extends the link between blockchain and traceability and provides a conditional effect. Hypothesis H7 addresses the direct link between blockchain and sustainability.

A conditional effect of Hypothesis 8 extends the link between traceability and sustainability. Finally, to explore blockchain adoption in the supply chain, Hypothesis H9 investigates the connection between traceability and sustainability. Furthermore, to support the indirect impact of traceability (TRA) between blockchain (BCAD) and sustainability, Hypothesis H10 has been developed. To this end, Hypothesis H10 examines the mediating role of traceability (TRA) between blockchain adoption and sustainability. Table 3.1 presents the research hypotheses for this study.

Table 3.1 Research hypotheses

Hypothesis No	Hypotheses
H 1	Market dynamics positively influence blockchain adoption.
H 2	Competitive pressure positively influences blockchain adoption.
H 3	Regulatory support positively influences blockchain adoption.
H 4	Blockchain adoption positively influences traceability.
H 5	Technology orientation moderates the relationship between blockchain adoption and traceability.
H 6	Upper management support moderates the relationship between blockchain adoption and traceability.
H 7	Blockchain adoption positively influences sustainability.
H 8	Sustainability governance moderate the relationship between traceability and sustainability.
H 9	Traceability positively influences sustainability.
H10	Traceability mediates the relationship between blockchain adoption and sustainability

3.2 Summary:

This chapter presented the hypothesis development of the research. Based on the research objectives, ten hypotheses have been developed considering an extensive literature review of dynamic capability theory, transaction cost theory, institutional theory and Blockchain's role in supply chain traceability for sustainability.

CHAPTER 4:

4.1 RESEARCH METHODOLOGY

4.2 Introduction

The previous chapter demonstrated the theoretical framework and hypothesis development of the study. This chapter seeks to expand the research model presented in Chapter 2, Figure 4, by incorporating epistemological perspectives and verifying the conceptual propositions. An extensive literature review of this study reveals that research in blockchain adoption in supply chain management deploys quantitative and qualitative methods (Di Vaio and Varriale, 2020, Saberi et al., 2019b, Cole et al., 2019). Conceptual studies (Howson, 2020, Treiblmaier, 2019, Jayaraman et al., 2019b) and case study research (Choi et al., 2020a, Kittipanya-ngam and Tan, 2020) are also prevalent in blockchain-enabled supply chain research. There is a limited amount of mixed-method research that integrates both qualitative and quantitative approaches in the field of blockchain-enabled supply chain studies. For example, Remko van (2019) explored a mixed-method approach and argued the importance of qualitative study before conducting quantitative research on blockchain in the supply chain domain. However, considering the research objective, the quantitative research method is best suited to answer the research questions of this study. Therefore, quantitative survey research on blockchain adoption for Agri-products supply chain traceability and sustainability study has been conducted. To achieve this, a comprehensive literature review was conducted to provide context for the preliminary study and to confirm the causal relationships among different factors within the research model.

From a philosophical standpoint, this study follows a positivist research approach and utilizes survey research as the primary method for data collection in this quantitative study. In line with the research objectives, this study adopted a positivist paradigm using a quantitative method (Chowdhury, 2016). To this end, the quantitative data collection of this research relies on a survey research design. This chapter provides a detailed explanation of the overall research design for this study. The first section explores the methodological choices and the underlying research paradigm or philosophy, clarifying the research method used and offering justification for its selection. Figure 4.1 depicts the research 'Onion' model for the underlying research design for the research process of this study (Saunders et al., 2009). The following section represents the research process of the quantitative study. Finally, a summary of the chapter is discussed.

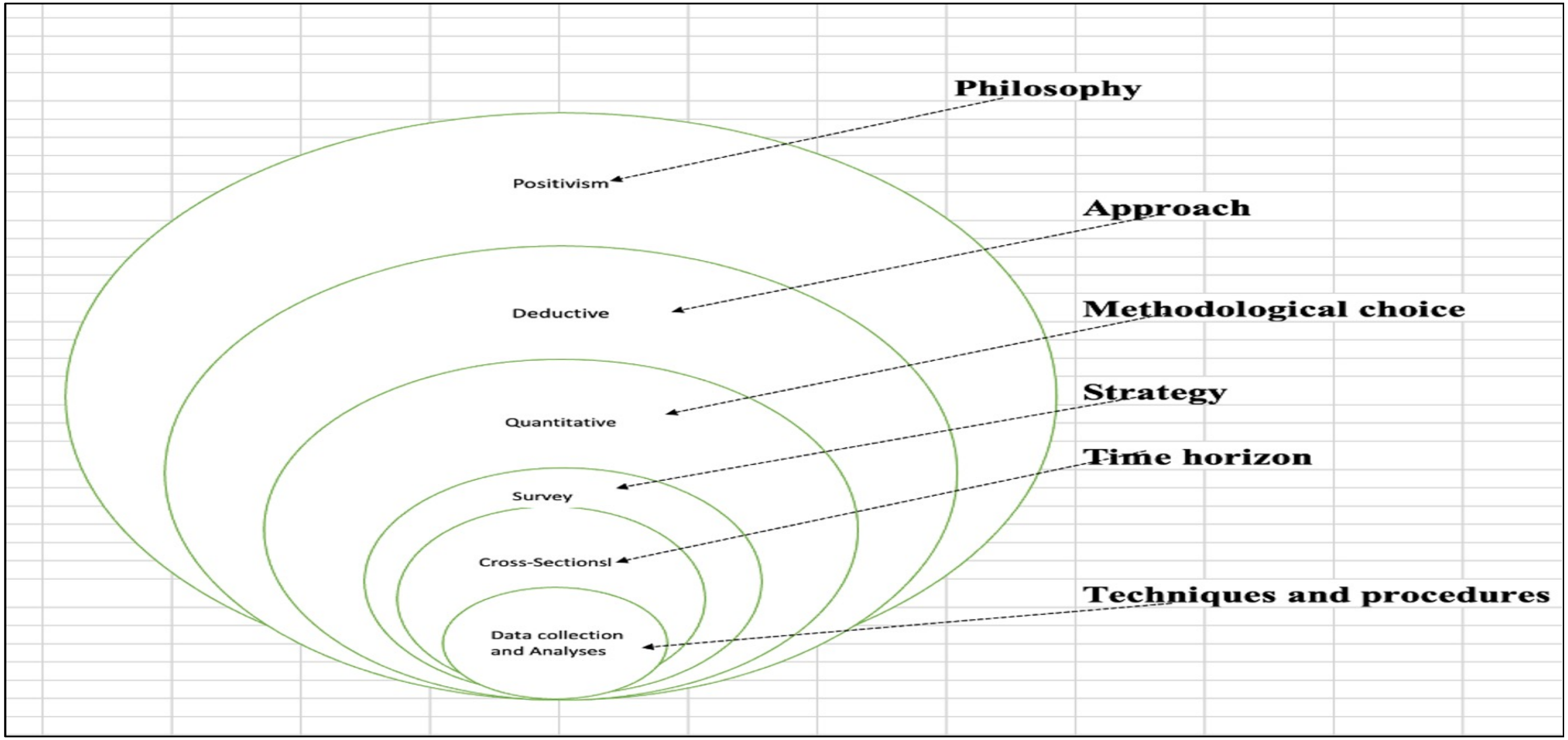

Figure 4.1 The research 'Onion' model.

Onion Research Model

The Research Onion, introduced by Saunders et al. (2019), provides a structured framework for designing research methodology in a step-by-step manner. At its outer layer, research philosophy reflects the researcher's assumptions about reality and knowledge, such as positivism, interpretivism, pragmatism, or critical realism (Creswell & Creswell, 2018). The next layer, research approach, determines how theory and data interact, whether through deduction (theory testing), induction (theory building), or abduction (iterative reasoning) (Bryman, 2016). Methodological choice guides whether the study adopts a mono-method, multi-method, or mixed-methods approach, depending on the complexity of the research questions (Creswell & Plano Clark, 2017). The research strategy layer outlines how the study will be conducted, with options such as surveys, case studies, ethnography, experiments, or grounded theory (Yin, 2018). The time horizon distinguishes between cross-sectional studies, which capture data at a single point in time, and longitudinal studies, which explore changes over time (Rindfleisch et al., 2008). At the core, techniques and procedures specify the actual tools and processes for data collection and analysis, including interviews, questionnaires, statistical tests, or thematic analysis (Silverman, 2020). By moving inward through these layers, the Research Onion ensures methodological consistency, linking philosophical assumptions with practical techniques to strengthen the rigour and validity of research (Saunders et al., 2019).

4.2.1 Research methodology decisions

Research design is the overall strategy or blueprint for collecting, measuring, analysing and interpreting data to answer research questions (Saunders et al., 2009, Guba and Lincoln, 1994, Creswell, 2018, Sekaran, 2016). It provides clarity to research strategy, findings and ethics design (Saunders et al., 2009). Research design needs to articulate decisions and answer research questions regarding research strategies, level of analysis, study location, unit of analysis and time horizon (Bougie and Sekaran, 2019). An appropriate quantitative method of survey research design, data collection procedure, and the most robust data analysis methods for determining the validity and reliability of the measures, hypothesis testing, and interpretation of the findings and results were all used in this study.

Evidence shows that any substantial research project must be based on rigorous scientific methodology (Irani et al., 1999). An appropriate methodological choice is vital for any research process to resolve a research problem or answer the research questions (Irani et al., 1999). In particular, methodology refers to the overall approach to the research process, from the theoretical underpinning to data collection and analysis. On the other hand, methods refer to the various means by which data can be collected and analysed (Collis and Hussey, 2013, Creswell, 2018, Strang, 2015a). Further, research methodology is a way of systematically solving the research problem. Conducting a research project requires a decision about the choice of methodology from the possible alternatives or opportunities, while the foundation of this choice is the research paradigm or philosophy.

4.2.2 Research paradigm or philosophy

Research philosophy refers to the beliefs and values guiding researchers to understand and develop knowledge, including their view of the world and its scientific nature (Saunders et al., 2007). The different research philosophies are realism, interpretivism, and positivism. Realism assumes a scientific approach to inquiry, while interpretivism, the opposite of realism, undertakes an empathetic view using a humanistic approach to research (Guba and Lincoln, 1994, Saunders et al., 2009, Sekaran, 2016). According to Saunders et al. (2007), positivism is aligned with knowledge development, uses existing theory to build hypotheses, and is commonly supported by a literature review to define variables. Positivism refers to the thinking that challenges the traditional notion of the absolute truth of knowledge and recognises that one cannot be positive in one's assertion of knowledge when analysing phenomena of behavioural patterns and human response (Creswell & Creswell, 2017). Positivism is the oldest research philosophy and is evidence- and theory-driven (Crotty, 1998).

Thomas Kuhn (1962) coined the term paradigm, which refers to an interpretive matrix. A paradigm is a set of ideas that shape how data is interpreted (Kuhn, 1962). Subsequently, the term paradigm extended to Research Paradigm (Johnson and Onwuegbuzie, 2004). Research paradigm is the way of knowing the world, worldview, and taken-for-granted beliefs (Kuhn, 1962, Babbie, 2020, Johnson and Onwuegbuzie, 2004). Worldview means "a basic set of beliefs that guide action'' (Guba, 1990). A research paradigm is a comprehensive belief system, worldview or framework that guides practices in a specific field (Willis et al., 2007). In particular, a research paradigm provides a basic or foundational layer of assumptions about fundamental issues, such as the nature of truth (ontology) and what it means to know (epistemology) (Willis et al., 2007). Strang (2015b) introduced a research paradigm as "How the researcher thinks about knowledge claims" (p, 18). To this end, several paradigms are available for creating and developing new knowledge. For example, four discrete research paradigms are introduced: positivism, post-positivism, critical theory, and constructivism (Guba and Lincoln, 1994). Similarly, it discusses four key paradigmatic perspectives on knowledge: post-positivism, constructivism, pragmatism, and participatory approaches (Creswell, 2018). Positivism and interpretivism are two leading research paradigms. Positivism paradigms are based purely on facts and consider the real world through an external objective approach (Gray, 2013). Under a positivistic paradigm, the normal process is to study the literature to establish an appropriate theory and construct a hypothesis for the study (Collis and Hussey, 2013). A hypothesis refers to an idea or proposition that needs to be tested using statistical analysis.

In blockchain adoption research within the Agri-product supply chain, ensuring methodological fit between research objectives, theoretical framing, and data analysis techniques is crucial for producing rigorous and credible findings. A coherent alignment among these elements enables researchers to capture the complex interactions between technology adoption, supply chain traceability, and sustainability outcomes (Edmondson and McManus, 2007). Given the multidimensional nature of agricultural supply chains, careful integration of theory and empirical design helps avoid inconsistencies that may obscure meaningful insights (Sekaran, 2016). High-quality research in this field requires not only a thorough literature review but also appropriate methodological choices that reflect the realities of agricultural contexts (Bryman, 2016, Edmondson and McManus, 2007). Ultimately, maintaining methodological fit strengthens the validity and applicability of blockchain research in advancing sustainable and transparent Agri-product supply chains (Saunders et al., 2009, Edmondson and McManus, 2007).

This study is based on the positivist paradigm, guided by its ontological stance (belief about the nature of reality), epistemological approach (understanding of knowledge and the separation between the researcher and the subject of study), and methodological framework (the process of investigating phenomena and generating knowledge) (Burrell and Morgan, 2019). Table 4.1 represents the summary of the research paradigm used for this study:

Table 4.1 Summary of this research paradigm

Positivism	**Ontology**	**Epistemology**	**Methodology**
Characteristics and explanation	Naïve realism The author believes that reality exists and can be observed and measured.	Objectivist The author believes knowledge is the transparent reflection of external reality and can be discovered objectively. The author is detached from what is to be studied, and the objective is to discover the truth.	Predominant quantitative method The study uses empirical data to verify and validate research hypotheses based on the literature and theories.

The research paradigm for this study is shaped by its objectives, nature, and contextual framework. The study aims to develop a model for blockchain adoption in supply chain traceability and sustainability, specifically within the agri-product sector. To achieve this, it seeks to identify measurable and observable determinants of supply chain traceability for sustainability. Thus, the study has developed hypotheses and identified variables that will be quantified and measured to test these hypotheses.

It will draw reasoning based on a statistical analysis of the research data of the study. A quantitative approach is the most suitable method for addressing the research questions and fulfilling the study's objectives. Therefore, the positivist research paradigm aligns well with this study.

Several rationales support the adoption of quantitative methods in this study. For example, blockchain adoption in the supply chain is still in its infancy, and the related theoretical foundations are yet to be established (Kummer et al., 2020). The factors (drivers) influencing blockchain adoption in the supply chain have not been explored yet. As a result, there is a need to conduct an exploratory study on blockchain adoption for supply chain traceability and sustainability because the concepts and theories applications are also in the nascent stage. Moreover, traceability is a context-dependent mediator; for instance, drivers and variables discussed in the related literature are verified with a pilot study through survey data from the Agri-products context to contextualise the research model (Aung and Chang, 2014). Additionally, the drivers related to BCDA have been explored in the context of the Agri-products. All the above factors justify adopting the quantitative method for this research. In particular, the logic behind applying the quantitative survey method for this research is very firm. The relevant factors and variables associated with blockchain adoption in supply chain traceability and sustainability (BCAD in SC) have been examined, and their relationships have been statistically tested and validated using quantitative data analysis. This reinforces the rationale for employing a quantitative research method.

4.3 Research method

Mixed-method research is becoming increasingly popular in many disciplines, including social and behavioural science (Johnson et al., 2007, Chowdhury and Quaddus, 2016). Mixed-method involves a collection of both qualitative (open-ended) and quantitative (close-ended) data in response to the research questions or hypothesis, which is incorporated into a distinct design according to a particular research philosophy (Creswell and Creswell, 2017, Tashakkori and Teddlie, 1998). Research suggests that a mixed-method approach often reflects a pragmatic worldview, where pragmatism allows for the integration of multiple methods, diverse perspectives, and varied data collection and analysis techniques (Creswell and Creswell, 2017).

Pragmatism paves the way for selecting methods from available opportunities and provides insight into how research approaches can be mixed effectively (Hoshmand, 2003). In particular, Mixed-methods research is widely recognized as the third research paradigm, serving as a bridge between qualitative and quantitative methods at different stages of the research process (Johnson et al., 2007; Onwuegbuzie & Leech, 2005). Equally, mixed-method research allows researchers to synthesise data that bridges ideas from qualitative and quantitative research fields (Johnson et al., 2007). It also offers a stronger understanding of the research problem or questions and helps to overcome the limitations of each method (from data collection strength and limitation point of view) (Creswell and Creswell, 2017). To this end, mixed-method research draws on both (qualitative and quantitative) research and minimises the weaknesses of both approaches (Tashakkori and Teddlie, 2021, Creswell and Creswell, 2017).

In contrast, there are many challenges involved in mixed-method research, such as extensive data collection challenges, the time-intensive nature of analysing data for both aspects (qualitative and quantitative), and the requirement for researchers' expertise in both methods (Creswell and Creswell, 2017). However, In mixed-methods approaches, qualitative and quantitative research complement each other, either in a parallel or sequential manner, to enhance the study's validity (Creswell & Creswell, 2017; Johnson et al., 2007). Morse (1991) argued that methodological triangulation strongly supports using at least two methods, usually qualitative and quantitative, to address the same research problem. On the one hand, qualitative research helps identify key factors and variables, while quantitative methods provide statistical validation and evidence for these elements. To this end, a mixed method may be suitable for this research.

Concerning mixed or multiple methods, Campbell and Fiske (1959) introduced the concept of triangulation. Denzin (1970) provided the logic behind triangulation and advocated that multiple methods (mixed methods) must be used in every investigation because "no single method ever adequately solves the problem of rival casual factors" (Denzin, 1070, p. 26). Field and Morse (1985) emphasised two types of methodological triangulation: simultaneous and sequential. Simultaneous Triangulation refers to the use of qualitative and quantitative methods at the same time. Sequential Triangulation is used if the result of one method is essential for planning the subsequent method. To this end, triangulation ensures the most comprehensive approach to solving the comprehensive research problem if a single research method is inadequate to solve the research problem (Morse, 1991). According to Denzin (1970), three triangulation approaches are convergence, inconsistency, and contradiction. Focusing on methodological triangulation, Creswell and Creswell (2017) introduced three core mixed-method designs: the convergent design, the explanatory sequential design, and the exploratory sequential design. In a convergent mixed-methods design, researchers gather and analyse qualitative and quantitative data independently, then compare the results to assess whether they align or contradict each other (Creswell and Creswell, 2017).

Moreover, the explanatory sequential mixed-method design involves a two-phase project in which the researchers collect quantitative data in the first phase, analyse the result, and then use the qualitative phase to help explain the quantitative result (Creswell and Creswell, 2017). Exploratory sequential mixed method design involves a three-phase project; in the first phase, the researchers collect qualitative data and analyse it, then design a quantitative feature based on the qualitative result (e.g., new variables, an experimental intervention, a website) and finally, test the quantitative feature (Creswell and Creswell, 2017). In particular, the triangulation design allows researchers to combine qualitative and quantitative data, using qualitative insights to validate or further elaborate on quantitative findings (Creswell and Creswell, 2017, Johnson and Onwuegbuzie, 2004). It is important to determine a suitable method for an appropriate research framework. To determine the most suitable research method for this study, its objectives were carefully evaluated. The primary goal is to develop a model for blockchain adoption in supply chains, focusing on traceability for sustainability in the Agri-product sector.

To help operationalise the research objectives, a primary research model (Figure 3, in Chapter 2) was proposed based on an extensive literature review. Since blockchain adoption in supply chains remains in its early stages and traceability is highly context-dependent, an extensive literature review was conducted to ensure the model's relevance and validity. Consequently, a comprehensive model has been developed based on this review, incorporating scales (see Chapter 2) from existing studies. Thus, a pilot test through a quantitative survey has been conducted to test the comprehensive model. To this end, this study is suitable for a quantitative (deductive approach) survey design to address the study's research questions. Therefore, deductive approaches to quantitative method are appropriate for analysing the research data for this study.

4.4 Level of analysis

The level of analysis refers to the scope of the study or perspective from which the research is conducted. This study focuses on blockchain in supply chain traceability and sustainability of Agri-products from the micro-level (firm-level-Agri-products supply chain) to macro-level (social, environmental and economic sustainability) analysis. This study specifically analysed the influence of blockchain adoption (BCAD) drivers on the Agri-products supply chain. The drivers such as three business environmental factors market dynamics (MDY), competitive pressure (CPR), and regulatory support (RGS). It incorporates mediator effects of traceability (TRA), along with three moderators' roles technology orientation (TOR), upper management support (UMS) and sustainability governance (SGV) in identifying social (SOC), environmental (ENV) and economic (ECO) supply chain sustainability.

4.5 Unit of analyses

The unit of analysis refers to the factors, variables, processes, relationships, and phenomena defined by the scope of the study (Krause et al., 2018). It sets the stage for the sampling method to identify appropriate respondents for the research (Sekaran, 2016). In particular, the unit of analysis defines the study's boundaries; it also determines what is in and what is not and enables researchers to identify potential key respondents (Krause et al., 2018). The unit of analysis needs to be consistent with the research questions and the purpose of the study (Krause et al., 2018). To ensure research findings and validate applicability, identifying appropriate units of analysis is important (Creswell and Creswell, 2017).

Considering the research questions addressed, the research strategy focused on analyzing the key factors—market dynamics, competitive pressure, and regulatory support—that primarily impact blockchain adoption in Agri-product supply chain traceability and sustainability (Wong et al., 2020a). The hypotheses of this study were tested using survey data, which was collected from the global Agri-products supply chain. Based on the boundaries established by the unit of analysis and the research questions, this research chose multiple respondent surveys to access information from the global Agri-products supply chain actors. Evidence shows that collecting survey data from multiple respondents can increase sample size and lower response rates (Krause et al., 2018).

However, several authors have argued that a single-respondent survey can lead to individual bias and recommended multiple respondents survey to ensure bias-free research findings and validity (Boyer and Verma, 2000, Malhotra and Grover, 1998, Hair Jr et al., 2014). To this end, this study surveyed supply chain actors focused on producers, processors, transporters, wholesalers, and retailers from the global Agri-products industries. The research design of this study focused on the specified areas from which to collect survey data because they were most likely to have knowledge and expertise in the blockchain adoption supply chain.

4.6 Measurement items and related constructs

Based on an extensive literature review and in light of the research objectives, this research emphasised testing blockchain adoption drivers, specifically focusing on business environmental drivers on blockchain adoption in supply chain traceability and sustainability, considering the mediating role of traceability, the moderating role of technology orientation, upper management support and sustainability governance for the Agri-product supply chain context (please refer to the Appendix 3). The following section provides all constructs and measurements for this study. First, Table 4.2 represents the three business environmental drivers of market dynamics (MDY), competitive pressure (CPR), and regulatory support (RGS). Secondly, blockchain adoption (BCAD) is presented in Table 4.3, while Table 4.4 shows traceability (TRA). The supply chain sustainability includes social (SOC), environmental (ENV), and economic (ECO) is presented in Table 4.5, while Table 4.6 presents technology orientation (TOR). Upper management support (UMS) is represented in Table 4.7, followed by sustainability governance (SGV) in Table 4.8. Finally, this research considered three control variables, including firm age and firm size, presented in Table 4.9.

Table 4.2 Constructs and measurement items of business environmental drivers

INDEPENDENT VARIABLES	CONSTRUCTS	MEASUREMENT ITEMS	SOURCES
Business Environmental Drivers	Market Dynamics (MDY)	MDY1: Customer preferences or requirements are always changing in my industry. MDY2: My industry is sensitive to changes in the marketplace. MDY3: In my industry, change is difficult to predict.	Wong et al. (2020a)
	Competitive Pressure (CPR)	CPR1: My firm believes that we may lose customers if we do not use BOSCM. CPR2: My firm believes that using BOSCM to gain competitiveness is important when making strategic decisions. CPR3: My firm believes that other firms in our industry have recently begun to explore BOSCM. CPR4: Social features such as customs and cultures force my firm to look into BOSCM. CPR5: Competitive pressures force my firm to look into BOSCM.	Wong et al. (2020a)
	Regulatory Support (RGS)	RGS1: BOSCM development receives financial support from the government or relevant authorities. RGS2: Relevant policies are introduced by the government to boost BOSCM development. RGS3: There is legal support for the use of BOSCM.RGS4: The laws and regulations that exist nowadays are sufficient to protect the use of BOSCM.	Wong et al. (2020a)

Table 4.3 Constructs and measurement items for blockchain adoption

VARIABLE	CONSTRUCTS	MEASUREMENT ITEMS	SOURCES
DEPENDENT VARIABLE Blockchain Adoption	Blockchain Adoption (BCAD)	BCAD1: My company invests resources in blockchain-enabled supply chain applications. BCAD2: Business activities in our company require the use of blockchain technologies. BCAD3: Functional areas in my company require the use of blockchain technologies	Wamba et al. (2020)

Table 4.4 Constructs and measurement for traceability

VARIABLES	CONSTRUCTS	MEASUREMENT ITEMS	SOURCES
MEDIATOR Traceability	Traceability (TRA)	TRA 1: We know the sources of our raw materials. TRA 2: We track the processes involved in producing product throughout our complete supply chain. TR A3: We trace the origins of our purchases through the entire supply chain. TRA 4: We track the environmental performance of our complete supply chain. TRA 5: We know what chemicals or elements are in our purchased components.	Cousins et al. (2019)

Table 4.5 Constructs and measurements for sustainability

DEPENDENT VARIABLE	CONSTRUCTS	MEASUREMENT ITEMS	SOURCES
Supply Chain Sustainability	Social (SOC)	SOC1: We emphasize on paying fair wages to the employees in our supply chain. SOC2: We emphasize on providing due benefits to the employees in our supply chain. SOC3: We emphasize on managing hazard and safety issues in our supply chain. SOC4: Our supply chain members manage adequate health and sanitation for the employees. SOC5: Our supply chain members do not use child labor in their plants. SOC6: Our supply chain members do not use force labor in their plants.	Chowdhury and Quaddus (2021)
	Environmental (ENV)	ENV1: We take measures to control water pollution in our supply chain. ENV2: We take measures to control Air pollution in our supply chain. ENV3: We take measures to control Soil pollution in our supply chain. ENV4: Our supply chain members recycle wastes or sell wastes to recyclers. ENV5: Our supply chain members do not use any environmentally hazardous material. ENV6: We emphasize on environment certification and audit process in our supply chain. ENV7: Our supply chain members comply environment legislation.	Chowdhury and Quaddus (2021)

	Economic (ECO) (financial)	ECO1: Our supply chain members manage satisfactory sales volume ECO2: Our supply chain members manage low cost of sales ECO3: Our supply chain members manage good profit margin.	Chowdhury and Quaddus (2021)

Table 4.6 Constructs and measurement for Technology orientation

MODERATOR	CONSTRUCTS	MEASUREMENT ITEMS	SOURCES
Technology Orientation	Technology Orientation (TOR)	TOR1. Our organisation proactively develops new technologies. TOR2. Use sophisticated technologies in new product development. TOR3. New products are always at the state of the art in the level of the technology. TOR4. Technological innovation is readily accepted in our program/project management. TOR5: Based on the results of technological innovation, it has been accepted by our organisation.	Yu et al. (2022)

Table 4.7 Constructs and measurement for upper management support

MODERATOR	CONSTRUCTS	MEASUREMENT ITEMS	SOURCES
Upper Management Support	Upper Management Support (UMS)	UMS 1: Our upper managers actively respond and pay attention when a project is initiated. UMS 2: Our upper managers support by providing labour resources, finances and materials for BOSCM. UMS 3: Our upper managers are willing to accept risks when adopting BOSCM. UMS 4: Our upper management inspires employees to apply the latest blockchain technologies in daily work. UMS 5: Our upper management encourages innovation.	Wong et al. (2020a)

Table 4.8 Constructs and measurement for sustainability governance

MODERATOR	CONSTRUCTS	MEASUREMENT ITEMS	SOURCES
Sustainability Governance	Sustainability Governance (SGV)	SGV 1: We monitor social compliance (e.g., fair payment, working condition, employee welfare, human rights, freedom of association etc) of our supply chain. SGV 2: We provide incentive to supply chain members to improve social sustainability. SGV 3: We evaluate sustainability performance of our supply chain. SGV 4: We monitor environmental performance of suppliers. SGV 5: We provide incentive to supply chain members to improve environmental performance. SGV 6: We strictly comply with labor laws (e.g., no child labor, no force labor, fair wages etc.) in our organization. SGV 7: We do career planning for staff development.	Chowdhury and Quaddus (2021)

Table 4.9 Constructs and measurement for control variable

	CONSTRUCTS	MEASUREMENT ITEMS	SOURCES
Control Variable	Control Variable (CV)	CV 1: Size of the firms has an impact on blockchain adoption supply chain. CV 2: Age of the has an impact on blockchain adoption supply chain.	Chowdhury (2014)

4.7 Research process

In line with the extensive literature review, we contextualised and validated the initial model and quantitative methods and executed the confirmatory factors of the study. Figure 4.2 illustrates the entire research process of this study

Step 1. Literature review

The first phase commenced with a critical review of the literature on blockchain adoption in supply chains for traceability and sustainability. An extensive literature review helped identify the research gap and build research questions. In particular, a literature review is the backbone of every academic piece of writing (Seuring and Gold, 2012). Adding to that, as a foundation of the model of this study, two relevant theories, namely, dynamic capability view (DCV) and transaction cost theory (TCT), were also reviewed from the strategic management literature. The critical review indicates that a blend of dynamic capability view (DCV) and transaction cost theory (TCT) can provide a solid theoretical foundation for the proposed model. Therefore, the key constructs identified in the study, along with their interrelationships in the proposed model, will be conceptualised to support the theoretical basis (refer to Chapter 3). This process is still underway.

Step 2: Development of an initial research model

An initial model of Blockchain for supply chain traceability and sustainability is developed based on the literature review, diagrammatically represented in Figure 4.2.

Additionally, the literature review helped to rationalise and justify the constructs, moderators, mediators, and the relationships between the constructs in the primary model.

Structure	**Descriptions**	**Output**
Chapter 1	1) Overview of the research. 2) Developing research problem.	Research questions and objectives
Chapter 2	1) Theoretical background. 2) Research gap. 3) Drivers/Construct/measurement items. 4) Conceptual framework. 5) Theoretical Framework	Review of the relevant literature and developing an initial research model, Grounded research model
Chapter 3	1) Hypothesis Development. 2) Dypothesis aligned with the research model.	Finalise hypothesis.
Chapter 4	1) Explaining the research design and methodological stances of this study. 3) Questionnaire development. 4) Details of the quantitative study. 5) Justification of using partial list squire (PLS) structural equation modelling (SEM) technique.	Determines the methodology for this study & design survey instrument.
Chapter 5	1) Analyses survey data by deploying the PLS-SEM technique.	Report the survey analysis data
Chapter 6	1) Discussion on findings.	Interprets the result of analysis
Chapter 7	Overview of the research, limitations and future research directions.	Summarises the thesis

Figure 4.2 The research process of the study

Step 3: Model refinement

The findings from the literature review were assessed by following existing studies (Kamble et al., 2023; Chowdhury, 2014). The essential addition of constructs and items and the subtraction of redundant items and constructs are chosen based on further literature review. The selected construct and dimension have been analysed and justified based on the previous theories and studies. A final research model will be proposed based on this refinement process.

Step 4: Hypothesis construction

To develop a logical and testable hypothesis in the proposed research model, the researcher will justify each link between constructs by carefully reviewing the relevant theories and applications. In this process, nine hypotheses are developed to verify the links between constructs quantitatively. Chapter 3 provides the development of the hypotheses and a detailed discussion.

Step 5: Questionnaire design

For this research, an initial questionnaire was created based on 11 constructs and nine hypotheses. Content validity was ensured by using measurement items for each construct derived from existing literature. The questionnaire was designed with a seven-point Likert scale. Chapter 5 presents the details of the questionnaire design and development. The reliability and validity of the measurement items is ensured via a developed questionnaire that will be evaluated and refined through the pre-testing procedure.

Step 8: Survey data collection

Online survey data will be collected using a questionnaire for global Agri-products industries. Data will be collected from supply chain decision-makers in these industries. Respondents from the Agri-products supply chain (producers, processors, transporters, wholesalers, and retailers) were selected by purposive sampling. As blockchain adoption in agriproduct supply chains is still in its nascent stage, it creates both opportunities and challenges for research. Since the technology is at an early phase of integration, empirical evidence remains limited, requiring a longer timeframe to capture meaningful data and outcomes (Casino et al., 2019). The evolving nature of blockchain applications in agriculture means that current findings may only reflect experimental or pilot initiatives rather than mature implementations (Saberi et al., 2019a).

Step 9: Cross-sectional study

The data collection for this study employed a cross-sectional time horizon, capturing information at a single point in time. Cross-sectional data collection is a research approach that gathers information from respondents at a single point in time, enabling researchers to identify patterns, associations, and prevalence of variables within a population (Bryman, 2016). This method is particularly useful in social science and management studies because it allows for the efficient comparison of groups without requiring extended follow-up periods (Setia, 2016). It provides a snapshot of reality, making it effective for hypothesis testing and identifying correlations between constructs (Levin, 2006). However, cross-sectional studies are limited in their ability to establish causality, as temporal relationships between variables cannot be fully captured

(Rindfleisch et al., 2008). Despite this limitation, they remain a cost-effective and practical strategy for collecting empirical data across diverse contexts (Creswell and Creswell, 2017). In supply chain and technology adoption research, cross-sectional surveys are widely applied due to their scalability and ability to capture stakeholder perspectives efficiently (Podsakoff et al., 2003).

Step 10: Data analysis

The collected data will be analysed using SPSS and PLS-based structural equation modelling (SEM) techniques (Chin, 1998, Richter et al., 2016, Ringle et al., 2012, Urbach and Ahlemann, 2010). SPSS will be employed for descriptive statistical analysis, whereas PLS-based SEM will be used for testing indicator weights and hypotheses.

Step 11: Discussion

The final step of the research process will involve discussing and interpreting the results derived from the quantitative data analysis.

4.8 Quantitative study

The quantitative analysis will begin with confirming and validating the factors, variables, and their relationships in the study. The quantitative phase of this research will involve developing the hypothesis and questionnaire, pre-testing the questionnaire, conducting a pilot study, selecting the sampling technique, collecting quantitative data, and analyzing the data using the partial least squares (PLS) method.

4.8.1 Hypothesis and questionnaire development

The primary questionnaire is designed to assess the various dimensions and relationships outlined in the refined model to test the hypothesised relationships among the constructs. Based on the comprehensive model of this research, nine hypotheses were developed to test the different links and relationships between the constructs of the model. This research deployed close-ended questions in designing the survey instrument. Evidence from previous studies indicates that most Structural Equation Modelling (SEM)-based empirical research use the Likert scale to measure items in the survey instrument (Wong et al., 2020a). SEM is the most popular technique for hypothesis and theory testing (Wamba et al., 2020a). To achieve this, a seven-point Likert scale has been used to gather data based on the participants' level of agreement or disagreement with each statement (1=Strongly disagree, 2= Disagree, 3= Somewhat disagree, 4= Neither agree or disagree, 5=Somewhat agree, 6=Agree, and 7=Strongly agree). Evidence shows many advantages of selecting a seven-point Likert scale in SEM-based empirical research; it (seven-point Likert) offers greater sensitivity and precision, improved data normality, and enhanced reliability and validity (Dawes, 2008, Cohen et al., 2013). A seven-point Likert scale offers more options for respondents to express their opinions, which can lead to more data reliability (Cohen et al., 2013). It is also evident that more subtle data collected with a seven-point scale can lead to increased statistical power in hypothesis testing (Cohen et al., 2013). To this end, this study deploys a seven-point Likert scale survey instrument for collecting research data.

4.8.2 Pre-testing of the questionnaire

The primary questionnaire was pre-tested by distributing it to 12 respondents, including six supply chain management academics, two Agri-products producers, two Agri-products processors, and two Agri-products retailers. The respondents were asked to provide suggestions/feedback about adding or deleting questions for clarification. This process aids in simplifying the questionnaire and reaching an agreement on its clarity and validity. Based on the feedback from these experts, necessary revisions were made, leading to the development of the final version of the survey instrument/questionnaire for the study.

4.8.3 Pilot study

A pilot study was conducted to enhance the simplicity, applicability, and validity of the questionnaire using feedback, and necessary changes will be made based on the research model on the outcome of the pilot study. In some firms, there is no designated supply chain manager role; instead, the responsibilities typically handled by a supply chain manager are carried out by the general manager, owner, or other staff members. The respondents were selected for the pilot study from the Australian Agri-products firm that performs the supply chain functions in those organisations. Respondents were initially contacted over the phone and through email, informed about the research objective, and sent the study's abstract. The respondents who consented to take part in the survey were chosen for the initial data collection in the pilot study of this research. During the pilot phase, 70 managers were approached, and 40 agreed to participate in the survey. Finally, 40 survey data were used for the pilot study.

4.8.4 Development of final questionnaires

Considering the relevant literature, a questionnaire (Appendix B) was developed to collect survey data for this research. The Ethics Committee of the University of Technology Sydney approved the developed questionnaire. The primary focus was to review the relevant literature to determine whether items could be adapted, adopted, or needed to be created for each construct in this study. The developed questionnaire underwent a pre-test for required refinement, with the pre-test procedure outlined in Section 5.6.2 of Chapter 5. Ultimately, a questionnaire was created to gather survey data for testing the proposed research hypothesis presented in the comprehensive model, as shown in Figure 4 of Chapter 2.

4.8.5 Population study and sampling technique

This study aims to develop a model for blockchain adoption in the Agri-products supply chain to explore traceability for sustainability. Therefore, the supply chain actors related to Agri-products are considered a targeted population of this research globally. Thus, the population of this research is defined as producers, processors, transporters, wholesalers, and retailers from the global Agri-products firms. Concerning the focal firm, data will be collected from firms of all sizes (small, medium, and large). Second, this study collected online survey data using a 7-point Likert scale questionnaire on the operations and supply chain of Agri-products industries (Wamba et al., 2020a, Chowdhury and Quaddus, 2021a). The target respondents are employees at decision-making levels of various Agri-products sectors, including producers, processors, transporters, wholesalers, and retailers. The survey data was analysed using the smart PLS-SEM modelling tool.

The survey method used the Qualtrics instrument to collect quantitative data globally for this study. In this regard and to understand the Agri-products industry, we completed initial email communication and telephone communication with Australian firms, including Blockchain Australia, blockchain for the meat supply chain (Meat and Life Stock Australia, Stockyard Beef, Teys Australia - meat processor, Argyle Prestige Meats), KPMG-blockchain platform for the Australian food industry (Sun Rice-Food export company, Mitchell Wines, Cane Growers), AgriFuture Australia and Blockchain Australia, GEORA-Tea Tree Oil, and Retail supply chain and Blockchain (Woolworth-Head office Sydney, Cools DC-Logistics, ALDI- Head office Sydney). The sampling procedure for this study is represented in Table 4.10.

Table 4.10 Sampling procedure for this study

Sampling process	The study's sampling approach.	Comments
Target population	Agri-products producers, processors, transporters, wholesalers, and retailers	Producing Agri-products and processing agri-food requires producers, processors, transporters, wholesalers, and retailers. As a target population, this study targeted all these related firms.
Sampling frame	Australia, United States of America, United Kingdom, Canada, Japan, China, Vietnam, India, France, Poland, New Zealand, Sri Lanka,	These twelve countries represent the sampling areas of the target population. The sample fame is closely related to the population.
Sampling unit	All primary and secondary Agri-products producers, processors, transporters, wholesalers, and retailers	This sample unit contains the elements of the target population to be sampled for this study
Sampling elements	Supply chain managers or individuals in charge of supply chain management and operational functions.	In certain companies, there is no formal supply chain manager role; instead, the general manager, owner, or other staff members handle the operational duties typically managed by a supply chain manager.
Sampling strategy	Random/Purposive	Three types of Agri-products firms such as large, medium and small, are chosen
Sample size	334 samples to be completed	For the pilot study, 40 participants and 294 participants for the main study.

4.8.6 Sample size determination

A key challenge in PLS-SEM is determining the minimum sample size and the desired power of a model. To test the proposed hypothesis, this study will use partial least squares (PLS) structural equation modelling (SEM). The sample size needed to be determined carefully in the research setting of this study. Selecting the right sample size in PLS-SEM is crucial for several reasons, including statistical power, model estimation accuracy, consistency and reliability, the complexity of the model, minimising error and improving fit, and recommended rules of thumb (Hair Jr et al., 2014). A common guideline for determining the sample size for PLS-SEM is the “10-times rule” (Hair Jr et al., 2014, Goodhue et al., 2012), which suggests the minimum requirement for PLS-SEM should be 10 times the maximum number of inner or outer paths pointing to any latent variable (Hair Jr et al., 2014). In contrast, some argue that larger sample sizes are often recommended depending on the model's complexity and the desired statistical power. Based on the 10 times rule, 77 responses (10 x 11) are the minimum requirement for this study. The sample size for this study is 294, exceeding the minimum required size of 70, which complies with the rule of thumb (Bollen, 2014; Hair Jr et al., 2014; Kaplan, 2008; Kline, 2023).

4.9 Ethics considerations

Ethics refers to a set of principles and guidelines that govern the conduct of scientific inquiry to ensure that the research is performed responsibly and with integrity (Saunders et al., 2009, Sekaran, 2016). Ethical considerations are crucial for maintaining public trust, ensuring fairness, and protecting human and animal subjects from harm (Saunders et al., 2009). Research ethics is critical in business research when involving human participants; thus, a university researcher must abide by ethical guidelines to maintain a responsible research practice (Wallace and Sheldon, 2015, Saunders et al., 2009).

This research is conducted and adheres to the University of Technology Sydney's ethical guidelines, code of conduct, and external regulatory standards concerning research involving human participants. The ethics approval from the university includes details of the project overview, data collection process, risk evaluation, data uses, secure data storage, and disposal. The University of Technology Sydney's Human Research Ethics Committee reviewed and approved the research project on 12 December 2023 (please refer to Appendix 1). Based on the Australia National Statement on Ethical Conduct in Human Research (2007), this research is defined as low-risk research. To this end, there was no foreseeable risk involving harms such as physical (i.e., injury), psychological (i.e., distress), social (damage to the social network), or economic (imposition of direct/indirect costs on the participant) collecting data for this research.

The data collection for this research followed ethical considerations that were in line with ethics approval. The participants of this research were provided with a Research Information Statement clearly stating the purpose and objectives of the research. Participation in this research was voluntary, and participants could terminate the survey anytime. The completion of the survey meant the consent of the participants. Amazon Mechanical Turk (MTurk) only recruited participants above 18 years old. Also, the research participants were selected through qualifying questions; only those who adopted blockchain in their operations and supply chain were allowed to continue the survey through the online MTurk platform. The participants were informed that the survey was conducted strictly anonymously and confidentially. The data information of this research will be secure and confidential during data analysis and disposed of after the findings are recorded. Therefore, the research project confirms the standards and guidelines of the university and maintains a high level of ethical conduct.

4.10 Survey data collection process

The data collection process of this study is carefully designed to ensure the validity, reliability, and generalisability of the research data (Hair Jr et al., 2019). This study used the survey method design to collect research data from the MTurk online platform. Based on the research requirement, the survey questionnaire was distributed to collect research data through MTurk. Before using MTurk, this study created a survey instrument using Qualtrics online survey creation software and activated it to receive a URL, which was copied into MTurk (Hunt and Scheetz, 2019). The participants were selected based on specific criteria relevant to the study. The research participants were selected through qualifying questions regarding technology adoption. These questions were industry-specific, and only those who adopted blockchain in their Agri-products operations and supply chain were allowed to continue the survey through the MTurk platform.

MTurk provides researchers access to a large and more diverse demographic background of participants (Aguinis et al., 2021, Buhrmester et al., 2018, Crump et al., 2013). MTurk has easy access; other advantages are the speed of data collection procedures at a reasonable cost and flexibility regarding research design and choice (Aguinis et al., 2021, Buhrmester et al., 2018). Some argue that the participants in MTurk are less likely to pay attention to the study instructions or may involve self-selection bias (Casler et al., 2013, Hunt and Scheetz, 2019). However, evidence shows that it is a powerful tool that allows for access to diverse participants, making it a more common data collection platform for behavioural science and business research (Hunt and Scheetz, 2019). In particular, survey data collection using MTurk has increased tenfold over the last decade (Aguinis et al., 2021). Studies indicate that the use of MTurk has grown increasingly in recent years. For example, it witnessed over 2,000% increase from 2012 to 2019 alone in management research (Aguinis et al., 2021).

As previous studies have shown, sample size determination is the important sampling factor for hypothesis testing (Cohen, 2013, Creswell, 2018, Strang, 2015a). This research aims to develop a model on blockchain adoption for agri-products supply chain traceability and sustainability. Thus, this study seeks to identify the measurable and observable determinants of supply chain traceability and sustainability. To this end, the study will be quantified and measured to test the hypotheses developed for the research. To this end, the "10-times rule," a common guideline for determining the sample size (Hair Jr et al., 2019), has been considered to draw reasoning for hypothesis testing using data through the PLS-SEM tool for this study. MTurk offers efficient data collection from diverse demographics, which allowed this research to gather significant data to meet the research requirements.

4.11 Justification of MTurk for data collection:

Amazon Mechanical Turk (MTurk) provides an efficient platform for collecting research data by offering access to a large and diverse pool of respondents across industries, including supply chain professionals. The platform enables researchers to reach participants quickly and cost-effectively, making it suitable for exploratory studies on emerging technologies such as blockchain (Buhrmester, Kwang, & Gosling, 2011). While traditionally used for general population surveys, MTurk has increasingly been utilized to target specialized groups, including managers and decision-makers, through careful screening mechanisms (Goodman & Paolacci, 2017). This flexibility allows researchers to recruit supply chain managers with relevant experience, thereby enhancing the validity of the findings. Moreover, MTurk's scalability supports data collection from geographically dispersed respondents, which is particularly valuable for global supply chain research (Mason & Suri, 2012).

The purpose of this study is to construct a model for blockchain adoption within the agri-product supply chain, with a specific focus on enhancing traceability to promote sustainability. Accordingly, the targeted research population comprises stakeholders actively engaged in agri-product supply chain operations at the global level (Saberi et al., 2019). This population includes key actors such as producers, processors, transporters, wholesalers, and retailers, all of whom play critical roles in the functioning and integration of blockchain systems (Agyekum et al., 2023; Tian, 2017). Defining the population in this way ensures that the perspectives of diverse supply chain participants are captured, thereby strengthening the relevance and applicability of the proposed model.

While Amazon Mechanical Turk (MTurk) has emerged as a widely used platform for data collection in social science and management research, some limitations exist. One key concern relates to sample representativeness, as MTurk participants may not accurately reflect the demographic or professional characteristics of the broader population under investigation. Although MTurk offers access to a large and diverse respondent pool, participants are often self-selected, leading to potential biases in motivation, attention, and response quality (Goodman et al., 2013, Chandler and Paolacci, 2017). Another limitation pertains to data reliability, as some respondents may engage in inattentive or dishonest behavior to complete surveys quickly for monetary gain. Despite the use of attention checks and validation mechanisms, response integrity can still be compromised, particularly when tasks are repetitive or poorly incentivised (Buhrmester et al., 2018, Keith et al., 2017). Moreover, MTurk samples may lack sufficient contextual expertise for studies requiring domain-specific knowledge, such as those involving managerial decision-making or technical supply chain practices. Cultural and geographical biases also persist, as a significant portion of MTurk workers are concentrated in specific regions such as the United States and India, which may limit the cross-cultural generalizability of findings(Hunt and Scheetz, 2019, Peer et al., 2017). Additionally, researchers have limited control over participant identity verification, making it challenging to ensure unique and authentic responses. These limitations necessitate careful design strategies, including screening criteria, attention filters, and validation tests, to enhance data quality and credibility. Overall, while MTurk provides an efficient and cost-effective avenue for empirical data collection, its methodological constraints highlight the importance of cautious interpretation and triangulation with alternative data sources to ensure research validity and robustness.

4.12 Quantitative data analysis using SEM

This study employs partial least squares (PLS) based structural equation modelling (SEM) as the technique for analysing the quantitative data. SEM is a powerful analytic method that has been used for quite a while. As with most statistical analyses, the findings of SEM analysis are derived from a large sample size, which tends to produce more reliable statistical results (Kim et al., 2015). The justification for using SEM is discussed in the next section.

4.12.1 Why use SEM?

Structural equation modelling (SEM) is a powerful statistical technique widely used in social science, behavioural science, and other business research to analyse complex relationships among variables (Sarstedt et al., 2021, Hair Jr et al., 2014). The PLS-SEM technique offers multivariant analysis for complex relationships associated with research directions/questions in social science research (Hair Jr et al., 2014). Multivariant analysis is applying a statistical method that simultaneously analyses multiple variables (Hair Jr et al., 2014, Bollen, 2014, Byrne, 2013, Kline, 2023, Murtagh and Heck, 2012). In particular, SEM offers many advantages. These include: 1) Complex Relationship Analysis: SEM can handle complex relationships among multiple variables, allowing researchers to model direct and indirect effects simultaneously; 2) Inclusion of Latent Variables: SEM allows for the incorporation of latent constructs (like attitudes or social behaviours) that are not directly observable, providing a more nuanced understanding of underlying factors; 3) Measurement Error Adjustment: It accounts for measurement errors in observed variables, leading to more accurate parameter estimates and enhanced reliability of results; 4) Model Fit Assessment: SEM provides statistical tools to assess how well the proposed model fits the data, helping researchers refine their theories based on empirical evidence; 5) Path Analysis: It enables researchers to visualise and analyse causal relationships through path diagrams, clarifying the dynamics between variables; 6) Simultaneous Equation Modelling: SEM can analyse multiple equations at once, offering a holistic view of relationships rather than piecemeal insights; 7) Flexibility with Data Types: It can be applied to various data types, including cross-sectional, longitudinal, and experimental data, making it versatile for different research designs; 8)

Multigroup Comparisons: SEM can evaluate how relationships differ across various demographic or cultural groups, providing insights into contextual factors; 9) Theory Testing and Development: Researchers can rigorously test existing theories or develop new ones based on empirical findings, contributing to theoretical advancement in the field; 10) Policy and Practical Implications: Results from SEM studies can inform policy decisions and practical interventions by identifying key variables that influence social outcomes (Hair Jr et al., 2014, Kaplan, 2008, Kline, 2023, Ullman and Bentler, 2012, Murtagh and Heck, 2012).

These advantages make SEM valuable for researchers exploring and explaining complex social phenomena. Additionally, first-generation statistical analysis has certain limitations that restrict creativity and depth (Barclay et al., 1995). In contrast, the second-generation SEM-based tool allows researchers to address multiple related research questions in one systematic and comprehensive analysis, facilitating the simultaneous modelling of relationships between independent and dependent constructs (Hair Jr et al., 2014, Murtagh and Heck, 2012). The research model in this study involves numerous constructs and variables that cannot be analyzed using first-generation regression-based methods. Therefore, SEM, a second-generation data analysis technique that supports multivariate assessment and measurement properties, as well as the structural model simultaneously, is ideal for this study. It is also clear that SEM has been successfully applied in many supply chain management studies, including those on blockchain adoption in operations and management models (Wong et al., 2020a).

4.12.2 Justification for using PLS-based SEM

Research has demonstrated the use of various SEM-based applications, including covariance-based SEM (CB-SEM) methods such as LISREL and AMOS, as well as PLS-SEM (Malhotra et al., 2006, Byrne, 2013, Hair Jr et al., 2014). Previous studies show that PLS-SEM is primarily a prediction-oriented method. In sustainability research, especially with blockchain, the focus often includes predicting the impact of traceability systems on outcomes like transparency, environmental, social and economic performance, and stakeholder trust (Kouhizadeh et al., 2021). PLS-SEM provides strong predictive power and allows researchers to focus on predicting key outcomes rather than on the goodness of fit of the model (Chong, 2013, Fornell and Bookstein, 1982, Hair Jr et al., 2014, Kaplan, 2008). Additionally, PLS-SEM is well-suited for exploratory research, while covariance-based SEM is designed for confirmatory analysis (Fornell and Bookstein, 1982, Hair Jr et al., 2014, Kaplan, 2008). In this study, blockchain adoption in the Agri-product supply chain assumes that traceability for sustainability could be improved, which often involves predicting how blockchain adoption enhances social, environmental and economic sustainability, aligning with the strengths of PLS-SEM.

For several reasons, studies indicate that PLS-SEM is suitable for blockchain-based supply chain traceability research. For example, blockchain-enabled traceability involves multiple constructs and many members and integrates various stakeholders, multi-layered transactions, and diverse data points from the supply chain network (Hasan, 2018, Bosona and Gebresenbet, 2013a, Wong et al., 2020a). PLS-SEM enables the analysis of such multiple constructs, especially when the relationships between latent variables are not easily defined or explored (Goodhue et al., 2012, Hair Jr et al., 2014). PLS-SEM establishes models for complex relationships without strict distributional assumptions, making it ideal for intricate systems like blockchain-based traceability (Hair Jr et al., 2014, Kaplan, 2008).

In terms of the Exploratory Nature of Research, blockchain in the context of sustainability is still an emerging field of research. PLS-SEM is preferred when the research is exploratory rather than confirmatory, as it can handle models with less theory-driven hypotheses and allows for simultaneous estimation of relationships between multiple constructs (Wamba et al., 2020a). In particular, since blockchain-based traceability for sustainability is relatively new, PLS-SEM's capability to explore new relationships and test theoretical models without requiring large sample sizes is also advantageous (Kouhizadeh et al., 2021, Sarstedt et al., 2017). Moreover, blockchain-based traceability often involves diverse data, including quantitative metrics (e.g., carbon footprint measurements) and qualitative assessments (e.g., trust or stakeholder perceptions) (Choi et al., 2019). Additionally, PLS-SEM is robust with various data types, including non-normal and small sample sizes, and is critical in nascent areas like blockchain adoption in sustainability (Wamba et al., 2020a, Hair Jr et al., 2014, Kouhizadeh et al., 2021). PLS-SEM does not require the data to follow a normal distribution, and it works well with small to medium sample sizes, which is often the case in sustainability research (Hair Jr et al., 2014, Fornell and Bookstein, 1982).

In blockchain-based traceability systems, multiple factors, such as regulatory requirements, environmental standards, and consumer expectations, may be interrelated, leading to multicollinearity (Gefen et al., 2000, Hair Jr et al., 2014). PLS-SEM can handle multicollinearity issues better than traditional regression techniques. Given the interdependence of variables in blockchain traceability (e.g., between transparency and trust), PLS-SEM's ability to manage multicollinearity is highly beneficial (Byrne, 2013, Hair Jr et al., 2014). PLS-SEM is justified for blockchain-based traceability in sustainability research due to its flexibility, ability to handle complex and exploratory models, predictive focus, and robustness with various data types (Hair Jr et al., 2014, Kline, 2023, West et al., 2012, Bag et al., 2023). It allows researchers to explore relationships between constructs like sustainability, transparency, and blockchain technology in a comprehensive and adaptable manner (Wong et al., 2020a, Bag et al., 2023).

4.12.3 Partial least square (PLS) procedure

PLS-based SEM analysis involves evaluating the structural model and assessing the measurement model (Hair Jr et al., 2019). First, a **structural model** (the inner model in the PLS-SEM context) that links the constructs (circles or ovals). The structural model also displays the relationship between constructs. Second, a construct's **measurement model** (also referred to as the outer model in PLS-SEM) displays the relationships between the constructs and their observed items (measurement variables) (Hair Jr et al., 2019). The primary goal of the measurement model in PLS-SEM is to ensure that the latent constructs (these are unobserved and cannot be measured directly, e.g., customer satisfaction, brand loyalty, or attitude) are accurately represented by their corresponding observed indicators (Hair Jr et al., 2019). Based on the causal relationships between latent constructs and observed indicators, two types of measurement models are available:

reflective and formative (Hair Jr et al., 2019, Barclay et al., 1995, Kaplan, 2008, Kline, 2023, Ullman and Bentler, 2012). The assessment of measurement models differs for reflective and formative models. The model proposed in this study utilises a reflective measurement approach. Therefore, the measurement model was assessed by evaluating convergent validity, item reliability/outer loading, internal consistency, average variance extracted (AVE), discriminant validity, HTMT ratio, cross-loading AVE analysis, and the Fornell-Larcker criterion (Gefen et al., 2000, Hair Jr et al., 2019). The explanatory power of the endogenous constructs (blockchain, traceability, sustainability) is assessed through the structural model, which involves analysing the t-values of each path coefficient related to the study's hypothesis. Table 4.11 outlines the systematic process of the SEM analysis.

Table 4.11 Systematic procedure of SEM analysis

Stage	Type of Items	Type of measurement	Decision Parameters
Stage 1 Assessment of Measurement Model	Reflective	Convergent validity	
		Item reliability	≥0.7, and t-values > 1.65
		Internal consistency	≥ 0.7
		Average variance extracted (AVE)	≥ 0.5
		Discriminant validity	
		AVE analysis	Square root of the AVE of a construct is larger than its correlation with other constructs
		Cross loading metrix	Loading of an item within a construct is greater than its loading is any other constructs
	Formative	Indicator weight	Review constructs Conceptualization and t-value=1.6 (p=0.1)
		Multi-collinearity	VIF ≤ 10 *or* ≤ 5
Stage 2 Assessment of Structural model	Reflective and Formative	Coefficient of Determination	$R2 \geq 0.25$
		Test of hypothesis	Significant t-value =1.65

4.13 Measurement specification of reflective models

The research model of the study incorporates reflective measurement constructs. According to the study's conceptual framework, the reflective items are considered as effects of the latent variable (refer to Chapter 2, Figure 2.2). The specification of reflective measurement models is highlighted in the following section, thus clarifying the measurement model for the study.

Reflective measurement model

In PLS-SEM, measurement models define how constructs are measured using observed variables (indicators/items). As highlighted earlier, two types of measurement models are used in PLS-SEM. In a reflective measurement model, the indicators are considered outcomes or representations of an underlying latent construct, with all measures within a construct reflecting a shared theme (Goodhue et al., 2012, Hair Jr et al., 2014, Murtagh and Heck, 2012). The direction of the arrows is from the latent construct to the indicators, which indicates that the latent variables cause indicator changes (Hair Jr et al., 2014). The indicators are assumed to be interchangeable, which means that a change in the latent variable causes a change in all the indicators, and indicators can be dropped without affecting the meaning of the construct (Anderson and Gerbing, 1988, Chong, 2013, Hair Jr et al., 2019).

The measurement error is typically associated with the indicators (Gefen et al., 2000, Hair Jr et al., 2014). Therefore, there is a high correlation between items. Reliability (Cronbach's Alpha, Composite Reliability) and convergent validity (Average Variance Extracted, AVE) are critical for reflective models. Discriminant validity (e.g., Fornell-Larcker criterion or HTMT ratio) is also assessed (Fornell and Bookstein, 1982, Hair Jr et al., 2014). The decision rules for a reflective measurement model are presented in Table 4.12.

Table 4.12 Reflective models' decision rules

Feature	Reflective model	References
Causal Direction	From construct to indicators	Hair Jr et al. (2019), Sarstedt et al. (2017)
Indicator Correlation	High correlations expected	Hair Jr et al. (2019)
Indicator Dropping	Dropping an indicator does not change construct meaning	Hair Jr et al. (2019), Sarstedt et al. (2017)
Measurement Error	At indicator level	Hair Jr et al. (2019), Sarstedt et al. (2017)
Example	Customer satisfaction	Hair Jr et al. (2019), Sarstedt et al. (2017)
Validation Approach	Internal consistency, convergent validity	Hair Jr et al. (2019), Sarstedt et al. (2017)

Figure 4.3 represents the relationship between the latent and manifest variables of a reflective model (Coltman et al., 2008).

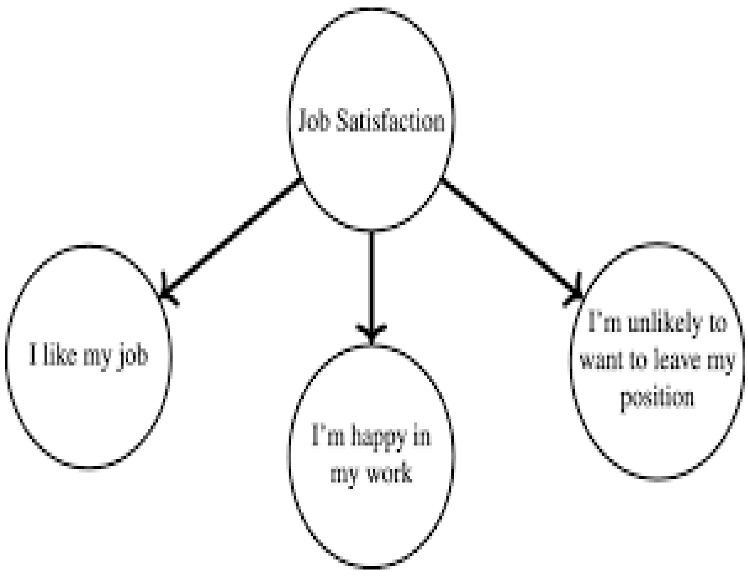

Figure 4.3 Reflective model structure

According to Chowdhury and Quaddus (2021a), Cousins et al. (2019), Wamba et al. (2020a), Wong et al. (2020a), Yu et al. (2022), and other relevant studies, the constructs used in the research were modelled to be reflective (Hair Jr et al., 2019). Based on the extensive literature review and references, constructs relating to blockchain adoption (BCAD) (Wamba et al., 2020a), three business environmental drivers (market dynamic (MDY), competitive pressure (CPR), and regulatory pressure (RGS) (Wong et al., 2020a), one mediator role, Traceability (TRA) (Cousins et al., 2019), three moderators roles (technological orientations (TOR) (Yu et al., 2022), upper management support (UPS) (Wong et al., 2020a)}, and sustainability governance (SGV) (Chowdhury and Quaddus, 2021a), including outcome variables, sustainability, social (SOC), environmental (ENV) and economic (ECO) (Chowdhury and Quaddus, 2021a) were considered reflective.

4.14 Reflective measurement model assessment

Figure 4.3 above outlines the assessment process for a reflective measurement model in PLS-SEM. Reflective measurement models propose that the latent construct influences the observed indicators or items. Evaluating the measurement model is essential to determine the validity of the constructs by referencing manifest indicators or items (Chong, 2013, Gefen et al., 2000, Hair Jr et al., 2014, Kaplan, 2008, Kouhizadeh et al., 2021). In this study's reflective measurement model, both convergent validity and discriminant validity were examined (Barclay et al., 1995, Chong, 2013, Gefen et al., 2000, Hair Jr et al., 2014, Kaplan, 2008, Kouhizadeh et al., 2021, Sarstedt et al., 2021). A typical step-by-step process for assessing the reflective measurement model includes the following:

Internal consistency reliability:

This step ensures that the indicators consistently measure the latent construct. It also highlights metrics. These include **Cronbach's Alpha** (α): A traditional measure of internal consistency. **Composite Reliability** (CR): Preferred over Cronbach's Alpha in PLS-SEM, as it does not assume equal indicator loadings. Threshold: Both Cronbach's Alpha and Composite Reliability should be above 0.70 for adequate reliability (Fornell and Bookstein, 1982, Hair Jr et al., 2014).

The internal consistency can be calculated as follows:

Internal consistency = $\frac{(\Sigma\lambda i)^2}{(\Sigma\lambda i)^2 + \Sigma var\ (\in i)}$

Where λi factor loading represents the simple correlation between the item and its constructs, and Var $(\in i)$ = 1- λi, the unique/error variance.

Indicator/Item reliability:

Indicator/ Item reliability refers to the need to evaluate each indicator's loading on its respective latent construct. Metric: **Indicator/Item Loadings**: Indicators should have loadings greater than 0.70 to ensure they are reliable and adequately contribute to the construct (Fornell and Bookstein, 1982, Hair Jr et al., 2014, Murtagh and Heck, 2012). Threshold: Loadings above 0.70 are acceptable, while loadings between 0.40 and 0.70 may be retained under certain conditions.

Convergent validity:

This step assesses whether the indicators collectively represent the latent construct well. Metric: **Average Variance Extracted (AVE)**: The AVE should be greater than 0.50 to show that the construct explains more than half of the variance in its indicators (Fornell and Bookstein, 1982, Hair Jr et al., 2014). Threshold: AVE > 0.50 indicates good convergent validity (Barclay et al., 1995, Fornell and Bookstein, 1982, Hair Jr et al., 2019, Sarstedt et al., 2017). The calculation of Average Variance Extracted (AVE) follows this formula:

$$\text{Average Variance Extracted (AVE)} = \frac{\Sigma \lambda i^2}{\Sigma \lambda i^2 + \Sigma Var\ (\epsilon i)}$$

Where λi factor loading represents the simple correlation between the item and its constructs (item loading), and Var (ϵi) = 1- λi^2 (the variance).

Discriminant validity:

Discriminant validity is the extent to which a construct is truly distinct from other constructs by empirical standards (Hair Jr et al., 2014). Discriminant validity establishes the distinctiveness of different constructs in the measurement model of the study (Fornell and Larcker, 1981, Hair Jr et al., 2019, Lucas et al., 1996). One of the key building blocks of measurement model evaluation is discriminant validity analysis (Henseler et al., 2015, Hair Jr et al., 2019, Lucas et al., 1996). This analysis establishes whether latent constructs are distinct from other constructs in the measurement model (Sarstedt et al., 2021). It can be measured by the Fornell-Larcker Criterion, Heterotrait-Monotrait Ratio (HTMT) and Cross Loading of indicators. A frequently applied approach to analyse discriminant validity is the Fornell-Larcker Criterion: the square root of each construct's AVE (average variance) should be greater than its correlations (as a measure of shared variance between constructs) with other constructs (Fornell and Larcker, 1981). However, evidence shows that the Heterotrait-Monotrait Ratio (HTMT) is more suitable for measuring discriminant validity than the Fornell-Larcker Criterion metrics (Henseler et al., 2015). Heterotrait-Monotrait Ratio (HTMT) is a recent approach to assess discriminant validity. HTMT ratio of less than 0.90 is considered to establish a discriminant validity (Barclay et al., 1995, Fornell and Bookstein, 1982, Hair Jr et al., 2019, Sarstedt et al., 2017). However, others suggest a threshold value of less than 0.85 (Henseler et al., 2015, Hair Jr et al., 2014). HTMT value close to 1 indicates a lack of discriminant validity (Sarstedt et al., 2021). In addition, using cross-loading to measure discriminant validity indicates that an item in a construct shall load substantially well onto its own construct instead of the other constructs in the study (Hair Jr et al., 2014). Table 4.13 represents the summary of the reflective measurement assessment.

Table 4.13 Summary of Reflective Model Assessment

Assessment	Metric	Threshold	References
Internal Consistency	Cronbach's Alpha CR	> 0.70	Hair Jr et al. (2014), Fornell and Bookstein (1982), Sarstedt et al. (2021)
Indicator Reliability	Indicator/Item Loadings	> 0.70	Hair Jr et al. (2014), Fornell and Bookstein (1982), Sarstedt et al. (2021)
Convergent Validity	AVE	> 0.50	Hair Jr et al. (2014), Fornell and Bookstein (1982)
Discriminant Validity	Fornell-Larcker, HTMT	Fornell-Larcker (√AVE > corr); HTMT < 0.90	Hair Jr et al. (2014), Fornell and Bookstein (1982), Sarstedt et al. (2021)

4.14.1 Assessment of reflective constructs

The measurement model in this study includes reflective constructs. For instance, the justification of constructs is essential (Becker et al., 2023). Theoretical justification is very important when operationalising a reflective construct (Sarstedt et al., 2019).

4.14.2 Measurement model of the study

Higher-order constructs or hierarchical component models in the PLS-SEM allow researchers to simultaneously model a construct by means of more abstract dimensions (Becker et al., 2023). At the first-order level, blockchain adoption (BCAD) is measured by the first-order constructs market dynamics (MDY), competitive pressure (COP), and regulatory support (RGS) as a reflective model. It is demonstrated that blockchain adoption is highly influenced by market dynamics, competitive pressure, and regulatory support in the changing business environment. It can also be argued that there is a high interdependence among the reflective first-order constructs (market dynamics, competitive pressure, and regulatory support) and traceability (TRA) in the model. At the outcome level of the model, sustainability is a higher-order construct measured by first-order constructs such as social-SOC, economic-ECO and environmental-ENV factors. The conditional effect of technology orientation-TOR, upper management support-UMS, and sustainability governance-SGV are supportive roles in the model. The conditional indirect effect of traceability (TRA) also supports the model of the study. Previous studies have shown that it is logical to model supply chain sustainability as a higher-order construct (Becker et al., 2023).

4.14.3 Measuring the reflective construct

The latent variable measurement can be performed using three approaches: (1) the repetitive indicator approach (Becker et al., 2012), (2) the two-stage approach (Sarstedt et al., 2019) and (3) the hybrid approach (Wilson and Henseler, 2007). Regarding the repeated indicator approach, a higher-order latent variable can be constructed by specifying a latent variable representing all the underlying lower-order latent variables' manifest variables (Becker et al., 2012). In the two-stage approach, the first-order constructs score is represented in a first-stage model, and these first-stage construct scores are subsequently used as indicators for the higher-order latent variable in a separate second-stage analysis (Hair Jr et al., 2014, Sarstedt et al., 2019, Wilson and Henseler, 2007). In this study, latent variable scores were used as the factors of the first-order constructs as they maximise the R^2 value estimation of the endogenous latent constructs of the model (West et al., 2012, Wilson and Henseler, 2007).

4.14.4 Structural model assessment

Once the measurement model assessment was confirmed and the construct measures were reliable and validated, the next step was to address the assessment of the structural model of this study (Bollen, 2014, Byrne, 2013, Hair Jr et al., 2014). The structural model assessment examines the statistical significance of the hypothesised relationship between constructs, which examines the path coefficients among the latent constructs (Barclay et al., 1995, Bollen, 2014, Hair Jr et al., 2019, Sarstedt et al., 2021). First, it is important to examine the structural model collinearity issues because, in the structural models, the estimation of path coefficients is based on the ordinary least-square regression of each endogenous latent variable on its corresponding predictor constructs (Hair Jr et al., 2014).

Path Coefficients:

The path coefficient represents the strength and direction of relationships between latent constructs in the model of the study (Gefen et al., 2000, Hair Jr et al., 2014). Each path coefficient ranges from -1 to +1, with values closer to ±1 indicating stronger relationships (Gefen et al., 2000, Hair Jr et al., 2014).

Bootstrapping:

Bootstrapping is an important procedure for SEM applications. Bootstrapping is a resampling procedure that considers the primary sample as representing the population (Hair Jr et al., 2014). One of the main reasons for using bootstrapping in PLS-SEM is to assess the statistical significance of path coefficients and gather standard errors and confidence intervals (Hair Jr et al., 2014). It helps to deal with the multivariant nonnormality of the data (Byrne, 2013). Typically, 5,000 bootstrap samples are recommended, and p-values or t-statistics indicate whether path coefficients differ significantly from zero (Streukens and Leroi-Werelds, 2016, Hair Jr et al., 2014).

Coefficient of determination (R^2):

The measures of R^2 Value explain variance in each endogenous construct. The range of R^2values is from 0 to 1, with higher values indicating that the model explains a greater proportion of variance. In behavioural and social science research, R^2 values of 0.25, 0.50, and 0.75 are often considered weak, moderate, and substantial, respectively.

One of the advantages of using the PLS-SEM technique is that it is effective for predicting and estimating the coefficient of determination (R^2) values, which are usually used to characterise the ability of the model to explain and predict endogenous latent variables (Byrne, 2013, Fornell and Bookstein, 1982, Hair Jr et al., 2014, Kaplan, 2008, Sarstedt et al., 2017, Ullman and Bentler, 2012). To this end, the structural model of this research has been assessed by examining the explanatory power of the proposed model. Concerning each construct, the explanatory power of the proposed model can be evaluated by the R^2 values for each construct (Hair Jr et al., 2014, Kaplan, 2008, Sarstedt et al., 2017). The R^2 value can be obtained from the bootstrapping result of the PLS run. There are differences of opinion regarding the acceptable values of R^2 (Hair Jr et al., 2014). However, many studies suggest a relatively lower value than the acceptable value R^2 (Podsakoff et al., 2003, Sarstedt et al., 2017).

According to previous studies, R^2 values, the path coefficients and t-values of the hypothesised relationships were calculated to assess the significance of the relationships among constructs of the model for this study (Hair Jr et al., 2014, Buckley et al., 1990, Coltman et al., 2008, Podsakoff et al., 2003, Streukens and Leroi-Werelds, 2016). Previous research suggests two non-parametric approaches to test the relationship between constructs, i.e., the jackknife and bootstrap (Streukens and Leroi-Werelds, 2016, Podsakoff et al., 2003). Studies indicate that both methods have advantages and disadvantages. The bootstrapping method is, however, chosen for analysing research data for the structural model of this study, as it is considered a more advanced approach than the jackknife method (Chong, 2013, Hair Jr et al., 2014, Podsakoff et al., 2003).

f^2 Effect size:

f^2 Effect Size assesses the impact of each predictor on the endogenous constructs by calculating the change in R^2 if the predictor was removed from the model. Cohen's guidelines interpret f^2 values as follows: 0.02 (small), 0.15 (medium), and 0.35 (large). In PLS-SEM, effect size is a measure that helps assess one construct's impact on another within the model (Hair et al., 2019). Specifically, it allows researchers to evaluate predictors' relative importance in explaining endogenous constructs' variance (Hair et al., 2019, Podsakoff et al., 2003). This can help to determine which constructs have a substantial effect on an outcome, which have a small effect, and which might have a negligible effect (Fornell and Larcker, 1981, Hair et al., 2019, Shmueli et al., 2019). The f^2 effect size measures the impact of a specific predictor construct on an endogenous (dependent) construct (Hair Jr et al., 2014, Shmueli et al., 2016). f^2 is calculated by observing the change R^2 when including or excluding a particular predictor variable in the PLS-SEM model (Hair Jr et al., 2014, Kaplan, 2008). The formula for f^2 is as follows:

$$f^2 = \frac{R^2\,included - R^2 excluded}{1 - R^2\ \text{included}}$$

Note:

- R^2 included: R^2 of the endogenous construct when the predictor construct is included in the model.
- $R^2 excluded$: of the endogenous construct when the predictor construct is excluded from the model.

Effect sizes help to identify the most important key predictors for explaining the variance in a specific outcome. It also helps model improvement by analysing constructs with small or negligible f^2 and R^2 values that might be candidates for removal or refinement to improve model parsimony without significantly sacrificing explanatory power (Hair et al., 2019, Podsakoff et al., 2003, Shmueli et al., 2019).

Nomological validity:

Nomological validity is one of the essential concepts in PLS-SEM. Nomological validity is evaluated to examine whether the indicator of focal constructs or sets of constructs relates to the measures of other constructs specified in the construct's theoretical network (Buckley et al., 1990, Coltman et al., 2008, Podsakoff et al., 2003, Streukens and Leroi-Werelds, 2016). It assesses whether the construct aligns with theoretical expectations in the model. In PLS-SEM, nomological validity Establishes Theoretical Rigor (Hair Jr et al., 2014). It ensures that the constructs in the model fit logically and consistently within a well-defined theoretical framework (Hair Jr et al., 2014). Nomological validity is essential because PLS-SEM is often used in exploratory research, and establishing a strong theoretical foundation enhances the credibility of the results (Hair Jr et al., 2014, Sarstedt et al., 2021). By confirming nomological validity, researchers can verify that the relationships between constructs align with previous research or theoretical expectations and validate relationships among constructs (Hair Jr et al., 2014, Podsakoff et al., 2003). This adds a layer of validation to the hypothesised relationships in the PLS-SEM model, ensuring that it reflects an accurate picture of the studied phenomena.

A model with nomological validity provides stronger support for the generalisability of its findings, as it suggests that the constructs and their interrelations can be applied across similar settings or populations (Hair Jr et al., 2014, Podsakoff et al., 2003). This is particularly valuable when using PLS-SEM in social sciences, marketing, and business, where theoretical generalisability is often needed. It also assists in construct validation. Nomological validity complements other types of construct validity (like convergent and discriminant) by testing the theoretical relationships among constructs rather than simply focusing on their internal consistency or uniqueness (Byrne, 2013). To this end, it helps determine whether constructs measure what they are supposed to in the context of the entire model (Sarstedt et al., 2021). In addition, PLS-SEM is often employed to maximise the predictive accuracy of models. Nomological validity ensures that these predictions are grounded in established theory (Hair Jr et al., 2014, Kouhizadeh et al., 2021, Podsakoff et al., 2003).

A model with high nomological validity is statistically sound and theoretically meaningful, which is especially important for studies aiming to make predictions or inform decision-making (Streukens and Leroi-Werelds, 2016). In PLS-SEM, evaluating nomological validity involves examining the model's structural paths to see if they behave according to the theoretical expectations (Hair Jr et al., 2014). If a relationship exists as predicted by theory, this strengthens the model's nomological validity (Fornell and Larcker, 1981).

Predictive validity:

Predictive validity refers to the model's ability to predict future outcomes based on its structural relationship in the PLS-SEM (Shmueli et al., 2019). Predictive validity is a holdout sample-based procedure that generates case-level predictions on the construct's level to gather the benefits of predictive model assessment (Shmueli et al., 2016). Since PLS-SEM is often employed for predictive purposes, it is essential to establish predictive validity to confirm that the model explains past data and provides accurate forecasts for new data (Hair Jr et al., 2014, Shmueli et al., 2019). Assigning a statistical model's predictive power is a crucial aspect of any study (Shmueli et al., 2019). The predictive sample's reuse technique (Q^2) can be used to ensure predictive validity (Chin, 2009). For a large complex model in PLS-SEM, the (Q^2) value evaluates the predictive relevance based on the blindfolding procedure (Shmueli et al., 2016). The following parameters can be measured for the predictive relevance of a particular construct.

Predictive relevance (Q^2) = 1- $\frac{\text{Sum of squared prediction errors}}{\text{Sum of squared errors for the devendent variable}}$

Predictive relevance (Q^2) =1- $\frac{\sum_D E_D}{\sum_D 0_D}$

- Note: where E = the sum of squares of prediction error, 0 = the sum of squares errors using the mean for prediction, and D = the omission distance.

In structural modelling, two prediction techniques can be used for the estimation and interpretation of Q^2 value. Such techniques are 1) **Cross-validated redundancy**, which focuses on the prediction quality for the latent variables, and 2) **Cross-validated commonality**, which looks at the quality of prediction for each indicator individually (Hair Jr et al., 2014, Shmueli et al., 2016, Shmueli et al., 2019). Therefore, this study uses cross-validated redundancy to estimate the predictive relevance of the model's hierarchical supply chain sustainability constructs and other endogenous constructs. The Q^2 value is generally calculated using an omission distance of 5-10 under existing PLS software packages (Hair Jr et al., 2014, Shmueli et al., 2016). A cross-validated redundancy of. Q^2 > 0.5 is considered a predictive model as the rule of thumb (Chin, 2009, Shmueli et al., 2016, Shmueli et al., 2019).

Goodness-of-Fit (GoF)

Goodness-of-Fit (GoF) is used to determine the overall prediction power and evaluate the performance of both measurement and structural parameters in large, complex models (Hair et al., 2019, Podsakoff et al., 2003, Shmueli et al., 2019). Model fit is a significant aspect of PLS-SEM that evaluates the similarity of the observed variables and estimated covariance among the indicator items in the model, helping to link the theory to reality (Hair et al., 2019). Once the measurement model proves all construct validity and reliability of the measurement scales, the model fits must be evaluated to ensure that the data accurately reflects the underlying theory using a variety of goodness-of-fit (Henseler and Sarstedt, 2013, Hair et al., 2019). The GoF in PLS-SEM is calculated as follows:

GoF = $\sqrt{Average\ Communality\ x\ Average\ R^2}$

- **Average Communality**: The average of commonalities for all reflective measurement models. Communality reflects the variance in indicators explained by the constructs they measure.

- **Average R^2:** This is the average R^2 of the endogenous (dependent) constructs in the model, which reflects the amount of variance in these constructs explained by the predictor constructs.

Power Analysis:

Power analysis in SEM modelling helps researchers to determine the minimum sample size in developing and validating a complex model, equally offering the probability of obtaining a statistically significant result (Cohen, 1988). Three important parameters based on power analysis are the significance level (α), the sample size (N) of the study and the effect size (Byrne, 2013, Cohen, 2013, West et al., 2012). According to Cohen (2013), the power of a statistical test should be more than 0.80. This confers adequate confidence in the hypothesised relationships in a model having power > 0.80 (Byrne, 2013, Hair Jr et al., 2014, West et al., 2012).

Endogeneity test:

Endogeneity in PLS-SEM refers to where an explanatory variable (predictor) is correlated with the error term in the model, leading to biased and inconsistent estimates. This can weaken the validity of the results, especially when making causal inferences (Hair et al., 2019, Sarstedt et al., 2020, Shmueli and Koppius, 2011). Previous studies indicate that endogeneity can arise in several ways in PLS-SEM (Hair et al., 2019, Haschka, 2022, Park and Gupta, 2012, Shmueli and Koppius, 2011), including 1) Simultaneity: When two or more variables mutually influence each other, creating a feedback loop. For example, if X and Y influence each other, the relationship between X and Y cannot be determined without bias (Mason and Perreault Jr, 1991, Park and Gupta, 2012). 2) Omitted Variable Bias: When a relevant variable that should explain variation in the dependent and independent variables is left out of the model (Hair et al., 2019, Haschka, 2022, Shmueli and Koppius, 2011). The omission of this variable causes the remaining predictors to be correlated with the error term, which leads to biased results (Park and Gupta, 2012). 3) Measurement Error: When a variable is measured with error, this can lead to a correlation between the variable and the error term, which introduces endogeneity. Inaccurate measurement of constructs can distort the relationship between constructs and introduce bias in estimates (Haschka, 2022, Park and Gupta, 2012). 4) Common Method Variance: Common Method Variance (CMV) refers to the amount of spurious covariance shared among variables due to the common method used in collecting data (Buckley et al., 1990) through the survey method. It can be a cause of endogeneity issues in PLS-SEM.

Previous studies suggest assessing endogeneity issues in the model using Gaussian Copula to identify whether there are endogeneity issues in the model in PLS-SEM (Hair et al., 2019, Park and Gupta, 2012, Shmueli and Koppius, 2011). In the PLS-SEM model, using the Gaussian Copula, each relationship from the exogenous constructs (independent variable) to endogenous constructs (dependent variable) needs to be checked individually and together in such a fashion: one copula, two copula, three copulas, and four copulas accordingly. Evidently, the threshold of the P value should be more than 0.05 (Hair et al., 2019, Park and Gupta, 2012, Shmueli and Koppius, 2011).

While PLS-SEM itself does not directly correct for endogeneity, some strategies can be applied to mitigate its effects (Haschka, 2022, Park and Gupta, 2012). These strategies include:

I. **Modelling Strategies:** Researchers can build their model to minimise the risk of endogeneity by ensuring that the relationships between constructs are theoretically justified and that they use a well-specified model with correct paths and interactions (Park and Gupta, 2012).

II. **Use of Instrumental Variables (IV)**: Instrumental variables can be introduced into the model to address the endogeneity issue by providing valid instruments correlated with the endogenous variables but not with the error term (Haschka, 2022, Park and Gupta, 2012).

III. **Latent Variable Interaction Effects**: Carefully modelling latent variable interactions might help reduce potential endogeneity issues related to complex relationships between constructs (Hair et al., 2019, Haschka, 2022, Shmueli and Koppius, 2011).

IV. **Control Variables**: Including control variables that account for omitted variable bias can sometimes help reduce endogeneity. However, this depends on the extent to which the omitted variable correlates with the independent and dependent variables (Hair et al., 2019, Haschka, 2022, Shmueli and Koppius, 2011).

While PLS-SEM is a flexible and powerful tool for causal modelling, it's essential to understand and address potential endogeneity issues in research data to avoid invalid conclusions.

4.15 Summary

This chapter presented the research design of the study. The first section of the chapter provided the research design, philosophy, level of analysis, unit of analysis, and selection for the quantitative survey method for the study, including the rationale for the quantitative method. This section presented details of the constructs and measurement items among the constructs used for the study. The details of the quantitative study phase are described in the final section of the chapter.

CHAPTER 5:

5.1 QUANTITATIVE DATA ANALYSIS

5.2 Introduction

The previous chapter outlined the research methodology, paradigm, and method adopted for this study. This chapter describes the procedure and method used for quantitative data for this study. It begins with data screening in Section 5.2.1, followed by a reliability and validity test, and finally, provides the descriptive data analysis.

5.2.1 Data screening

Data screening is a key initial step in the data analysis process. Data screening ensures that missing value treatment, data distribution patterns, outliers, and other issues, such as duplication or extraction, are assessed (Hair et al., 2019). Appropriate data screening enhances the validity and reliability of data analysis (Hair et al., 2019, Lowry and Gaskin, 2014). Data screening ensures that results are accurate and interpretable. Before testing for validity and reliability of data, the following are important steps to consider: missing values treatment, constructs evaluation for assumptions for variance, outliers, normality, and multicollinearity to assess any violation of the basic assumptions for multivariate application of data analysis (Lowry and Gaskin, 2014). Before starting data analysis, it is necessary to assess the properties of that data.

5.2.2 Missing value treatment

As with other statistical analyses, treating missing values is important in PLS-SEM (Hair Jr et al., 2014). According to Hair Jr et al. (2014), this includes a reasonable missing values limit of 5% per indicator and the missing values treatment options, such as mean replacement in PLS-SEM. Newman (2014) introduced two types of missing data: 1) item-level missingness (the respondent does not answer all items from a scale) and 2) construct-level missingness (the respondent answers zero items of a multi-item scale). In particular, the survey instrument of this study was developed with a "force response" component, where force response requires respondents to answer all questions and prevents them from moving on to the next question until they answer the current question or opt to end the survey; thus, this component removes missing data (Roberts and Allen, 2015). There was no missing data in the dataset. Table 5.1 below represents descriptive statistics for survey data and shows missing values.

Table 5.1 Descriptive statistics for the survey

Items	Missing value	Mean Statistics	Standard deviation	kurtosis statistics	Skewness
MDY1	0	5.517	1.301	1.117	-1.147
MDY2	0	5.653	1.17	0.82	-0.885
MDY3	0	5.534	1.5	0.212	-1.021
CPR1	0	5.541	1.282	1.21	-1.09
CPR2	0	5.527	1.342	1.194	-1.162
CPR3	0	5.793	1.291	1.6	-1.332
CPR4	0	5.779	1.284	1.762	-1.403
RGS1	0	5.507	1.282	0.875	-1.041
RGS2	0	5.446	1.408	0.701	-1.076
RGS3	0	5.541	1.318	0.845	-1.06
RGS4	0	5.711	1.307	0.963	-1.188
BCAD1	0	5.463	1.202	0.992	-0.95
BCAD2	0	5.656	1.238	0.852	-0.947
BCAD3	0	5.816	1.198	1.667	-1.287
TOR1	0	5.602	1.193	2.342	-1.319
TOR2	0	5.677	1.122	1.932	-0.992
TOR3	0	5.908	1.079	1.345	-1.089
TOR4	0	5.816	1.088	2.337	-1.158
TOR5	0	5.918	1.085	2.463	-1.331
UPS1	0	5.605	1.275	1.621	-1.246
UPS2	0	5.707	1.282	1.66	-1.262
UPS3	0	5.622	1.308	1.413	-1.245
UPS4	0	5.762	1.301	0.925	-1.136
UPS5	0	5.755	1.348	1.407	-1.363
TRA1	0	5.656	1.283	1.312	-1.277
TRA2	0	5.847	1.312	1.264	-1.313
TRA3	0	5.769	1.315	1.937	-1.47
TRA4	0	5.799	1.274	1.664	-1.365
TRA5	0	5.959	1.316	1.909	-1.516
SGV1	0	5.439	1.221	1.511	-1.079
SGV2	0	5.626	1.316	1.082	-1.131
SGV3	0	5.776	1.316	1.082	-1.236
SGV4	0	5.667	1.247	0.891	-1.071

SGV5	0	5.69	1.257	0.853	-1.112
SGV6	0	5.762	1.316	0.53	-1.038
SGV7	0	5.687	1.311	0.821	-1.1
SOC1	0	5.306	1.299	0.538	-0.808
SOC2	0	5.735	1.303	1.335	-1.176
SOC3	0	5.69	1.303	1.354	-1.286
SOC4	0	5.701	1.291	1.211	-1.203
SOC5	0	5.796	1.291	1.586	-1.332
SOC6	0	5.901	1.178	2.477	-1.501
ENV1	0	5.35	1.313	1.003	-1.049
ENV2	0	5.684	1.25	1.56	-1.199
ENV3	0	5.612	1.312	0.615	-1.083
ENV4	0	5.707	1.305	1.012	-1.161
ENV5	0	5.667	1.295	1.706	-1.343
ENV6	0	5.701	1.203	1.008	-1.091
ENV7	0	5.786	1.25	0.78	-1.069
ECO1	0	5.51	1.253	1.09	-1.108
ECO2	0	5.755	1.302	1.764	-1.35
ECO3	0	5.673	1.235	1.562	-1.219
ECO4	0	5.816	1.254	2.032	-1.481
ECO5	0	5.85	1.2	2.164	-1.489

5.2.3 Outliers

In a dataset, an outlier is a single observation that deviates from the normal distribution of the population. Researchers assume that an outlier can be suspicious due to some process or misrepresentation of information (Grable et al., 2004). It is difficult to justify the deletion of outliers that do not exist on a Likert scale (Lowry and Gaskin, 2014). Researchers can also use outliers to understand the phenomenon being studied (Lowry and Gaskin, 2014). Also, choosing 1 or 7 on a Likert scale does not necessarily indicate outlier behaviour or an unengaged respondent (Goodhue et al., 2012, Hair et al., 2019). Three types of outliers include *univariate outliers*, extreme values in a single variable, and *multivariate outliers,* unusual combinations of values across multiple variables (Lowry and Gaskin, 2014, Hair et al., 2019). A data point may not be extreme on any one variable but may be an outlier when considering all variables together. *Contextual* outliers are identified within a specific context, such as time series or spatial data (Hair et al., 2019, Lowry and Gaskin, 2014, Podsakoff et al., 2003).

The dataset of this study was further examined to identify outliers. The data file was imported to SPSS for outlier analysis. It is important to highlight that the solution to handle outliers is a non-mathematical decision (Leys et al., 2019, Newman, 2014). In some cases, mathematics cannot detect the nature of outliers, but it can help find the potential outlier in the dataset (Leys et al., 2019). For example, univariate outliers can be typically identified using standardised Z scores at a cut of (z score > 3.00 or < -3.00) as an outlier (Allen et al., 2014). According to (Hair Jr et al., 2014), with a small sample size of less than 80, outliers can be identified with standard scores of 2.5 or higher and the larger sample size standard scores of 4 and above. A few univariate outliers in the dataset were removed after evaluating standard scores.

5.2.4 Normality

The normal distribution was examined after assessing outliers in the dataset. The normality of the data was identified through the study's skewness and kurtosis index (Allen et al., 2014). A normal distribution is fundamental assumption for multivariate analysis (Hair Jr et al., 2014). Normality is characterised as the type of distribution of data for individual variables and its relationship to the standard distribution for statistical methods (Hair Jr et al., 2014). The deviation of data from normality, with skewness and kurtosis less than 3 and 10, respectively, was still acceptable, and anything above that range would signal a problem in normality (Kaplan, 2008). The Kolmogorov-Smirnov and Shaprio-Wilk test was performed through the SPSS tool to test the normality of the survey data of this study. The result of the normality test is presented in Table 5.2. The table reveals that the test for all constructs was significant at $p<0.05$ for both tests. Therefore, we could accept that the sample data were not normally distributed.

Table 5.2 Normality test

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
Constructs	Statistic	df	Significance	Statistic	df	Significance
BCAD1	.223	294	<.001	.879	294	<.001
BCAD2	.187	294	<.001	.862	294	<.001
BCAD3	.255	294	<.001	.821	294	<.001
CPR2	.240	294	<.001	.852	294	<.001
CPR3	.264	294	<.001	.816	294	<.001
CPR4	.286	294	<.001	.804	294	<.001
ECO2	.248	294	<.001	.818	294	<.001
ECO3	.264	294	<.001	.843	294	<.001
ECO4	.293	294	<.001	.787	294	<.001
ECO5	.308	294	<.001	.786	294	<.001
ENV3	.269	294	<.001	.843	294	<.001
ENV5	.278	294	<.001	.822	294	<.001
ENV6	.248	294	<.001	.847	294	<.001
ENV7	.224	294	<.001	.839	294	<.001
MDY1	.270	294	<.001	.851	294	<.001
MDY2	.198	294	<.001	.868	294	<.001
MDY3	.268	294	<.001	.842	294	<.001
RGS1	.241	294	<.001	.865	294	<.001
RGS2	.221	294	<.001	.853	294	<.001
RGS3	.238	294	<.001	.860	294	<.001
RGS4	.271	294	<.001	.831	294	<.001
SGV2	.227	294	<.001	.847	294	<.001
SGV3	.268	294	<.001	.820	294	<.001
SGV4	.248	294	<.001	.851	294	<.001
SGV5	.264	294	<.001	.842	294	<.001
SGV7	.247	294	<.001	.845	294	<.001
SOC2	.196	294	<.001	.832	294	<.001
SOC3	.288	294	<.001	.821	294	<.001
SOC4	.255	294	<.001	.836	294	<.001
SOC5	.260	294	<.001	.814	294	<.001
SOC6	.268	294	<.001	.790	294	<.001
TOR1	.256	294	<.001	.840	294	<.001
TOR2	.188	294	<.001	.858	294	<.001
TOR3	.231	294	<.001	.837	294	<.001
TOR4	.227	294	<.001	.845	294	<.001
TOR5	.261	294	<.001	.820	294	<.001
TRA2	.240	294	<.001	.798	294	<.001
TRA3	.287	294	<.001	.792	294	<.001
TRA4	.270	294	<.001	.809	294	<.001
TRA5	.244	294	<.001	.760	294	<.001
UMS2	.226	294	<.001	.832	294	<.001
UMS3	.283	294	<.001	.836	294	<.001
UMS4	.212	294	<.001	.828	294	<.001
UMS5	.283	294	<.001	.795	294	<.001
a. Lilliefors Significance Correction						

5.2.5 Collinearity

Collinearity in SEM refers to high correlations among predictors or exogenous variables (Hair Jr et al., 2014). Specifically, collinearity can cause significant issues when estimating the path coefficients in SEM, affecting the stability and interpretability of the model's result (Ullman and Bentler, 2012, Hair et al., 2019). To identify collinearity issues among predictor variables, SEM researchers often rely on important measures like the Variance Inflation Factor (VIF), one of the more significant measures to identify collinearity issues. VIF indicates how much the variance of a regression coefficient is increased due to collinearity. A VIF value above 5 (or, more conservatively, 3) suggests potential collinearity issues, while values above 10 indicate severe collinearity (Becker et al., 2023, Hair Jr et al., 2014). Tolerance is another important measure for collinearity issues. Tolerance is the reciprocal of VIF, and it measures the proportion of a variable's variance that other predictors do not explain (Hair Jr et al., 2014). Low tolerance values (close to 0) indicate high collinearity. Condition Index can also measure collinearity issues; in this case, the index measures collinearity based on eigenvalues (Kaplan, 2008). A condition index above 30 generally signals a collinearity problem. 3) The Correlation Matrix is another tool for measuring collinearity issues. A simple inspection of the correlation matrix can reveal pairs of predictors that are highly correlated (usually above 0.80 or 0.90), indicating possible collinearity issues (Hair et al., 2019).

5.2.6 Common method variance

Common Method Variance (CMV) refers to the amount of spurious covariance shared among variables due to the common method used in collecting data (Buckley et al., 1990) through the survey method. One of the limitations of the survey method research is the occurrence of common method bias, which is a potential threat to validating the result in the survey method study (Podsakoff et al., 2003). In this research, several initiatives were taken to reduce the chance of common method bias. First, data were collected carefully from target respondents with knowledge and expertise about the subject area—for example, supply chain managers or those responsible for supply chain management and operations functionalities. Second, the respondents were assured that their responses would be kept anonymous. Third, the questions were developed simply and precisely to avoid ambiguity. Some terminologies relating to questionnaires were explained with relevant examples so the respondents could easily understand them, simplifying the technical term of the scale item. In addition, this study applied the Harman-one-factor test (Podsakoff and Organ, 1986). All the items (44 items of the 11 constructs) related to the model were entered into SPSS for factor analysis. An unrotated factors analysis was conducted for all the items with eigenvalue 1. The cumulative variance for the factors is 54.867% (Podsakoff and Organ, 1986). According to a previous study, if the cumulative variance is less than 5, it can be concluded that there is no common method variance in the study (Podsakoff and Organ, 1986). Therefore, this study did not consider common method variance a major concern. Table 5.3 below represents the factors analyses and total variance explained for the Harman-one factor test for this study.

Table 5.3 Harman-one factor test

Total Variance Explained						
	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	24.142	54.867	54.867	24.142	54.867	54.867
2	1.481	3.365	58.232			
3	1.205	2.739	60.972			
4	1.064	2.419	63.391			
5	.992	2.254	65.645			
6	.940	2.136	67.781			
7	.886	2.013	69.794			
8	.795	1.808	71.602			
9	.728	1.656	73.257			
10	.675	1.533	74.791			
11	.646	1.469	76.259			
12	.609	1.384	77.644			
13	.603	1.369	79.013			
14	.585	1.329	80.342			
15	.547	1.243	81.585			
16	.507	1.153	82.738			
17	.473	1.075	83.813			
18	.464	1.054	84.867			
19	.434	.987	85.854			
20	.419	.953	86.807			
21	.401	.912	87.718			
22	.387	.879	88.598			
23	.352	.799	89.397			
24	.346	.787	90.185			
25	.334	.759	90.944			
26	.325	.739	91.683			
27	.310	.705	92.388			
28	.297	.675	93.063			
29	.278	.633	93.696			
30	.271	.617	94.312			
31	.253	.576	94.888			
32	.252	.573	95.461			
33	.227	.516	95.977			
34	.212	.482	96.459			
35	.203	.462	96.921			
36	.195	.444	97.365			
37	.185	.420	97.785			
38	.169	.385	98.170			

39	.160	.364	98.534			
40	.154	.350	98.884			
41	.146	.333	99.217			
42	.128	.290	99.507			
43	.116	.265	99.771			
44	.101	.229	100.000			
Extraction Method: Principal Component Analysis.						

5.2.7 Demographic information of samples

Table 5.4 summarises the demographic information of the survey respondents regarding supply chain entity, firm size (number of employees), and the number of years in business of the sample firms of the study.

Supply chain entity

Table 5.4 shows the data related to the position of the sample firm in the Agri-product supply chain respondents for the study. The respondents were selected from five supply chain entities: Agri-products producer, processor, wholesaler, distributor, and retailer. It was revealed that the highest number of participants, 34.01%, were from Agri-product retailers; accordingly, distributors (30.62%), producers (17%), and processors (11.57%) and the lowest number of participants, 6.80%, were from Agri-products wholesalers.

Table 5.4 Demographic information of participants

Supply Chain Entity	**Number of companies**	**Percentage %**
Agri-products producer	50	17
Agri-product processor	34	11.57
Agri-products wholesaler	20	6.80
Agri-product distributor	90	30.62
Agri-product retailer	100	34.01
Number of Employees	**Number of companies**	
Less than 20	80	27.21
20 or less than 200	34	11.58
200 or less than 300	100	34.01
300 or less than 400	50	17
400 or less than 500	20	6.80
More than 500	10	3.40
Number of Years in Business	**Number of companies**	
Less than 5 years	50	17
5 to 9 years	39	13.27
10 to 14 years	75	25.52
15 to 19 years	80	27.21
20+ years	50	17

Size of the firm

The survey data relating to the firm size was also summarised in Table 5.4 for this research. It was revealed that 34.01% of respondents, the majority, were from organisations with 200 or less than 300 employees. The lowest respondent rate (3.4%) was from organisations with more than 500 employees.

Number of years in business

Table 5.4 also presents the number of years in business in terms of the experience level of the sample firms. It was revealed that the highest respondent rate (27.21%) contributed to this study, with 15 to 19 years of experience in business. The 5 to 9-year firms are the lowest respondents' rate (13,27%) for this study.

5.3 PLS-Based Structural Equation Modelling (SEM)

This study analysed data by deploying partial least-squire structural equation modelling (PLS-SEM) that aligns with the research objective. In particular, the model assessment in PLS-SEM includes a two-step process:

- Assessment of measurement model
- Assessment of structural model

These sequential processes of assessments were conducted to ensure that construct measurements qualify for reliability and validity before finalising the relationship among the study model. The process involves a separate assessment of the measurement and structural models. The sequential assessments are presented in Table 5.5 (Hair Jr et al., 2014).

Table 5.5 Sequential assessments of the model

Stage	Analysis	Analysis	Constructs
1	Measurement model assessment	1-Indicator reliability 2- Internal consistency (Cronbach's alpha, composite reliability, reliability coefficient) 3- Discriminant validity (HTMT)	Reflective Reflective Reflective
2	Structural model assessment	1-Bootstrapping 2-Amount of variance explained (R^2) 3- Path coefficient (b) 4-Statiscial significance of t-values	Reflective Reflective Reflective Reflective

In the following section, the sequential assessments are discussed as per Table 5.5

5.3.1 Measurement model assessment

The final model of this study consists of 11 constructs, including first-order and higher-order constructs. The constructs in the measurement model were refractive. In this study, business environmental drivers such as market dynamics (MDY), competitive pressure (CPR), and regulatory support (RGS) were first-order constructs (exogenous constructs), and blockchain adoption (BCAD) (endogenous construct) was a first-order construct. In this study, exogenous constructs (MDY, CPR, RGS) directly affect endogenous constructs (BCAD) without influencing other constructs or variables. Previous study indicates that PLS-SEM implies that exogenous constructs directly affect endogenous constructs without any systematic influence of other variables (Hair Jr et al., 2014). However, in many instances, this assumption is not the case (Gefen et al., 2000, Hair Jr et al., 2014, Murtagh and Heck, 2012). In this study, sustainability is only a higher order construct measured by three first order constructs: social (SOC), environmental (ENV), and economic (ECO). In addition, conditional effects of technology orientation (TOR) and upper management support (UMS) played a supportive role in the study and extended the relationship between BCAD and TRA. Also, conditional effect of sustainability governance (SGV) played a supportive role in the study. The supportive role of SVG extended the relationship between traceability and sustainability. Figure 5.1 represents the model for reflective constructs and measurement of the study.

The measurement model was analysed based on indicator reliability, internal consistency, discriminant validity, cross-loading, and outer loading.

5.3.2 Reflective measurement model assessment

A reflective measurement model was assessed based on indicator reliability, internal consistency reliability, convergent validity and discriminant validity. The study's first-order and higher-order level constructs are consistent with the reflective measurement model. The first-order measurement model was assessed first. After the first-order measurement model was refined, the higher-order model was evaluated.

5.3.3 First-order measurement model

In this study, the measurement model consists of 11 constructs (including first-order and higher-order); all constructs were reflective. Among the constructs, the following constructs were measured at the first-order level: market dynamics (MDY), competitive pressure (CPR), and regulatory support (RGS). Also, blockchain adoption (BCAD) was measured by traceability (TRA), technology orientation (TOR), and upper management support (UMS). TRA was measured by sustainability governance (SGV). Also, TRA was measured by three first-order constructs: social (SOC), environmental (ENV) and economic (ECO) factors. Drawing from previous studies (Chowdhury and Quaddus, 2021b, Cousins et al., 2019, Wamba et al., 2020b, Wong et al., 2020a, Yu et al., 2022), these constructs and their indicators (measurement items) were assessed regarding indicator reliability, internal consistency, and discriminant validity (Barclay et al., 1995, Becker et al., 2023, Chin, 2009, Hair et al., 2019). Hair Jr et al. (2014) Suggests that the measurement model evaluation delivers empirical measures of the relationships between the indicators and the constructs. Figure 5.1 demonstrates the constructs and their measurement items in the model of the study.

5.3.4 Indicator reliability

The first step in the reflective measurement model assessment requires the examination of the outer loading of the indicators (Hair et al., 2019). According to previous studies, the common rule of thumb is that the standardised outer loadings should be 0.708 or higher (Becker et al., 2023, Byrne, 2013, Hair et al., 2019, Lowry and Gaskin, 2014). To this end, the cut-off value for the outer loading of this study was 0.70 to achieve the convergent validity of the measurement model (Becker et al., 2012, Hair et al., 2019, Sarstedt et al., 2021). All bars in the chart appear green, indicating that all constructs measured for this study are above the 0.70 threshold (Becker et al., 2012, Hair et al., 2019, Sarstedt et al., 2021). However, during the second PLS run, a total of ten indicators (items) (CPR1, TRA1, UPS1, SGS1, SGS6, SOC1, ENV1, ENV2, ENV4, AND ECO1) were deleted due to them having loading values less than 0.70 (Hair et al., 2019). Table 5.5 represents the outer loading of the indicators for the study.

Figure 5.1*: Market Dynamics (MDY), Competitive Pressure (CPR), Regulatory support (RGS) (Exogenous Constructs), Blockchain Adoption: BCAD (Endogenous constructs), Traceability (TRA)- Mediator, Technology Orientation (TOR)- Moderator, Upper Management Support (UMS) -Moderator. Sustainability Governance (SGV)- Moderator, Sustainability (outcome variable) Social (SOC), Environmental (ENV), Economic (ECO).

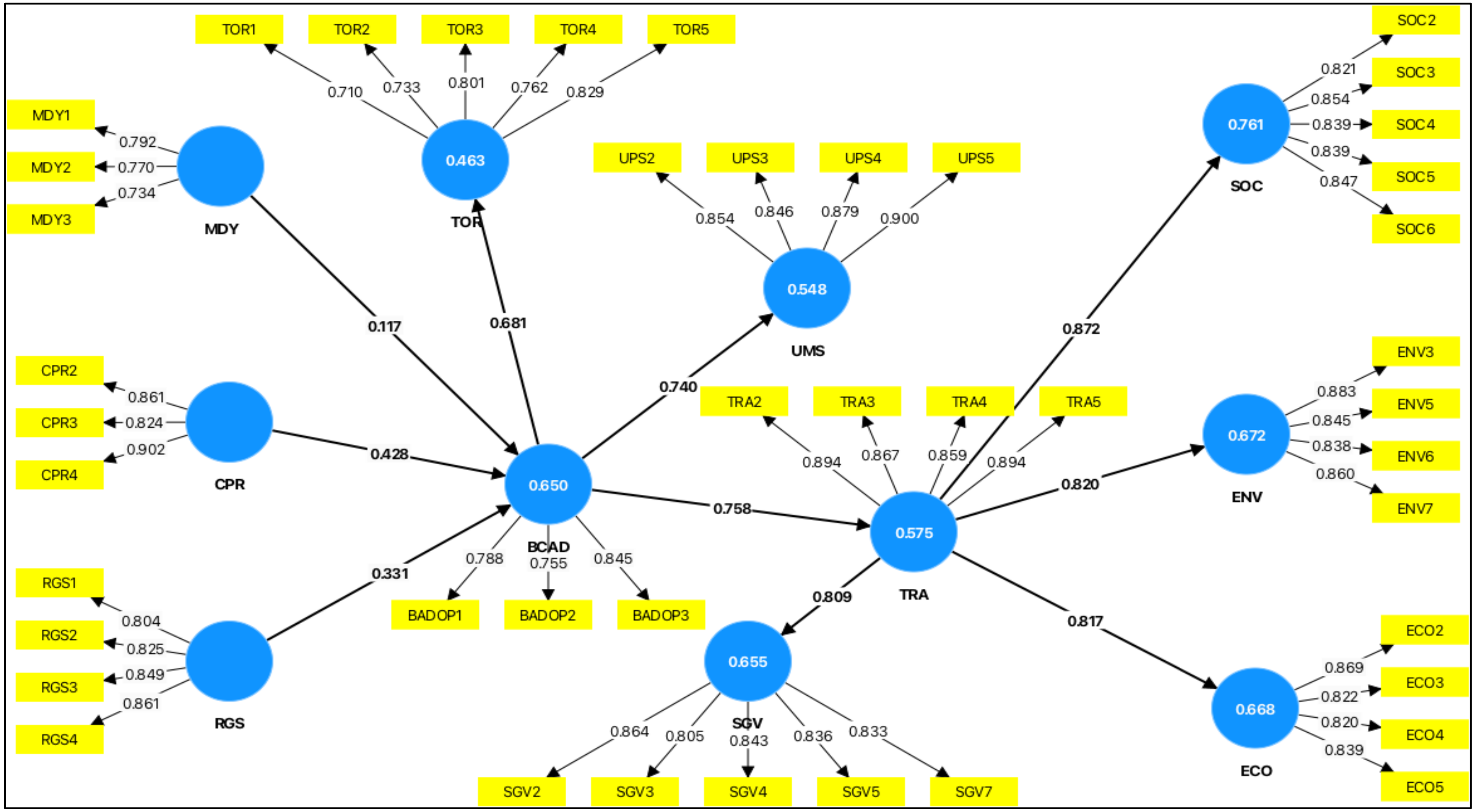

Figure 5.1 Measurement model of the study

Table 5.6 Outer loading for reflective constructs

	BCAD	CPR	ECO	ENV	MDY	RGS	SGV	SOC	TOR	TRA	UMS
BADOP1	0.788										
BADOP2	0.755										
BADOP3	0.845										
CPR2		0.861									
CPR3		0.824									
CPR4		0.902									
ECO2			0.869								
ECO3			0.822								
ECO4			0.820								
ECO5			0.839								
ENV3				0.883							
ENV5				0.845							
ENV6				0.838							
ENV7				0.860							
MDY1					0.792						
MDY2					0.770						
MDY3					0.734						
RGS1						0.804					
RGS2						0.825					
RGS3						0.849					
RGS4						0.861					
SGV2							0.864				
SGV3							0.805				
SGV4							0.843				
SGV5							0.836				
SGV7							0.833				
SOC2								0.821			
SOC3								0.854			
SOC4								0.839			
SOC5								0.839			
SOC6								0.847			
TOR1									0.710		
TOR2									0.733		
TOR3									0.801		
TOR4									0.762		
TOR5									0.829		
TRA2										0.894	
TRA3										0.867	
TRA4										0.859	
TRA5										0.894	
UPS2											0.854
UPS3											0.846
UPS4											0.879
UPS5											0.900

5.3.5 Internal consistency

All bars in the chart appear green, indicating that all constructs measured for this study are above the 0.70 threshold (Becker et al., 2012, Hair et al., 2019, Sarstedt et al., 2021). Concerning the quality criteria of the constructs' reliability and validity, the bar chart of Cronbach's alpha and composite reliability of this research met the 0.70 threshold. Cronbach's alpha was used to evaluate the reliability of the measurement model. Reliability tests ensure that the observed indicators consistently measure the latent constructs (Hair et al., 2019). Table 5.7 represents the constructs' reliability and validity for this research.

Table 5.7 Constructs' reliability and validity overview

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
BCAD	0.711	0.717	0.839	0.635
CPR	0.828	0.835	0.897	0.745
ECO	0.858	0.858	0.904	0.702
ENV	0.879	0.880	0.917	0.734
MDY	0.706	0.706	0.809	0.586
RGS	0.855	0.857	0.902	0.697
SGV	0.892	0.894	0.921	0.699
SOC	0.896	0.896	0.923	0.706
TOR	0.825	0.829	0.878	0.590
TRA	0.902	0.903	0.931	0.772
UMS	0.893	0.895	0.926	0.757

5.3.6 Composite reliability

This study also assessed the composite reliability of the measurement model. According to previous studies, the common minimum threshold of composite reliability is 0.70 (Hair Jr et al., 2014). The following figure indicates that all constructs were on the threshold of composite reliability in this study. Figure 5.2 represents the composite reliability of the measurement model.

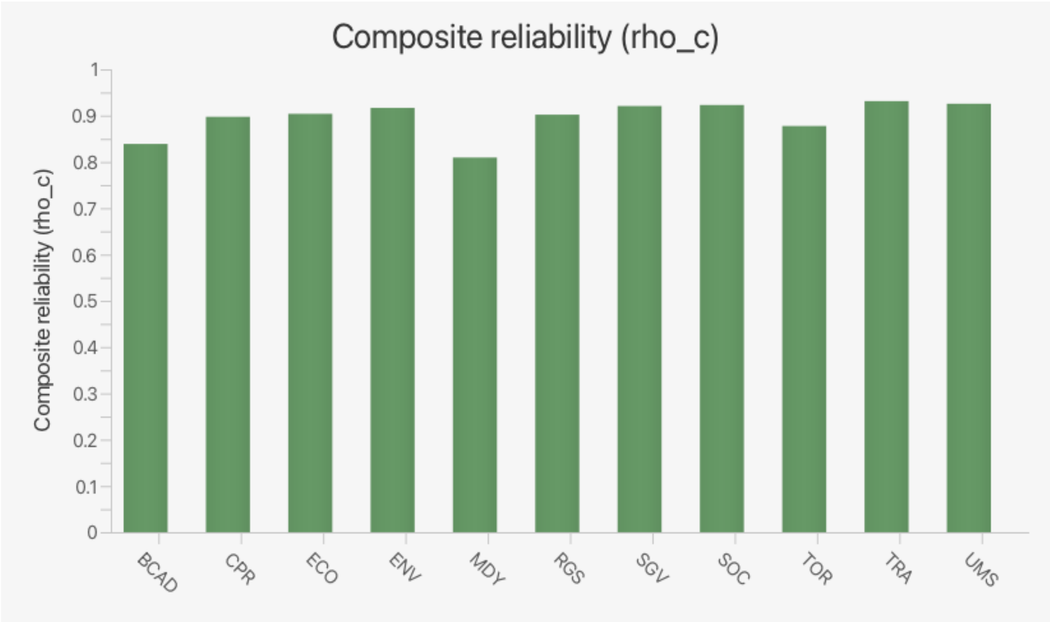

Figure 5.2 Composite reliability of constructs

5.3.7 Average variance extracted (AVE)

The average variance extracted was also measured as part of internal consistency to identify the constructs' reliability and validity. Convergent validity is based on AVE values. According to earlier studies, this research met the minimum AVE level of 0.50. Figure 5.3 represents the satisfactory average variance extracted for this study.

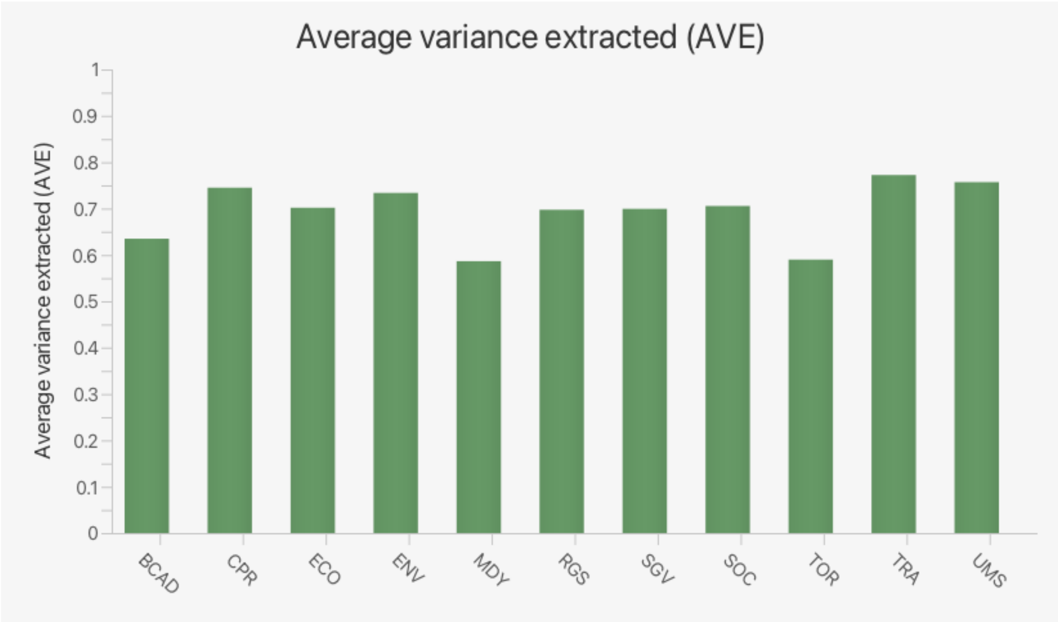

Figure 5.3 Average variance extracted

5.3.8 Discriminant Validity

Compression between the square root of average variance extracted (AVE) and the constructs' correlations were conducted according to the criteria of Fornell and Larcker (1981) to declare discriminant validity for each construct. The values of the square root of AVE (bold diagonal numbers) and the latent variables correlations score (off-diagonal elements) are shown in Table 5.8 (Hair Jr et al., 2014, Lucas et al., 1996, Sarstedt et al., 2019). Discriminant validity was also checked through a cross-loading matrix for this study. According to previous studies, the loading of an indicator with the corresponding construct should be greater than its loading with other constructs (Hair Jr et al., 2014, Lucas et al., 1996, Sarstedt et al., 2019). In the first PLS model run of the study, ten indicators were removed due to the outer loading threshold being less than 0.70. Accordingly, discriminant validity was not established, and a second PLS model run was performed. The refined measurement model was evaluated, and it was asserted that all loading was above the threshold of 0.70. In the refined model, discriminant validity was established, and no issue of discriminant validity was found, as shown in Table 5.8. The result of the cross-loading is presented in Table 5.9.

Table 5.8 Discriminant validity-Fornell-Larcker Criterion (generated by SmartPLS)

	BCAD	CPR	ECO	ENV	MDY	RGS	SGV	SOC	TOR	TRA	UMS
BCAD	**0.797**										
CPR	0.768	**0.863**									
ECO	0.702	0.761	**0.838**								
ENV	0.677	0.758	0.840	**0.860**							
MDY	0.643	0.710	0.602	0.655	**0.766**						
RGS	0.741	0.775	0.680	0.734	0.669	**0.835**					
SGV	0.719	0.759	0.810	0.841	0.657	0.733	**0.862**				
SOC	0.722	0.791	0.870	0.875	0.673	0.739	0.832	**0.864**			
TOR	0.681	0.703	0.729	0.738	0.656	0.713	0.706	0.781	**0.776**		
TRA	0.758	0.840	0.817	0.820	0.708	0.777	0.809	0.872	0.746	**0.879**	
UMS	0.740	0.784	0.834	0.804	0.638	0.717	0.799	0.840	0.770	0.843	**0.870**

Table 5.9 Cross Loading (generated by SmartPLS)

	BCAD	CPR	ECO	ENV	MDY	RGS	SGV	SOC	TOR	TRA	UMS
BCAD1	0.788	0.590	0.587	0.586	0.529	0.604	0.557	0.564	0.593	0.564	0.534
BCAD2	0.755	0.598	0.523	0.441	0.433	0.538	0.522	0.558	0.482	0.583	0.575
BCAD3	0.845	0.646	0.570	0.587	0.568	0.627	0.634	0.604	0.552	0.662	0.655
CPR2	0.618	0.861	0.649	0.631	0.615	0.626	0.610	0.659	0.609	0.681	0.653
CPR3	0.643	0.824	0.616	0.634	0.592	0.685	0.631	0.663	0.575	0.703	0.671
CPR4	0.721	0.902	0.703	0.695	0.630	0.692	0.718	0.722	0.636	0.785	0.703
ECO2	0.575	0.640	0.869	0.732	0.510	0.558	0.694	0.757	0.605	0.692	0.720
ECO3	0.628	0.669	0.822	0.682	0.517	0.576	0.681	0.718	0.635	0.690	0.653
ECO4	0.562	0.634	0.820	0.686	0.539	0.535	0.640	0.703	0.596	0.669	0.724
ECO5	0.587	0.608	0.839	0.714	0.453	0.606	0.698	0.738	0.606	0.685	0.700
ENV3	0.608	0.653	0.724	0.883	0.606	0.677	0.731	0.739	0.677	0.729	0.702
ENV5	0.597	0.673	0.724	0.845	0.548	0.628	0.713	0.731	0.638	0.716	0.705
ENV6	0.541	0.667	0.721	0.838	0.606	0.608	0.727	0.761	0.626	0.689	0.680
ENV7	0.572	0.601	0.710	0.860	0.481	0.597	0.711	0.717	0.585	0.672	0.666
MDY1	0.541	0.552	0.466	0.520	0.792	0.565	0.512	0.547	0.502	0.578	0.506
MDY2	0.478	0.545	0.445	0.448	0.770	0.448	0.513	0.494	0.501	0.516	0.445
MDY3	0.451	0.535	0.475	0.539	0.734	0.520	0.485	0.503	0.507	0.532	0.516
RGS1	0.629	0.587	0.464	0.513	0.478	0.804	0.529	0.525	0.543	0.563	0.501
RGS2	0.560	0.633	0.549	0.574	0.559	0.825	0.575	0.609	0.598	0.641	0.563
RGS3	0.627	0.658	0.585	0.651	0.578	0.849	0.642	0.610	0.578	0.657	0.626
RGS4	0.653	0.706	0.666	0.707	0.618	0.861	0.696	0.720	0.663	0.732	0.699
SGV2	0.609	0.680	0.737	0.724	0.577	0.602	0.864	0.755	0.624	0.723	0.745
SGV3	0.629	0.660	0.635	0.695	0.554	0.609	0.805	0.707	0.587	0.698	0.655
SGV4	0.560	0.609	0.687	0.709	0.531	0.590	0.843	0.708	0.556	0.650	0.632
SGV5	0.612	0.610	0.679	0.691	0.545	0.672	0.836	0.748	0.620	0.668	0.677
SGV7	0.590	0.609	0.643	0.697	0.534	0.592	0.833	0.679	0.558	0.637	0.623
SOC2	0.559	0.621	0.700	0.686	0.555	0.580	0.671	0.821	0.659	0.706	0.686
SOC3	0.680	0.687	0.761	0.756	0.582	0.683	0.787	0.854	0.689	0.745	0.752
SOC4	0.638	0.664	0.726	0.702	0.583	0.620	0.700	0.839	0.666	0.733	0.738
SOC5	0.578	0.652	0.734	0.742	0.556	0.610	0.765	0.839	0.670	0.718	0.730
SOC6	0.576	0.693	0.733	0.727	0.552	0.608	0.695	0.847	0.598	0.759	0.724
TOR1	0.511	0.456	0.484	0.446	0.450	0.467	0.443	0.485	0.710	0.463	0.443

TOR2	0.455	0.506	0.506	0.528	0.459	0.566	0.539	0.595	0.733	0.578	0.554
TOR3	0.561	0.586	0.554	0.588	0.550	0.566	0.576	0.610	0.801	0.640	0.655
TOR4	0.520	0.560	0.585	0.591	0.499	0.587	0.561	0.655	0.762	0.604	0.653
TOR5	0.556	0.586	0.662	0.672	0.552	0.557	0.587	0.651	0.829	0.686	0.641
TRA2	0.664	0.754	0.733	0.709	0.618	0.682	0.712	0.805	0.732	0.894	0.769
TRA3	0.671	0.712	0.691	0.709	0.581	0.648	0.713	0.739	0.640	0.867	0.714
TRA4	0.642	0.734	0.669	0.702	0.620	0.699	0.658	0.728	0.668	0.859	0.727
TRA5	0.687	0.752	0.774	0.761	0.669	0.705	0.757	0.791	0.686	0.894	0.754
UPS2	0.673	0.711	0.682	0.656	0.551	0.616	0.692	0.720	0.667	0.746	0.854
UPS3	0.591	0.649	0.708	0.657	0.526	0.595	0.654	0.712	0.641	0.682	0.846
UPS4	0.647	0.647	0.736	0.735	0.571	0.657	0.707	0.786	0.664	0.735	0.879
UPS5	0.658	0.717	0.777	0.748	0.571	0.626	0.725	0.789	0.706	0.767	0.900

Based on the above analysis, it is evident that the measurement model of the study was considered satisfactory in terms of indicator reliability, internal consistency, and discriminant validity. This meets the criteria of convergent validity (loading > 0.70, AVE > 0.50, CR > 0.80) and discriminant validity (AVE > correlations). Thus, the first-order measurement model was confirmed to be satisfactory. In addition, the following section details the measurement model between BCAD and first-order sustainability constructs (SOC, EVN, & ECO) and the measurement model between TRA and first-order sustainability constructs (SOC, EVN, & ECO) accordingly.

5.3.9 Measurement model for BCAD and SOC, ENV, & ECO

In this section, the measurement model evaluated the relationship between BCAD and first-order constructs, including social (SOC), environmental (ENV), and economic (ECO) accordingly. The measurement properties of the reflective constructs were assessed by reliability, internal consistency, and AVE, represented in Table 5.10. The outer loading is represented in Table 5.11. At this stage, blockchain adoption (BCAD) was measured by social (SOC), environmental (ENV), and economic (ECO). Figure 5.4 presents a reflective measurement model for BCAD and first-order constructs.

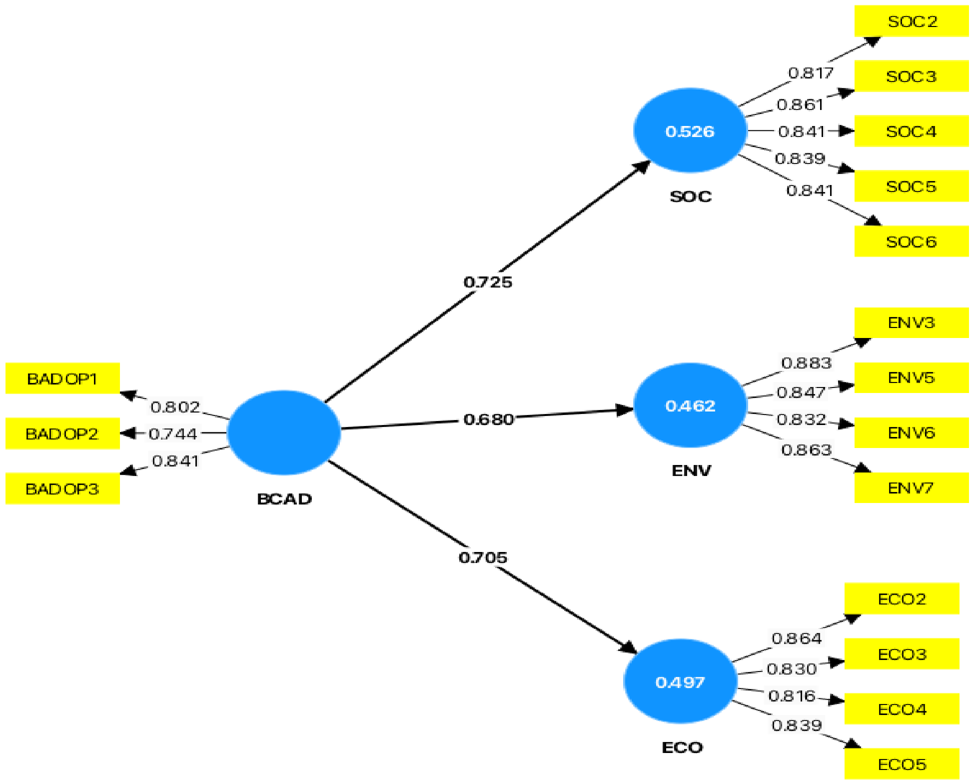

Figure 5.4 Measurement model for BCAD & first-order sustainability constructs

Table 5.10 Reflective measurement for BCAD & first-order sustainability constructs

	Constructs	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
BCAD	Endogenous	0.711	0.717	0.839	0.635
ECO	First-Order	0.858	0.859	0.904	0.701
ENV	First-Order	0.879	0.881	0.917	0.734
SOC	First-Order	0.896	0.899	0.923	0.705

Table 5.11 Outer loading for BCAD & first-order sustainability constructs

Constructs	BCAD	ECO	ENV	SOC
BCAD1	0.802			
BCAD2	0.744			
BCAD3	0.841			
ECO2		0.864		
ECO3		0.83		
ECO4		0.816		
ECO5		0.839		
ENV3			0.883	
ENV5			0.847	
ENV6			0.832	
ENV7			0.863	
SOC2				0.817
SOC3				0.861
SOC4				0.841
SOC5				0.839
SOC6				0.841

Table 5.11 reveals that the loading of the first-order constructs scores corresponding to blockchain adoption is more than 0.80, above the threshold of 0.70 (Hair et al., 2019, Sarstedt et al., 2019). The AVE value also proved the convergent validity of the model, which is more than 0.70, also above the threshold level of 0.50 shown in Table 5.10 (Hair et al., 2019, Sarstedt et al., 2019).

5.3.10 Measurement model for TRA and SOC, ENV, & ECO

The reflective measurement model for TRA and first-order sustainability constructs is represented in this section. The measurement model evaluated the relationship between TRA and SOC, ENV, & ECO. The measurement properties of these reflective constructs were assessed by reliability, internal consistency, and AVE. They are presented in Table 5.10, while the outer loading is presented in Table 5.11. So, traceability (TRA) was measured by first-order constructs of social (SOC), environmental (ENV), and economic (ECO). Figure 5.5 presents a model for traceability (TRA) and first-order sustainability constructs.

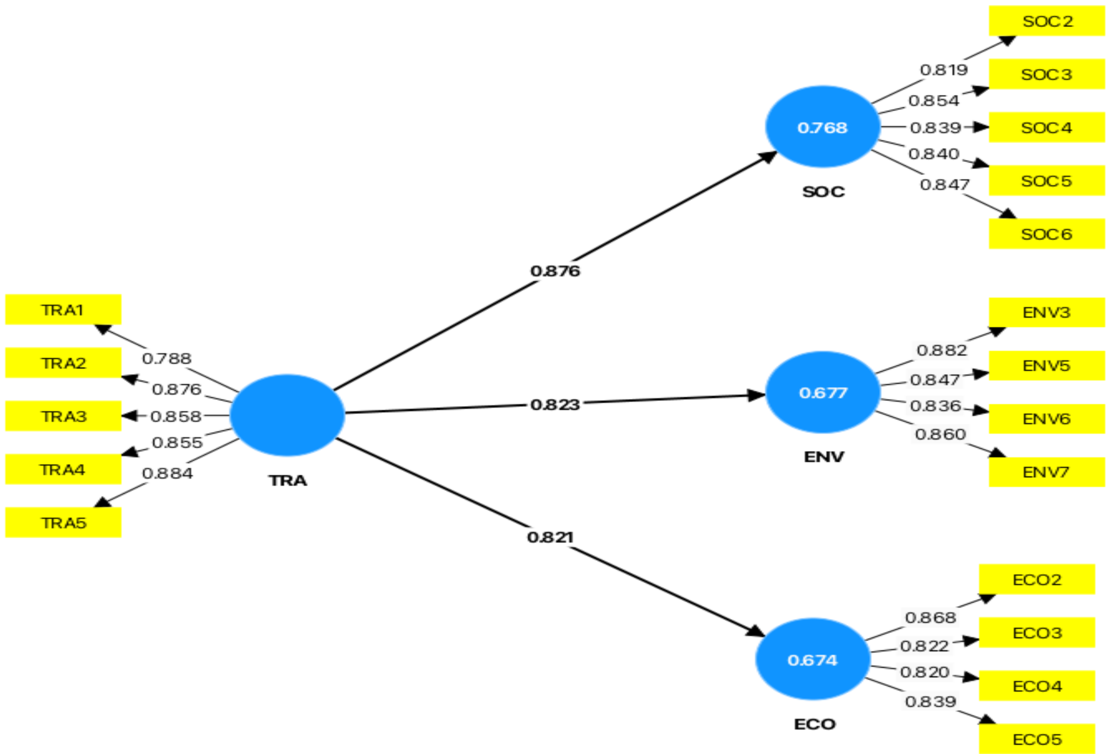

Figure 5.5 Measurement model for TRA & first-order sustainability constructs

Table 5.12 reveals that the loading of three first-order reflective constructs score corresponding to TRA is more than 0.80, above the threshold of 0.70 (Hair et al., 2019, Sarstedt et al., 2019). The AVE value also proved the convergent validity of the model, which is more than 0.70, above the threshold level of 0.50 in Table 5.13 (Hair Jr et al., 2019, Sarstedt et al., 2021).

Table 5.12 Outer Loading for TRA and SOC, ENV, & ECO

	ECO	ENV	SOC	TRA
ECO2	0.868			
ECO3	0.822			
ECO4	0.820			
ECO5	0.839			
ENV3		0.882		
ENV5		0.847		
ENV6		0.836		
ENV7		0.860		
SOC2			0.819	
SOC3			0.854	
SOC4			0.839	
SOC5			0.840	
SOC6			0.847	
TRA1				0.788
TRA2				0.876
TRA3				0.858
TRA4				0.855
TRA5				0.884

Table 5.13 Reflective measurement for TRA & SOC, ENV, & ECO

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
ECO	0.858	0.858	0.904	0.702
ENV	0.879	0.88	0.917	0.734
SOC	0.896	0.896	0.923	0.705
TRA	0.906	0.91	0.93	0.728

The above analysis was evident that the measurement model of the study was considered satisfactory in terms of indicator reliability, internal consistency, and discriminant validity. Once the measurement model confirmed that the constructs were reliable and valid, the next step was addressing the structural model analysis (Hair et al., 2019, Kaplan, 2008, Sarstedt et al., 2019). The measurement model analysis of this study proved that all the measurement items were consistent and conveyed significant measurement properties. These findings made the measurement model valid for structural model assessment for this research. The following section details the structural model assessment for the study.

5.4 Structural model assessment

As mentioned in Chapter 4, the structural model of this study was evaluated and assessed through the statistical significance of the path loadings, path coefficients and corresponding t-values among the constructs (Becker et al., 2023, Hair Jr et al., 2014, Kaplan, 2008). The model explanatory power was assessed for this study by estimating the percentage of variance explained or the R-squared (R^2) value of the endogenous constructs (Hair Jr et al., 2014, Kaplan, 2008, Sarstedt et al., 2019). In addition, the nomological validity of constructs and predictive validity were assessed. Two non-parametric approaches, including the jackknife and bootstrap techniques, are significantly important in testing the relationship between constructs in a PLS-SEM-based structural model assessment. To this end, this study considered the bootstrapping method, a relatively more advanced approach than the jackknife method (Becker et al., 2023, Hair et al., 2019, Streukens and Leroi-Werelds, 2016).

5.4.1 Collinearity test

This study used the variance inflation factor (VIF) to evaluate the structural model collinearity test. It is evident that the VIF is used to evaluate the collinearity of the formative model indicator in PLS-SEM; however, VIF can be applied to evaluate the structural model for the collinearity test of indicators (Hair et al., 2019). A VIF value of 5 or above indicates critical collinearity issues among the indicators of the model. However, collinearity issues can occur at a lower VIF value of 3 (Mason and Perreault Jr, 1991, Hair et al., 2019). Ideally, the VIF value should be 3 or lower (Hair et al., 2019). Table 5.14 below represents VIF values for 44 items of the structural model of this study, and all the values are shown to be below 5. It shows no strong indicator of collinearity issues in this model.

Table 5.14 Collinearity test

Constructs	**VIF**
BCAD1	1.410
BCAD2	1.313
BCAD3	1.552
CPR1	1.631
CPR2	2.144
CPR3	1.712
CPR4	2.478
ECO1	1.541
ECO1	2.299
ECO2	2.966
ECO2	2.348
ECO3	2.485
ECO3	1.991
ECO4	1.978
ECO4	2.339
ECO5	2.124
ECO5	2.705
ENV1	2.470
ENV1	1.740
ENV2	2.003
ENV2	2.391
ENV3	3.128
ENV3	2.751
ENV4	2.262
ENV4	2.691
ENV5	2.817
ENV5	2.377
ENV6	2.926
ENV6	2.289
ENV7	2.618
ENV7	2.425
MDY1	1.264
MDY2	1.296
MDY3	1.244
RGS1	1.708
RGS2	1.977
RGS3	2.081
RGS4	2.187
SGV1	1.925
SGV2	2.605
SGV3	2.193
SGV4	2.478
SGV5	2.312
SGV6	1.910
SGV7	2.411
SOC1	1.780
SOC1	1.427
SOC2	2.121
SOC2	2.593
SOC3	3.322

SOC3	2.769
SOC4	2.376
SOC4	2.825
SOC5	2.881
SOC5	2.425
SOC6	2.841
SOC6	2.377
TOR1	1.422
TOR2	1.611
TOR3	1.945
TOR4	1.643
TOR5	2.142
TRA1	1.920
TRA2	3.066
TRA3	2.567
TRA4	2.612
TRA5	3.132
UPS1	1.563
UPS2	2.270
UPS3	2.567
UPS4	2.592
UPS5	3.364
TOR x BCAD	1.000
UPS x BCAD	1.000
SGV x TRA	1.000

5.4.2 Path coefficient (β) and t-value

Path coefficients and corresponding t-values were calculated to assess the relationships among the constructs hypothesised in this research (Becker et al., 2023, Hair et al., 2019, Streukens and Leroi-Werelds, 2016). In particular, the path coefficient's positive value indicates a positive relationship between the constructs and vice versa (Hair et al., 2019). The t-value evaluates whether the relationships among the constructs are significant. The figure represents the path coefficient (β) and t-values for the structural model of the study. The path coefficient t-values, as well as blockchain adoption (BCAD), Traceability (TRA), supply chain sustainability of social (SCO), environmental (ENV), and economic (ECO) are presented in Figure 5.6 and Table 5.15.

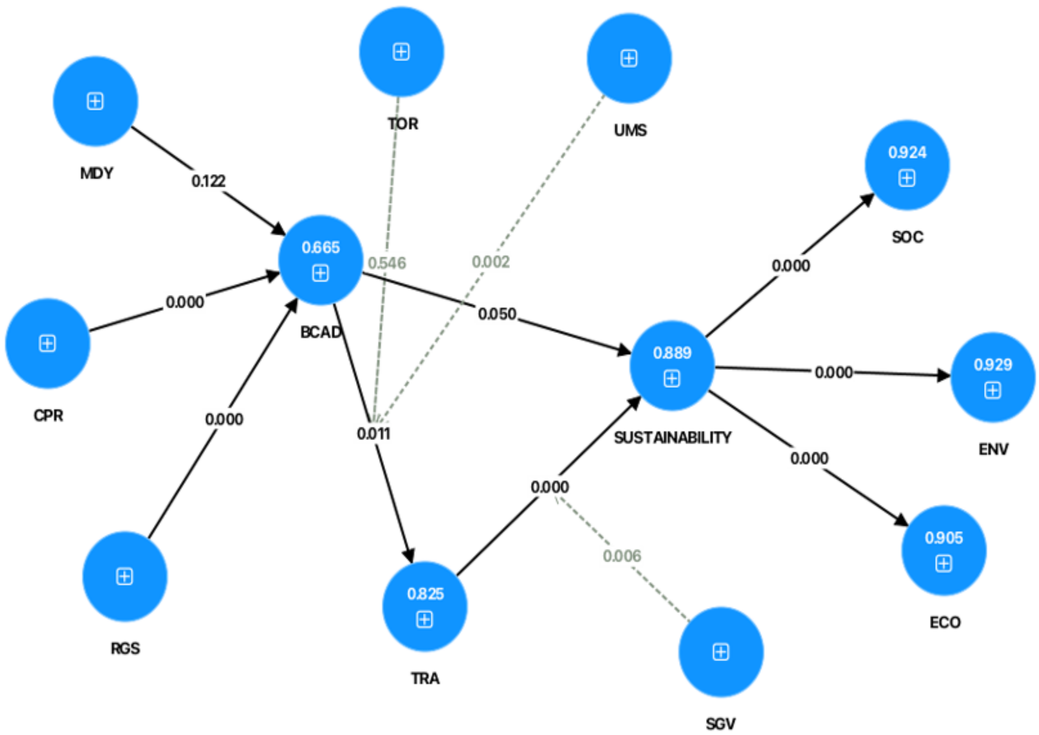

Figure 5.6 t-values from the bootstrapping output of the structural model

Table 5.15 Path coefficient (β) values, t-values, and p-values

Hypothesis	Link	Beta (β) Coefficient	Standard deviation	T statistics	P values	Outcome
H1 (+)	MDY -> BCAD	0.111	0.072	1.545	0.122	Not Supported
H2 (+)	CPR -> BCAD	0.479	0.077	6.182	0	Supported
H3 (+)	RGS -> BCAD	0.293	0.076	3.871	0	Supported
H4 (+)	BCAD -> TRA	0.147	0.058	2.542	0.011	Supported
H5 (+)	TOR x BCAD -> TRA	0.029	0.048	0.604	0.546	Not Supported
H6 (-)	UMS x BCAD -> TRA	-0.122	0.04	3.029	0.002	Supported
H7 (+)	BCAD -> SUSTAINABILITY	0.062	0.032	1.964	0.05	Supported
H8 (-)	SGV x TRA -> SUSTAINABILITY	-0.049	0.018	2.75	0.006	Supported
H9 (+)	TRA -> SUSTAINABILITY	0.361	0.059	6.086	0	Supported

Significant *p < 0.05, **p< 0.01, ***p<0.005, Significant t-values=1.96 (Green indicates p-value significance and Red indicates p-value not significant).

5.4.3 Coefficient of determination (R^2)

As evident from earlier studies, the R^2 values evaluate the ability of the model to explain and predict the endogenous latent variables (Buckley et al., 1990, Cohen, 2013, Hair et al., 2019, Malhotra et al., 2006, Sarstedt et al., 2019). The R^2 values of endogenous latent constructs (BCAD, TRA, SUS) in this model of the study are presented in Table 5.16. The following Table shows that all the R^2 values are above 0.5, which indicates either the large or at least the moderate explanatory power of the endogenous constructs (Buckley et al., 1990, Cohen, 2013, Hair et al., 2019, Malhotra et al., 2006, Sarstedt et al., 2019). In addition, the values confirm the nomological validity of the endogenous constructs with respect to their exogenous constructs (Hair et al., 2019, Kouhizadeh et al., 2021, Malhotra et al., 2006). In particular, the model has adequate merits because the important endogenous construct, blockchain adoption (BCAD), can explain the 68.9.% variance in supply chain traceability and sustainability model. Note:

Table 5.16 Coefficient of determination (R^2)

Constructs	R-square	R-square adjusted
Blockchain adoption (BCAD)	0.689	0.683
Traceability (TRA)	0.791	0.788
Sustainability (SUS)	0.919	0.917

5.4.4 Predictive validity

To measure predictive relevance, this study used Q^2, calculated according to Stone and Peeke (1974) and Geisser (1975), who tested the predictive relevance of the focus multidimensional constructs of the model. The predictive relevance values were calculated and represented in Table 5.17 based on the blindfolding procedure and the cross-validated redundancy approach. The Q^2 values for the model for all endogenous constructs are positive and above 0.05 (Geisser, 1975, Shmueli et al., 2019, Stone and Peeke, 1974). Table 5.17 shows the satisfactory values of predictive validity for the outcome constructs of sustainability (SOC, ENV and ECO), so there is good predictive power at the inner model structural level (Geisser, 1975, Shmueli et al., 2019).

Table 5.17 Predictive relevance for sustainability

Predictive relevance with respect to sustainability	Q^2predict
BCAD	0.648
TRA	0.831
Sustainability	0.892
SOC	0.863
ENV	0.804
ECO	0.792

5.4.5 Endogeneity test of the model

This study used the Gaussian Copula approach to identify the presence or absence of endogeneity issues in the model. In this model, using the Gaussian Copula, each relationship from the exogenous constructs (MDY, COP, RGS) to endogenous constructs (BCAD) was checked individually and together accordingly (Hair et al., 2019, Park and Gupta, 2012, Shmueli and Koppius, 2011). The P value threshold should be more than 0.05 (Park and Gupta, 2012). Table 5.18 shows that the P values are more than 0.05 for all relationships of One Copula, Two Copula and Three Copula of the exogenous constructs (MDY, CPR, RGS) to endogenous constructs (BCAD). No endogeneity issues are present in the model (Hair Jr et al., 2014).

Table 5.18 Endogeneity test using the Gaussian copula approach

One Copula	Original sample (O)	P values
GC (MDY -> BCAD) -> BCAD	0.103	0.193
GC (CPR -> BCAD) -> BCAD	-0.075	0.188
GC (RGS -> BCAD) -> BCAD	-0.034	0.552
Two Copula		
GC (MDY -> BCAD) -> BCAD	0.077	0.382
GC (CPR -> BCAD) -> BCAD	-0.053	0.388
GC (MDY -> BCAD) -> BCAD	0.1	0.24
GC (RGS -> BCAD) -> BCAD	-0.008	0.896
GC (CPR -> BCAD) -> BCAD	0.104	0.190
GC (RGS -> BCAD) -> BCAD	-0.115	0.083
Three Copula		
GC (MDY -> BCAD) -> BCAD	0.072	0.528
GC (CPR -> BCAD) -> BCAD	-0.148	0.121
GC (RGS -> BCAD) -> BCAD	-0.09	0.356

5.4.6 Effect size

Endogenous constructs are presented along with examining R^2 values. This study also examined effect size (f^2) values calculation for all constructs. The measures of the specific endogenous predictor's constructs are highlighted in yellow in Table 5.19 (Hair Jr et al., 2014).

Table 5.19 Total f^2 effect

Constructs	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values	Outcome
BCAD -> ECO	0.11	0.111	0.029	3.848	0	Supported
BCAD -> ENV	0.111	0.112	0.029	3.837	0	Supported
BCAD -> SOC	0.111	0.112	0.029	3.838	0	Supported
BCAD -> SUSTAINABILITY	0.115	0.116	0.03	3.851	0	Supported
BCAD -> TRA	0.147	0.149	0.058	2.542	0.011	Supported
CPR -> BCAD	0.479	0.477	0.077	6.182	0	Supported
TOR -> ENV	0.1	0.1	0.03	3.288	0.001	Supported
TRA -> SOC	0.347	0.347	0.057	6.098	0	Supported
TRA -> SUSTAINABILITY	0.361	0.361	0.059	6.086	0	Supported
UMS -> ECO	0.134	0.131	0.04	3.364	0.001	Supported
UMS x BCAD -> TRA	-0.122	-0.122	0.04	3.029	0.002	Supported

5.4.7 Results of hypotheses testing

The hypothesis testing result of the model is presented in Table 5.15 in sub-section 5.4.2, in this same chapter, implying that 7 out of 9 hypotheses were supported where t-values corresponding to the hypothesis were satisfactory, more than the critical values. In hypothesis 1 (H1*), the relationship between MDY and BCAD (+) was not supported; in this regard, the path coefficient was supposed to be negative, but the result was positive. Also, in hypothesis 5 (H5**), TOR moderates the relationship between BCAD and TRA, which is also unsupported; the path coefficient was supposed to be negative, but the result was positive. Therefore, these relationships would be further clarified through the meditation results of the model of the study.

5.5 Mediation and moderation analysis

5.5.1 Mediation effects analysis

Mediation, where an indirect effect in the analysis can change the understanding of the nature of the direct relationship under consideration, exists in this study (Hair et al., 2019). To this end, traceability (TRA) mediates the relationship between BCAD and sustainability in this study. According to Kenny (1981) and Baron and Kenny (1986), four important mediation characteristics (cited in Chowdhury (2014)) are as follows:

Step 1: The predictor variable (X) should have a significant relationship with the outcome variable (Y).

Step 2: The predictor variable (X) should have a significant relationship with the mediating variable (M).

Step 3: The mediating variable (M) should have a significant relationship with the criterion variable (Y).

Step 4: In control of the mediating variable, the relationship between the predictor variable and criterion variable is no longer significant if there is a full mediation;

whereas, if the relationship is still significant, a partial mediation exists between the two variables.

5.5.2 TRA as a mediator between BCAD and Sustainability

Addressing the mediating effects of this study, H10 was developed to examine the role of the mediating effect in the model. The model of this study shows that traceability (TRA) mediates the relationship between blockchain (BCAD) and sustainability (SUS). Figure 5.8 presents the relationship between the predictor and the mediator, and the relationship between the mediator and the criterion variables is significant.

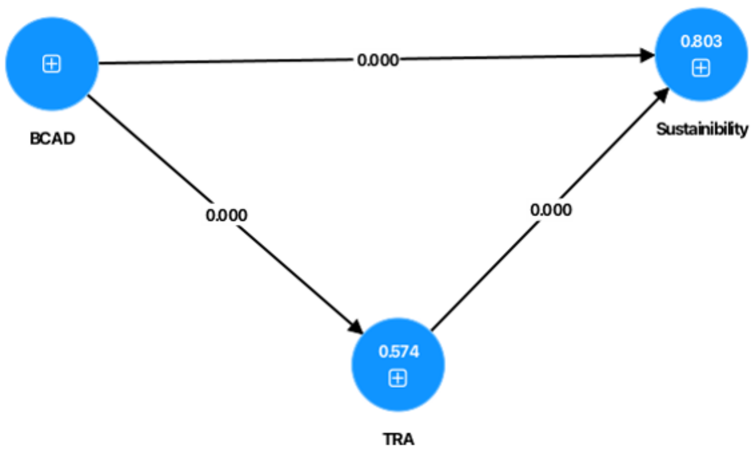

Figure 5.7 Mediating role of TRA between BCAD & SU

Table 5.20 represents the mediation analysis for BCAD->TRA->SUS. The analysis shows that t-statistics were satisfactory, p-values are significant for each relationship, and mediating influence is also significant. Therefore, the statistical grounding is proven to accept hypothesis H10.

Table 5.20 Mediation analysis result

Hypothesis	**Link**	**Beta Coefficient**	**Standard deviation**	**T statistics**	**P values**	**Outcome**
H10	BCAD -> TRA-> SUSTAINABILITY	O.053	0.022	2.397	0.017	Supported
H7	BCAD -> Sustainability	0.180	0.043	4.195	0.000	Supported
H4	BCAD -> TRA	0.783	0.034	22.882	0.000	Supported
H8	TRA -> Sustainability	0.753	0.043	17.312	0.000	Supported

5.5.3 Individual hypothesis testing

Table 5.21 depicts the analysis of the relationship between blockchain and sustainability. The result for hypothesis 7 (H7) identified a satisfactory path coefficient (β) value and t-value as well as a P-value significant- for the analysis. Based on the analysis, blockchain adoption positively influences sustainability. Therefore, the statistical grounds are used to accept hypothesis H7.

Table 5.21: Induvial hypothesis testing

Hypothesis	Link	Beta coefficient	Standard deviation	T statistics	P-values	Outcome
H7	BCAD ->Sustainability	0.775	0.031	24.844	0	Supported

5.5.4 The impact of control variables assessment

The impact of control variables was evaluated and assessed for this study. Using control variables in the model ensures that other factors do not confound the observed relationships. Studies indicate that adding control variables in the research model improves the precision of the model estimation, as they explain the statistical noise of the endogenous construct in the research model (Hair et al., 2019). In this study, the control variables, such as firm age (Age) and firm size (Size), were evaluated by estimating the path coefficients (b) and t-values corresponding to the link between control variables and endogenous variables of the study, such as blockchain adoption (BCAD), traceability (TRA) and sustainability. With the control variable, the result shows no significant effect on the model and considerable path coefficients (b) and t-values for BCAD, TRA, and Sustainability are noted. Also, path coefficients (b) and t-values are substantial for these endogenous constructs without the control variable. Also, p values corresponding to the control variables to end variables seem insignificant. That is, the control variables (firm size and firm age) do not impact the model of this study. The results with the control variable of firm age and size are presented in Table 5.22 and without the control in Table 5.23.

Table 5.22 With the control variable of firm age and size

Relationship	With Control		
Link	Beta Coefficient	T statistics	P values
MDY -> BCAD	0.102	1.341	0.09
CPR -> BCAD	0.475	6.055	0
RGS -> BCAD	0.273	3.517	0
BCAD -> TRA	0.167	2.817	0.002
TOR x BCAD -> TRA	0.028	0.614	0.27
UMS x BCAD -> TRA	-0.116	2.953	0.002
BCAD -> SUSTAINABILITY	0.265	1.677	0.47
SGV -> SUSTAINABILITY	0.466	9.851	0
TRA -> SUSTAINABILITY	0.354	5.96	0
Age -> BCAD	-0.006	0.153	0.439
Age -> SUSTAINABILITY	0.043	1.677	0.047
Age -> TRA	0.076	2.227	0.013
Size -> BCAD	0.075	1.528	0.063
Size -> SUSTAINABILITY	0.075	2.907	0.002
Size -> TRA	-0.081	2.402	0.008
SUSTAINABILITY -> ECO	0.952	108.53	0
SUSTAINABILITY -> ENV	0.964	144.01	0
SUSTAINABILITY -> SOC	0.961	147.82	0
TOR -> TRA	0.266	3.972	0
TRA -> SUSTAINABILITY	0.354	5.96	0
UMS -> TRA	0.4	4.106	0

Table 5.23 Without the control variable of firm age and size

Relationship	Without Control		
	Beta Coefficient	T statistics	P values
MDY -> BCAD	0.111	1.545	0.061
CPR -> BCAD	0.479	6.182	0
RGS -> BCAD	0.293	3.871	0
BCAD -> TRA	0.147	2.542	0.006
TOR x BCAD -> TRA	0.029	0.604	0.273
UMS x BCAD -> TRA	-0.122	3.029	0.001
BCAD -> SUSTAINABILITY	0.062	1.964	0.025
SGV x TRA -> SUSTAINABILITY	-0.049	2.75	0.003
SGV -> SUSTAINABILITY	0.483	9.349	0
SUSTAINABILITY -> ECO	0.952	108.538	0
SUSTAINABILITY -> ENV	0.964	143.612	0
SUSTAINABILITY -> SOC	0.961	148.019	0
TOR -> TRA	0.287	4.277	0
TRA -> SUSTAINABILITY	0.361	6.086	0
UMS -> TRA	0.389	3.979	0

Goodness-of-Fit (GoF)

To measure the overall fitness of the proposed model, this study estimated the Goodness-of-Fit (GoF) index. AVE and R^2 values of the endogenous constructs are used to calculate the GoF index for the PLS path modelling (Hair et al., 2019) for this study. Table 5.24 shows the AVE and R^2 values of the endogenous constructs.

Table 5.24: Goodness of model fit

	AVE	R^2
BCAD	0.635	0.665
ECO	0.702	0.905
ENV	0.734	0.929
SOC	0.706	0.924
TRA	0.772	0.825

The geometric mean for AVE = $\sqrt[5]{0.635x0.702x0.734x0.706x0.772}$ =0.920

The geometric mean for R^2= $\sqrt[5]{0.665x0.905x0.929x0.924x0.825}$ =0.842

Therefore, GoF = $\sqrt{AVExR^2}$ = $\sqrt{0.920x0.842}$ = 0.880

In this study, the GoF yielded 0.880. This is large, according to set measures in previous studies (Hair Jr et al., 2014, West et al., 2012). Therefore, the fit index for this model was considered good enough.

5.5.5 Statistical Power Analysis

G* Power 3.1 was used to obtain the statistical power analysis of the model for this study (Faul et al., 2009). The result of the power analysis is represented in Figures 5.9 and 5.10, where the overall power of the model is 95%, and the t-value is 1.979. It shows that the statistical power is more than the required power of 80% (Cohen, 2013). Therefore, the model of this study has adequate confidence in the hypothesised relationship. This analysis also revealed that the increase in the sample size would ensure an increase in the power of the overall model. For example, if the sample size increases to 120, the model power will be more than 95%, ensuring that the sample size in this study is adequate to validate the model.

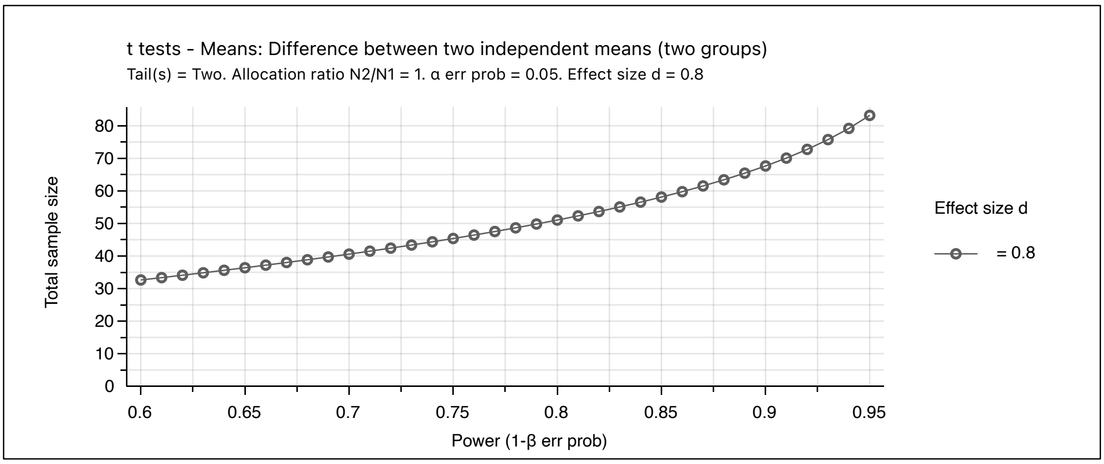

Figure 5.8 Statistical power of the model

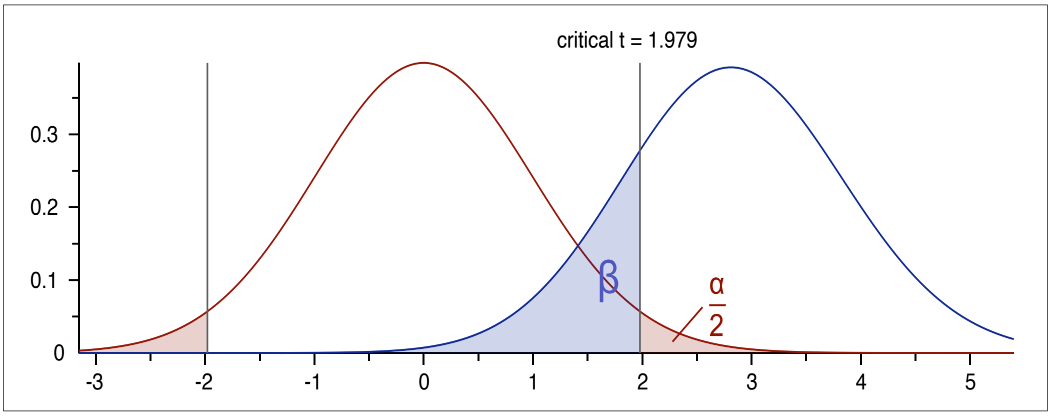

Figure 5.9 Critical t-values for the Statistical power of the model

5.6 Summary

This chapter presented the quantitative result and analysis of the survey conducted on blockchain adoption for agri-products supply chain traceability and sustainability. 294 usable responses were collected to analyse the proposed research model. The normality test for all constructs was significant at p<0.05. Therefore, we could accept that sample data were not normally distributed. Smart PLS-SEM techniques were used to analyse the research data for the study. To achieve the research objective of the study, PLS-

SEM techniques were considered due to the nature of the data (reflective items) and the smaller sample size. The quantitative data analysis considered two-phase approaches: the measurement model assessment and the structural model assessment. The measurement model assessment was performed with convergent validity and discriminant validity. Convergent validity was affirmed by examining the item loadings for the reflective indicators. Reflective items with loadings of less than 0.7 were deleted. In addition, data analyses also examined composite reliability and AVE (average variance extracted). In particular, discriminant validity was ensured by (i) examining the square root of AVE to the inter-construct correlations and (ii) developing and analysing an item-loading matrix. To assess the structural model, the R^2 (the amount of variance explained) value for each predicted variable, the path coefficient (β), and the significance of the values were examined. The result of the data analysis revealed that R^2 values for all endogenous constructs were above 0.5. Specifically, blockchain adoption (BCAD) as an endogenous construct could explain 68.9.% of the variance in the supply chain traceability and sustainability model. The model was assessed for endogeneity using Gaussian Copula, with P values above 0.05. There were no endogeneity issues in the model.

CHAPTER 6:

6.1 DISCUSSIONS, IMPLICATIONS & CONTRIBUTION

6.2 Introduction

This chapter presents an interpretation of findings achieved from the quantitative survey and highlights the contribution of the theoretical and practical implications of the study. The interpretation of the empirical findings will be discussed in a manner consistent with the hypothesised relationship among different constructs in the research model, research questions, and the study's objectives. Considering the research objectives and based on the three research questions, this chapter uncovered and justified the valuable findings and tested several hypotheses not addressed before in the domain of blockchain adoption in supply chain management in the context of Agri-products. The specific contribution of this study was empirical validation of blockchain adoption in the Agri-products supply chain traceability and sustainability model, as well as testing the impact of business environmental drivers on blockchain adoption and the relationship between blockchain adoption, traceability, and sustainability by using PLS-based SEM (Hair et al., 2019, Sarstedt et al., 2019, Shmueli et al., 2019, Wong et al., 2020a). The following section discusses the findings of this study through the lens of statistical evidence and existing theories and practices.

The next section of this chapter describes the hypothesis related to the research model. Then, it discusses the impact of the control variable, followed by the findings, which consider the research objectives.

6.2.1 Findings in light of the hypothesis

Table 6.1 Research objectives and corresponding hypothesis

Research objective (RO)	Hypothesis	Relationship	Result
RO1: To investigate the impacts of business environmental drivers on blockchain adoption in the Agri-products supply chain.	H 1*	MDY -> BCAD (+)	Not Supported
	H 2	CPR -> BCAD (+)	Supported
	H 3	RGS -> BCAD (+)	Supported
RO2: To examine the direct, indirect and conditional effect of blockchain adoption on Agri-products supply chain traceability and sustainability.	H 4	BCAD -> TRA (+)	Supported
	H 5**	TOR x BCAD -> TRA (+)	Not Supported
	H 6	UMS x BCAD -> TRA (-)	Supported
	H 7	BCAD -> SUSTAINABILITY (+)	Supported
	H 8	SGV x TRA -> SUSTAINABILITY (-)	Supported
	H 9	TRA -> SUSTAINABILITY (+)	Supported
	H10	BCAD -> TRA-> SUSTAINABILITY	Supported

Significant *p < 0.05, **p< 0.01, ***p<0.005, Significant t-values=1.96

Hypothesis 1: Market dynamics positively influence blockchain adoption in SC.

This study investigates the relationship between market dynamics (MDY) and blockchain adoption (BCAD), which is aligned with research objective one. The statistical analysis findings revealed that there is significant statistical evidence for a positive relationship between market dynamics and blockchain adoption in SC. The outcome reports of the study indicate the association between MDY and BCAD (b=

0.111 and t=1.545,) and the report proves the theoretical relationship that MDY is necessary for supply chain sustainability in the changing business environment. In light of the dynamic capability view, it also specifies that the impact of market dynamics on blockchain adoption in the organisational supply is profound, particularly in the changing business environment, consistent with the literature with Teece et al. (1997) Wong et al. (2020a), Kamble et al. (2023), Humdan et al. (2023), Wamba and Queiroz (2020b) and Hsing Wu et al. (2013). As industries evolve, driven by emerging technological innovation, enhancing regulatory landscapes, and global challenges, blockchain technology offers a transformative potential through secure information-sharing architecture in how the supply chain could operate differently. Thus, the findings of this study emphasise the importance of market dynamics as an essential decision-making variable to influence blockchain adoption by developing dynamic capability and designing a secure information-sharing network, improving product traceability, reducing lead times, reducing cost, removing intermediatory, and ensuring traceability mechanism, which can provide a strategic advantage in the complex Agri product supply chain. Therefore, Agri-products supply chain actors will be capable of improving information transparency in their complex supply chain, where market dynamics profoundly impact the adoption of blockchain technology. In the Australian agri-food supply chain, blockchain facilitates end-to-end visibility by allowing upstream producers, such as farmers, to record critical production data (e.g., origin, farming practices, and quality certifications) that can be securely accessed by downstream actors including processors, retailers, and consumers (Rejeb et al., 2023). This transparency reduces information asymmetry, builds consumer trust in food safety and provenance, and supports compliance with stringent export standards, particularly relevant for Australia’s beef, dairy, and wine sectors (Caro et al., 2018;

Jabbour et al., 2020). Moreover, blockchain-based traceability helps eliminate fraudulent practices and improves supply chain efficiency by ensuring that verified information flows seamlessly across all stages, from farm to fork, strengthening Australia's position in global agri-food markets (Hastig & Sodhi, 2020).

Hypothesis 2. *Competitive pressure positively influences blockchain adoption in SC.*

The hypothesised relationship between competitive pressure (CPR) and blockchain adoption (BCAD) also aligns with research objective one and is supported by the statistical analysis findings. The statistical analysis revealed significant evidence of the study's findings, which showed a positive relationship between competitive pressure and blockchain adoption in SC. The analysis indicates the coefficient of the association between CPR and BCAD (b= 0.479) and the corresponding t value (t=6.182); the analysis implies a significant positive relationship between CPR & BCAD. Evidence proves that CPR is a vital variable of blockchain adoption for supply chain sustainability in the increasingly competitive business environment. Relying on the dynamic capability view, the positive influence of competitive pressure on blockchain adoption in the organisational supply chain addresses many more, including demand transparency, regulatory compliance, global competition, competitive benchmarks, and traceability and accountability in the changing business environment. The literature also supports this finding (Teece et al. (1997), Wen et al. (2021). Thus, the findings of this study supported the importance of competitive pressure in blockchain adoption on the Agri-product supply chain for sustainability, which may change the insight into how businesses currently operate.

The findings confirmed that the hypothesised link between regulatory support (RGS) and blockchain adoption (BCAD) is consistent with the first research objective. Statistical analysis validated this relationship, with results showing a significant association between RGS and BCAD (b=0.293, t=3.871). This demonstrates that regulatory support is pivotal in driving blockchain adoption to enhance supply chain sustainability. Moreover, the evidence indicates that supply chain stakeholders are unlikely to achieve their strategic objectives without adequate regulatory frameworks at the organisational level. The study further reveals that regulatory support may either foster innovation or act as a hindrance, depending on the transparency, completeness, and enforcement of the regulations. These results align with previous research emphasising the centrality of regulatory mechanisms in facilitating technology adoption (Kamble et al., 2020a, Wong et al., 2020a).

In the context of the agri-product supply chain, regulatory support plays a decisive role in ensuring traceability, sustainability, and carbon accountability through blockchain-enabled systems. For instance, Meat & Livestock Australia (MLA) highlights the importance of carbon accounting and climate initiatives, which are more effectively monitored through blockchain-based traceability frameworks (MLA, 2023). Similarly, the Department of Primary Industries (DPI) advocates for digital innovation and transparent regulatory structures to improve food safety, reduce emissions, and strengthen global market access (DPI, 2022). The integration of blockchain with regulatory backing ensures reliable carbon tracking and compliance with sustainability policies, thereby reinforcing consumer trust and industry competitiveness. Thus, regulatory agencies act not only as enforcers but also as enablers of technological transformation within agricultural supply chains.

Effective regulatory support is essential for blockchain adoption, as it establishes clear guidelines, incentives, and promotes international cooperation. Such frameworks enable the technology to reach its full potential in transforming supply chain operations, while ensuring a balance between compliance and innovation. Conversely, fragmented or overly restrictive regulatory measures may slow down or limit progress within agri-product supply chains. The results of this study therefore reinforce the significance of strong regulatory support in advancing blockchain adoption for sustainable supply chain practices. This underscores the necessity of well-designed regulatory frameworks to promote technological innovation while safeguarding compliance. Ultimately, regulatory clarity and collaboration remain central to the successful implementation of blockchain systems in agricultural contexts.

In the agri-product supply chain, regulatory support strengthens blockchain adoption by ensuring traceability, carbon accountability, and food safety compliance. For example, Meat & Livestock Australia (MLA) has highlighted blockchain's potential for improving carbon accounting and advancing the industry's goal of carbon neutrality by 2030 (MLA, 2023). Likewise, the NSW Department of Primary Industries (DPI) emphasises the role of digital innovation and regulation in enhancing transparency, consumer confidence, and access to international markets (DPI, 2022). When combined with robust regulatory backing, blockchain ensures reliable verification of sustainability claims, certification processes, and emission reduction reporting. Without such regulatory alignment, supply chain stakeholders may face barriers to adoption and reduced competitiveness. Therefore, regulatory institutions serve as both enablers and gatekeepers in ensuring blockchain achieves its intended impact in agricultural supply chains.

Hypothesis 3. Regulatory support positively influences blockchain adoption in SC.

It was affirmed that the hypnotised relationship between regulatory support (RGS) and blockchain adoption (BCAD) align with research objective one. This relationship is supported by the statistical analysis findings of the study. The study's results also support the association between RGS and BCAD (b=0.293, t=3.871), which proves that regulatory support plays a critical role in blockchain adoption for supply chain sustainability. It also proves that supply chain actors could not achieve their desired goal without regulatory support at the organisation's strategic level. It also identifies that regulatory support serves as a stimulus for innovation or a barrier depending on the supply chain's clarity, comprehensiveness, and enforcement of regulations; the findings supported previous studies (Wong et al., 2020a, Kamble et al., 2021). Thus, the findings of this study supported the significant importance of regulatory support for adopting blockchain in the Agri-products supply chain, where proactive and balanced regulatory support is essential for blockchain adoption. Regulatory support is critical for blockchain adoption to identify clear rules and incentives, as well as international collaboration. It can unlock the full potential of blockchain in supply chain operations and, at the same time, ensure the right balance between innovation and compliance. Restrictive or fragmented regulatory support may hinder progress in the Agri-product supply chain. Therefore, the findings of this study support the importance of regulatory support in blockchain adoption for supply chain sustainability in the Agri-product context.

Regulatory support (RGS) is the regulatory bodies that frame the policies and laws that directly or indirectly impact blockchain adoption for organisations in the changing business environment. To this end, it has to do with the government initiative to increase safety by adopting blockchain technology in the organisation and providing a mandatory traceability policy to improve the trackback capability of the product's journey through end-to-end supply chain processes. For example, regulatory support in Australia is increasingly aligning with initiatives such as "zero emission" or "carbon counting" and stronger traceability requirements, which have implications for blockchain adoption in Agri-product supply chains. The **National Agricultural Traceability Strategy 2023-2033**, for example, provides a framework whereby governments and industry partners are co-designing data-led traceability systems to support biosecurity, food safety, trade, and sustainability credentials (DAFF, 2024).

This strategy includes implementation plans through 2028 that fund projects aimed at improving harmonised traceability across supply chains, partly to meet emerging demands for verifying environmental performance.

From the Meat & Livestock Australia (MLA) perspective, traceability is central not only for food safety and market access but increasingly for demonstrating environmental outcomes. MLA's environment sustainability R&D invests in tools and metrics for measuring greenhouse gas emissions, natural capital, and other sustainability attributes alongside developing stronger traceability systems (MLA, 2024). The MLA's recent global review of livestock traceability systems (V.ISC.2407) emphasises integrating newer technologies, including blockchain, GPS/IoT, and permanent identifiers to enhance the traceability, improve supply chain efficiency, and respond to both regulatory and consumer demands (MLA, 2024).

Moreover, at the state level, for example in NSW, the **Livestock Traceability Policy 2023** under the Department of Primary Industries (DPI) mandates components of traceability (such as the National Livestock Identification System or NLIS), movement documentation and databases as regulatory tools to assure food safety and biosecurity, which are capabilities that mesh well with blockchain's immutable and distributed ledger features. According to the NSW Department of Primary Industries, these regulatory measures generate legal or market pressures (regulatory support, or RGS) that can encourage organisations to adopt blockchain for mandatory traceability and carbon tracking, because compliance with policy increasingly requires verifiable provenance, emissions data, or sustainability credentials (NSW DPI, 2024). In particular, the regulatory environment, both at the national and industry levels, is providing stronger incentives for the adoption of blockchain (or other digital traceability tools) for "zero initiative" and carbon counting, by making traceability and sustainability credentials part of what is required to maintain market access and regulatory compliance.

Previous studies indicate a relative lack of research focusing on business environment drivers—such as competitive pressure, market dynamics, and regulatory support—within the supply chain context regarding blockchain adoption (Wong et al., 2020a). Consequently, this study focused on examining these business environmental drivers. Therefore, the research framework incorporates business environmental drivers as defined by Wong et al. (2020a).

Hypothesis 4: Blockchain adoption positively influences traceability.

The statistical analysis shows that the hypothesised relationship between blockchain adoption (BCAD) and traceability (TRA) supports research objective two and that BCAD positively supports sustainability. The findings of the statistical results also supported the association between BCAD and TRA, the path coefficient (b=0.147), and the corresponding t value (t=2.542). These results prove a positive relationship between BCAD and TRA. Thus, the findings of the study interpreted that blockchain adoption is vital to improve traceability in the supply chain. The potential of blockchain adoption enhanced product traceability by allowing immutable, time-stamped record-keeping opportunities in the transaction process of the supply chain at every point. This process ensures tracking the origin/provenance of products/information from the source to the end customer. It provides visibility at every transaction stage of the end-to-end supply chain, as evidenced by Bai and Sarkis (2020) and Garcia-Torres et al. (2019). Blockchain-based traceability also reduces fraud and counterfeiting in the supply chain process (Hughes et al., 2019). It also specifies that blockchain or decentralised-based traceability is supported for securing food safety and quality in the agri-food supply chain (Tan et al., 2020). It can be assured that a blockchain/ distributed ledger system has the potential to enhance traceability and improve supply chain sustainability compared to a centralised system. It also identifies that BCAD, as a decentralised mechanism, ensures the absence of a central point of failure; in contrast, a single point of failure in the centralised system is significantly alarming (Feng et al., 2020a, Saberi et al., 2019b). As a result, blockchain chain-based traceability leads to superior reliability, high scalability and transparency in supply chain operations management. Therefore, the study's findings asserted that blockchain adoption is essential in tracking and tracing the Agri-product supply chain, ensuring real-time visibility and transparency for end-to-end supply chain members.

Hypothesis 5: Technology orientation positively influences the relationship between blockchain adoption and traceability.

The technology orientation (TOR) moderates the hypothesised relationship between blockchain (BCAD) and traceability (TRA), and the findings of statistical analysis positively supported this relationship. With moderator effects of the TOR, the coefficient of association between BCAD and TRA (b=0.029) and t value (t=0.604), the result provides a positive relationship. It is also important to highlight that without the moderation of TOR, the coefficient and corresponding t-value results (b=0.147, t=2.542) between BCAD and TRA show a positive relationship. Technology orientation is critical for successfully adopting blockchain for traceability in the supply chain. Thus, the technology orientation is essential for blockchain adoption in supply chains, ensuring clarity, readiness, and alignment across organisational levels and stakeholders. Companies can effectively leverage blockchain technology to enhance supply chain transparency, efficiency, and resilience by fostering a deep understanding of blockchain's capabilities and implications. The findings are also supported by previous literature (Yu et al., 2022). Therefore, the result of the study's moderator role of TOR between BCAD and TRA is essentially crucial for the Agri-products supply chain.

Hypothesis 6: Upper management support positively influences the relationship between blockchain adoption and traceability.

The findings of the study investigated and confirmed the positive influence of the moderator role of upper management support (UMS) between BCAD and TRA, and the statistical findings resulted in negative support (b=-0.122, t=3.029). The finding also affirmed that without any moderation, the relation between BCAD and TRA shows a significant positive relationship (b=0.147, t=2.542). It proves that UMS helps to achieve blockchain adoption for traceability and sustainability. UMS encourage blockchain adoption and enhances traceability in the supply. Previous studies support the findings of the study (Wong et al., 2020b). Therefore, the result of the study's moderator role of UMS between BCAD and TRA is essentially important for the Agri-products supply chain.

Hypothesis 7: Blockchain adoption positively influences sustainability.

The study's findings supported the idea that there is a positive relationship between blockchain adoption (BCAD) and sustainability. The coefficient of association between BCAD and sustainability (b=0.062) and t value (t=1.964) imply a significant positive relationship between BCAD and sustainability. These findings support previous studies and specify that blockchain adoption in the supply chain has the potential to generate a positive economic contribution to ensure the triple bottom line of supply chain sustainability (Manupati et al., 2020). BCAD ensures increasing economic sustainability and focuses on supply chain productivity or growth aspects in the supply chain practices (Nayak and Dhaigude, 2019). It enhances security, information transparency, privacy, anonymity, traceability, accountability, integrity, robustness, trustworthiness, and authentication in supply chain practices. As a result, organisations achieve long-term economic sustainability in their supply chain (Queiroz and Wamba, 2019). BCAD also ensures the environmental dimension of sustainability, including concerns about ecological balance, reduces carbon emission and renewable energy use and increases energy efficiency, biodiversity, and climate changes (Kouhizadeh et al., 2019, Manupati et al., 2020). Blockchain has the potential to support social supply chain sustainability and the equitable economic distribution of benefits in society, as well as address human rights, labour rights, the working environment, and other localised social issues (Bai and Sarkis, 2020, Shen and Pena-Mora, 2018). Thus, there are significant positive approaches blockchain offers in terms of supply chain sustainability. Therefore, the findings of this study reiterate the importance of blockchain adoption in improving the Agri-products supply chain for sustainability.

Hypothesis 8: Sustainability governance moderates the relationship between traceability and sustainability.

The statistical analysis findings supported the notion that sustainability governance (SGV) moderates the relationship between traceability (TRA) and sustainability. Considering the moderator effects of the SGV, the statistical findings resulted in negative support with the coefficient of association between TRA and sustainability (b=-0.049) and t-value (t=2.75). Without the moderator effects of the SGV, the relationship between traceability (TRA) and sustainability is positively supported (b=0.361, t=6.086), proving that the direct effects are more significant than the indirect effects of the relationship. It specifies that sustainability governance and practices are essential to improving sustainability, and previous studies also support the findings (Chowdhury et al., 2023, Tabesh et al., 2024). Evidently, sustainability governance is a profound need for organisations and their supply chain to comply with and achieve sustainable performance (Chowdhury and Quaddus, 2021a, Dauvergne and Lister, 2012, Queiroz and Wamba, 2019). In particular, organisations with robust sustainability governance contribute to societal and environmental well-being; equally, they position themselves for long-term success in sustainability goals (Garcia-Torres et al., 2019). Therefore, the findings of this study claim the importance of sustainability governance in improving the Agri-products supply chain for sustainability.

Hypothesis 9: Traceability positively influences sustainability.

The findings of this study investigated and confirmed that traceability (TRA) positively influences sustainability. It was revealed that the coefficient of association between TRA and sustainability (b=0.361) and t value (t=6.086) imply a significant positive relationship. From the findings, it can be interpreted that traceability has substantial implications for achieving sustainability in supply chain operations (Saberi et al., 2019b, Wamba et al., 2020a). Blockchain-based traceability can significantly influence sustainability across the supply chain. The literature supports that blockchain-based traceability ensures sustainability by enhancing provenance tracking through transparency, improving accountability, and data-driven optimisation across the supply chain (Kamble et al., 2023, Tian, 2016b, Helo and Hao, 2019, Kamble et al., 2020a, Kouhizadeh and Sarkis, 2018, Queiroz et al., 2019b, Saberi et al., 2019b). Blockchain provides a decentralised and immutable ledger where each transaction or movement of goods/information is recorded. The smart contracts, a self-executed program, allow this process in supply chain operations and enable stakeholders to trace products/information from origin to final delivery, ensuring transparency in sourcing, production, and distribution processes. In light of transaction cost theory, this process helps reduce or remove intermediation from the end-to-end supply chain, reducing transaction costs and minimising opportunistic behaviour in the supply chain network (Kamble et al., 2023, Srivastava and Dashora, 2022). As a result, consumers and businesses can verify claims like “organic,” “fair trade,” or “sustainably sourced,” reducing greenwashing /fraud and encouraging companies to adopt more sustainable practices (Garcia-Torres et al., 2019, Hughes et al., 2019, Kamble et al., 2023, Srivastava and Dashora, 2022, Chowdhury, 2014). It aligns supply chain operations with environmental, social, and economic goals, leading to a more ethical and sustainable economy. Therefore, the findings of this study claim the importance of traceability in improving the Agri-products supply chain for sustainability.

Hypothesis 10: Traceability mediates the relationship between blockchain adoption and sustainability

The findings of this study investigated and confirmed the mediating role of traceability (TRA) between blockchain adoption and sustainability. The findings affirmed that without any mediation, the direct effect between BCAD and sustainability is significant (t=4.195, p=0), which is supported by the outcome. It was also affirmed that the indirect effect between BCAD and sustainability is significant (t=14.284, p=0), and the total indirect effects-confidence intervals, 97.5%, between BCAD and sustainability. Therefore, a partial mediating role of TRA was found between the BCAD and sustainability, in reference to Chowdhury et al. (2023) and Baron and Kenny (1986). The findings of the study confirmed that the indirect effects of TRA between BCAD and sustainability had not been previously tested. The findings relating to the mediator relationship are presented accordingly for Special Indirect Effect in Table 6.2, Total Indirect in Table 6.3, Total Effect in Table 6.4, and Beta Coefficient, t-values and p-values in Table 6.5.

Table 6.2 Special Indirect Effect

Hypothesis	Link	Beta Coefficient	Standard deviation	T statistics	P values
H10	BCAD -> TRA -> Sustainability	0.536	0.037	14.284	0

Table 6.3 Total Indirect Effects-Confidence Intervals

Link	Beta Coefficie nt	Sample mean	2.5 %	97.5%
BCAD -> Sustainability	0.536	0.533	0.45 6	0.603

Table 6.4 Total Effect

Link	Beta Coefficient	Standard deviation	T statistics	P values
BCAD -> Sustainability	0.536	0.037	14.284	0.000

Table 6.5 Beta Coefficient, t-values & p-values of mediator relationship

	Beta Coefficient	Standard deviation	T statistics	P values	Outcome
BCAD -> Sustainability	0.18	0.043	4.195	0	Supported
BCAD -> TRA	0.783	0.034	22.882	0	Supported
TRA -> Sustainability	0.753	0.043	17.312	0	Supported
BCAD -> TRA-> SUSTAINABILITY	O.053	0.022	2.397	0.017	Supported

6.3 Control Variable

The study's findings examine the impact of the control variables on three major endogenous constructs. It examined the effect of control variables on blockchain adoption (BCAD), traceability (TRA) and sustainability perspective.

Firstly, the result for three endogenous constructs (BCAD, TRA, and SUSTAINABILITY) with the age control of the firms. The impact of AGE was insignificant (b= -0.006, t=0.153, p= 0.439) for the relationship between Age -> BCAD, for the relationship between Age -> TRA, the impact of AGE was significant (b= 0.076, t=2.227, p=0.013), and equally, for the relationship between Age -> SUSTAINABILITY, the impact of AGE was significant (b= 0.043, t=1.677, p=0.047).

Secondly, the results for three endogenous constructs (BCAD, TRA, and SUSTAINABILITY) with the size control of the firms. The impact of SIZE was significant (b= 0.075, t=1.528, p= 0.063) for the relationship between Size -> BCAD. Also, for the relationship between Size -> SUSTAINABILITY, the impact of SIZE was significant (b=0.075, t=2.907, p=0.002). However, for the relationship between Size -> TRA, the impact of SIZE was insignificant (b= -0.081, t=2.402, p=0.008).

Finally, it appears that the age and size of the firms in this study did not significantly impact the result of the model. The control variable outcomes were found to be insignificant, showing that regardless of firm size (small, medium or large) and firm age, blockchain adoption has no impact on the traceability and sustainability of the model.

6.4 CONTRIBUTIONS

This study makes significant contributions theoretically and practically. The novel contribution of this study is summarised in the following section accordingly: First, theoretical contribution, followed by managerial contributions.

6.4.1 Theoretical contribution

This research draws from two theoretical viewpoints, including the Dynamic Capability View (DCV) and the Transaction Cost Theory (TCT), to enhance the understanding of the impact of emerging technology adoption in supply chain operations management. Drawing upon these theoretical frameworks, the study presents significant empirical findings that align with the theoretical perspective. As a result, the research contributes to extending and advancing knowledge on blockchain adoption in the supply chain traceability and sustainability field, as detailed below.

Firstly, the research model developed for this study raises the significance of theoretical areas. The study provides a better understanding of blockchain adoption in the supply chain for traceability and sustainability by testing and validating the measurement properties, which is one of the significant contributions of this research. This study explains the relationship between blockchain adoption drivers and other constructs in the model: traceability, mediator, moderators, and outcome constructs. *Specifically, this study identified blockchain adoption drivers for SC in general and for the Agri-products SC in particular, which is a unique contribution.* The significant research gaps were identified through an extensive literature review on blockchain adoption in supply chains, blockchain adoption in Agri-products supply chains, supply chain traceability, and supply chain sustainability context. Building on previous research and filling the gaps in the existing literature, this study offers novel insights by developing a research model. Furthermore, the developed model was contextualised through an extensive literature review.

The final research model thus developed addresses blockchain adoption as a dynamic capability that requires improved supply chain traceability in the agri-products to ensure sustainability. Considering the Dynamic Capability View (DCV), this study examined the impact of blockchain adoption on traceability and sustainability. The study indicates that blockchain adoption is an essential Dynamic Capability (DC) for organisations to meet and match the specificities of internal and external business environmental contexts. The study also argues that SC traceability is an Operational Capability (OC) for organisations that can be achieved by ensuring blockchain adoption in the SC (DC for organisation and their SC). This study identified the significance of utilising the Transaction Cost Theory (TCT) lens to understand transaction costs for supply chain traceability, sustainability, and emerging blockchain technology. It also identified that the blockchain-based traceability mechanism reduces internal and external transaction costs and limits opportunistic behaviour, removing intermediation in the end-to-end supply chain operations (Roeck et al., 2020). Further, the study posits that SC sustainability is an outcome of BC adoption and traceability. Thus, for the first time in the literature, this study investigates the role of DC in examining traceability in SC from a blockchain technology point of view. Further, the study investigates the role of dynamic capability (DC) and operational capability (OC) in examining sustainability in SC from a blockchain technology context. Therefore, the study contributes to the body of knowledge as no previous research model integrates blockchain adoption for supply chain traceability and sustainability by integrating DVC and TCT, particularly for the Agri-products supply chain in the global context.

In addition to the Dynamic Capability View (DCV) and Transaction Cost Theory (TCT), this research advances the **Institutional Theory** by elucidating the critical role of external institutional pressures in shaping blockchain adoption within global agri-product supply chains. The findings reveal that **coercive, normative, and mimetic influences** significantly determine firms' intentions to implement blockchain technologies to meet traceability and sustainability requirements (Saberi et al., 2019; Scott et al., 2017). Through the lens of Institutional Theory, this study deepens the understanding of how organisations pursue **legitimacy and compliance** in response to evolving stakeholder expectations and regulatory demands. It emphasises that firms are often motivated not solely by efficiency or capability enhancement but also by the need to conform to socially accepted norms and institutionalised practices. Integrating Institutional Theory into the analytical framework provides a more **holistic perspective**, capturing the interplay between internal strategic capabilities and external environmental pressures. This theoretical synergy demonstrates that blockchain serves not only as a **technological enabler** that strengthens operational competencies and reduces transaction costs but also as a **symbolic mechanism** that enhances organisational transparency and accountability. Consequently, the study enriches the theoretical discourse by linking institutional legitimacy with technological innovation in sustainable supply chain management. It further shows that blockchain adoption decisions are embedded within broader institutional contexts where compliance, reputation, and competitive imitation intersect. By unifying DCV, TCT, and Institutional Theory, the research delivers a **multi-dimensional explanation** of blockchain-driven sustainability transformation in agri-product supply chains.

Secondly, this study empirically validates the measurement of the multidirectional and hierarchal constructs: blockchain adoption. An empirically validated measurement for blockchain adoption constructs has not been developed yet. Therefore, this study enriches the literature on blockchain adoption for traceability and sustainability in supply chain management.

Thirdly, although there are increasing studies on blockchain for supply chain traceability, empirically validated measurements for supply chain traceability are rare. This study identifies the supply chain traceability of global Agri-products and develops an empirically validated measure for multidirectional constructs: supply chain traceability. Further, it also identified and confirmed the mediating role of traceability

(TRA) between blockchain and sustainability. It indicates that blockchain adoption directly, indirectly, and conditionally affects supply chain traceability and sustainability. The findings of the study confirmed that Nobody tested the indirect effects of TRA between BCAD and sustainability before, which is a unique contribution. Therefore, this study claims traceability as a mediator role used for the first time in the blockchain and supply chain literature.

Fourthly, the literature reveals that blockchain-based traceability ensures supply chain sustainability. However, an empirical study has not been conducted to validate the link between the two constructs (traceability and sustainability). This study finds a positive relationship between supply chain traceability and social, environmental and economic sustainability, which is a unique contribution.

Finally, the comprehensive research model is unique. It integrates three core theories, Dynamic Capability View (DCV), Transaction Cost Theory (TCT) and Institutional Theory (IT), to identify the applicable factors and their relationships in the blockchain adoption for supply chain traceability and sustainability model. The study also integrated DCV, TCT, and IT to explain the outcome of sustainability. Thus, this study extended the outcome perspective of the Dynamic Capability View, Transaction Cost Theory, and Institutional Theory in the context of blockchain for the global Agri-products supply chain. Therefore, this study makes an insightful contribution to the existing literature.

6.4.2 Practical contribution of the research

Firstly, beyond its theoretical contribution, this research provides practical insights for practitioners seeking to enhance supply chain sustainability in the increasingly competitive global market. The study advances existing academic literature by offering a deeper understanding of blockchain adoption in agri-food supply chains and presents a comprehensive model designed to facilitate traceability and sustainability. This model can serve as a practical framework for managers addressing supply chain challenges, particularly in achieving greater visibility and information transparency across end-to-end practices. By applying blockchain-based traceability mechanisms, managers can reduce transaction costs through the minimisation or removal of intermediaries from supply chain processes. Transparent track-and-trace systems further enable responsible procurement and ethical sourcing, reducing opportunistic behaviours while enhancing fraud detection within global agri-food chains as well as the broader field of supply chain management. Consequently, this research supports managerial decision-making regarding blockchain-based traceability and sustainability in the supply chain domain. Such understanding empowers managers to design and implement robust strategies that accelerate blockchain adoption within their operations. Moreover, blockchain adoption can create competitive advantages by improving consumer confidence in product authenticity and provenance, which is particularly crucial in export-oriented industries such as agriculture (Rejeb et al., 2023). It also encourages collaborative networks among stakeholders, enhancing resilience and innovation in complex supply chains (Queiroz & Wamba, 2019). Additionally, blockchain integration has the potential to align supply chain operations with sustainability-driven market pressures, thereby improving long-term strategic positioning (Saberi et al., 2019).

The model further underscores the importance of supply chain managers developing blockchain-enabled traceability practices that surpass traditional mechanisms to foster social, economic, and environmental sustainability. Unlike conventional systems, blockchain ensures immutable record-keeping, strengthens accountability, and provides end-to-end visibility that supports sustainability initiatives and stakeholder trust (Kouhizadeh & Sarkis, 2018).

Finally, the findings also carry significant implications for policymakers, who can leverage the results to formulate policies that accelerate blockchain implementation for food safety assurance and a sustainable agri-food supply chain in the global marketplace. By institutionalising standards and regulations for blockchain integration, policymakers can drive harmonisation across industries, thereby facilitating adoption at scale (Roeck et al., 2020). Such policies can also support international trade by improving compliance with global standards on transparency, sustainability, and quality assurance (Hastig & Sodhi, 2020).

6.5 Summary:

This chapter has discussed the research findings based on the PLS-SEM analysis and the contribution presented in Chapter 6. The findings of this research have been presented to support the objective and the related hypothesis of the study accordingly. This research revealed that adopting blockchain in supply chains has significant impacts on supply chain traceability and sustainability. The findings of this study substantial impacts and positive relationships between business environmental drivers and blockchain adoption, along with direct, indirect and conditional effects of blockchain adoption on Agri-products supply chain traceability and sustainability, thereby making an essential contribution to the literature on technology adoption in supply chain management.

CHAPTER 7:

7.1 CONCLUSION, LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

7.2 Introduction

The focus of this quantitative survey method research was to examine the hypothesised relationship in the model: blockchain adoption in the supply chain for traceability for sustainability. Specifically, it examined blockchain adoption drivers (business environmental drivers), traceability and sustainability, and the mediators' and moderators' role in the Agri-products supply chain context. The concluding chapter begins with a summary of the research. Then, it provides an overview of the research process and findings, followed by the significance of the theoretical and practical contributions. This chapter also reviews the limitations and then provides recommendations for future research.

7.2.1 SUMMARY OF RESEARCH

Blockchain adoption in supply chain management is increasingly receiving attention as it enhances traceability, transparency, and sustainability (Kamble et al., 2020b, Litke et al., 2019, Saberi et al., 2019b). By offering a decentralised and immutable ledger, blockchain technology enables supply chain members /stakeholders to track and trace products/information and materials throughout their lifecycle, ensuring accountability and trust (Garcia-Torres et al., 2019, Hughes et al., 2019). Blockchain-based traceability offers real-time visibility of goods, secure documentation of transactions, and verification of ethical sourcing in end-to-end supply chain practices to achieve sustainability (Kamble et al., 2020a, Makhdoom et al., 2019, Manupati et al., 2020). For instance, blockchain can record every step of a product's journey, from raw material extraction to final delivery, allowing organisations to validate compliance with environmental and social standards (Helo and Hao, 2019, Howson, 2020, Kamble et al., 2020a). This is particularly critical in the Agri-products, food, fashion, and electronics industries, where customers and regulators demand evidence of sustainable and ethical practices (Helo and Hao, 2019, Howson, 2020, Kamble et al., 2020a, Lin et al., 2019, Wamba et al., 2020a). In particular, traceability for sustainability is relatively minimal in the context of Agri-products in the conventional supply chain due to a lack of transparency and visibility (Cousins et al., 2019, Kouhizadeh et al., 2021, Aung and Chang, 2014, Bai and Sarkis, 2020, Garcia-Torres et al., 2019). Therefore, blockchain adoption is essential for Agri-products supply chain traceability for sustainability.

The existing literature indicates that smart contracts, a feature of blockchain, automate processes such as payments and quality checks when predefined conditions are met, reducing manual errors and delays (Saberi et al., 2019b, Treiblmaier, 2018, Dolgui et al., 2020). This process minimises or reduces intermediatory costs and drives cost reduction in supply chain activities, supporting transaction costs theory (Queiroz and Wamba, 2019, Wang et al., 2019a). Studies also indicate that blockchain integration with IoT devices can enhance data accuracy by providing real-time updates on environmental conditions like temperature or humidity during the transportation of Agri-products in the supply chain (Prashar et al., 2020, Wamba et al., 2020a, Wang et al., 2019b, Yadav et al., 2020, Feng et al., 2020a, Pearson et al., 2019). However, empirical research on the Agri-products supply chain context (Queiroz et al., 2019b, Zhao et al., 2019) is relatively lacking.

Challenges of adoption include high implementation costs, infrastructure costs, the need for collaboration across multiple supply chain members, and the complexity of integrating blockchain with existing systems (Helo and Hao, 2019, Min, 2019, Prashar et al., 2020, Wamba et al., 2020a, Wang et al., 2019b). Despite the challenges, the example of pilot projects by companies like IBM, Walmart, and Maersk have demonstrated the potential of blockchain to revolutionise supply chains, reduce fraud, and support sustainable development goals (Kamath, 2018, Wamba et al., 2020a). Existing literature on blockchain adoption in the supply chain (Hughes et al., 2019, Feng et al., 2020a, Kim and Laskowski, 2018, Mahyuni et al., 2020, Pearson et al., 2019, Wamba and Queiroz, 2020a) relatively lacks the empirically validated model that can address supply chain traceability for sustainability. With this backdrop, the present study aimed to develop a model of blockchain adoption for supply chain traceability and sustainability in agri-products based on an extensive literature review on blockchain adoption, supply chain traceability and sustainability. To ensure the theoretical foundations of the conceptual model, the related constructs and their hypothesised relationships were justified in light of the Resource-Based View (RBV) theory and Transaction Cost Theory (TCT). Finally, the constructs and variables of the conceptual model were subject to validation by the quantitative research approaches adopted for this study.

The final research model consisted of the dimensions of blockchain adoption in the Agi-products supply chain: blockchain adoption (BCAD) (Wamba et al., 2020a), three business environmental drivers (market dynamic (MDY), competitive pressure (CPR), and regulatory pressure (RGS) (Wong et al., 2020a), one mediator role, traceability (TRA) (Cousins et al., 2019), three moderators roles {(technological orientations (TOR) (Yu et al., 2022), upper management support (UPS) (Wong et al., 2020a), and sustainability governance (SGV) (Chowdhury and Quaddus, 2021a)}, including outcome variables, sustainability, social (SOC), environmental (ENV) and economic

(ECO) (Chowdhury and Quaddus, 2021a) were considered refractive. These constructs and measurement items included in this study were sourced from the theories and previous studies. These measurements were used for the development (see Chapter 4) of questionnaires for quantitative research. The developed questionnaire was pretested and refined, and a pilot study was conducted. Using the Qualtrics instrument, the final survey data, a total of 294, were collected through the MTurk platform. The collected data were analysed by using the partial-least-squares (PLS)-based structural equation modelling (SEM) technique (see Chapter 5). The PLS-SEM analysis was completed to assess the measurement model and structural model. In the measurement model assessment, low-reliability items were removed from the model. The refined model assured the acceptable level of item reliability, convergent validity, and discriminant validity. The structural model was then assessed once the measurement model assessment was satisfied.

The structural model assessment revealed that the constructs of blockchain adoption can explain 68.9.% variance, and the construct: traceability can explain 79.1% variance. The hypothesis testing result shows that all hypotheses were statistically significant (see Chapter 5, page, Table). It was also proved that the mediating hypothesis was supported. The result was also evident that the model confirmed the predictive validity, had no endogeneity issues, and had a 95% statistical power of the model (ensuring that the sample size in this study is adequate to validate the model) concerning the focal constructs. The results of the analysis have both managerial and research implications. The following section presents the contribution of the study.

7.3 LIMITATIONS

Firstly, there are limitations of this research that future researchers may resolve. For example, this research study was cross-sectional, like a static investigation. The major limitation of cross-sectional design in this research is that the investigation of the phenomenon of the study is limited to the point of time assessment. In the changing business environment, individuals' perceptions may change over time, and future researchers might consider extending this research with the dynamic nature of the phenomenon, using longitudinal study to overcome this limitation. Thus, a longitudinal focus is recommended for future research. Secondly, this research used a quantitative approach and a survey method design. Future research may overcome the limitation using a mixed-method philosophy, combining qualitative and quantitative approaches. Also, it can overcome the limitations by including semi-structured interview questionnaires in the qualitative data collection perspective. Thus, a mixed method (qualitative and quantitative) design is recommended for future research.

Thirdly, this study specifically analysed business environmental drivers, including market dynamics (MDY), competitive pressure (COP), and regulatory support (RGS). Future research may use organisational, technological, and social drivers to overcome the limitations. Thus, multiple drivers are recommended for future research.

Fourthly, the unit of analysis in this study surveyed supply chain actors focused on producers, processors, transporters, wholesalers, and retailers from the global Agri-products industries. Future research may consider all members of the supply chain network to overcome these limitations.

Finally, this study's data collection and analyses consider the global agri-products industries; however, the implications are significant for the services industry for one country's focus. Thus, future research into the services industry or a specific Agri-product for one particular country focus is recommended.

7.3.1 Findings considering the research objectives

Findings regarding the research objectives are discussed in this section. Research objective 1 addresses the investigation of the impacts of business environmental drivers (MDY, CPR, RGS) on blockchain adoption in the Agri-products supply chain of the global context. It is important to mention that in section 6.2, under sub-section 6.2.1, the hypothesised relationships (H1, H2, and H3) in the model are discussed, which addresses the research objective one. Research objective 2 of the study examines the direct, indirect and conditional effect of blockchain adoption on Agri-products supply chain traceability and sustainability. It is worth mentioning that in the same section 6.2, under sub-section 6.2.1, the hypothesised relationships (H4, H5, H6, H7, H8, H9, & H10) in the model are discussed, which addresses sub-research objective 2. Therefore, the findings in light of the research objectives (1 & 2) reflect the findings of the related hypothesised relationship of the study.

7.4 Summary of the findings

This chapter has provided a discussion of the findings based on PLS analysis. The interpretations of the findings have been carried out to support the research objectives and the related hypothesis of the study. The findings of this study confirm that there are significant impacts and positive relationships between business environmental drivers and blockchain adoption, along with direct, indirect and conditional effects of blockchain adoption on Agri-products supply chain traceability and sustainability, thereby making an important contribution to the literature on technology adoption in supply chain management. It was found that the business environmental drivers (market dynamics, competitive pressure, and regulatory support) positively impact blockchain adoption in the Agri-products supply chain. The findings of the study support that market dynamics profoundly impact the adoption of blockchain technology; similarly, competitive pressure and regulatory support profoundly impact blockchain adoption. Also, it was found that the direct (H7), indirect (H10), and conditional (H5, H6, & H8) effects of blockchain adoption on Agri-products supply chain traceability and sustainability have been established.

Furthermore, it was found that the hypnotised relationship (H9) aligns with the Transaction Cost Theory and claims the importance of traceability in improving the Agri-products supply chain for sustainability. In particular, the findings of this study reiterate the importance of blockchain adoption for traceability in improving the Agri-products supply chain for sustainability (social, economic and environmental). Specifically, the study empirically validated blockchain adoption in the Agri-products supply chain traceability and sustainability model by using PLS-based SEM.

7.5 FUTURE RESEARCH DIRECTIONS

This research produces several opportunities for future research that are summarised below:

To address the cross-sectional methodological limitations, a longitudinal study is recommended to analyse the factors influencing blockchain adoption in supply chain traceability and sustainability.

Future research should consider all supply chain members to address the limitation of the study’s unit (producers, processors, transporters, wholesalers, and retailers) of analysis.

Multiple drivers (organisational, technological, and social) are recommended for future research to address the limitations of business environmental drivers.

Future research recommended that the services industry for a specific country focus on addressing the limitation of data collection only from the global agri-products industry.

This study identified and investigated supply chain sustainability as an outcome construct of blockchain adoption for supply chain traceability, or in other words, supply chain traceability as antecedent constructs of supply chain sustainability. Future research may be conducted to investigate other antecedent factors, such as sustainability governance, technology orientation, and upper management support. Thus, the mediator role of the supply chain traceability between blockchain and sustainability is worth investigating.

This study identified that the literature on blockchain in supply chains is emerging over time; most of the studies are conceptual-focused, and empirical research is relatively limited. Future research may be conducted with more empirical studies. Empirical research is recommended in this field to overcome such limitations.

The study also identified that previous literature on blockchain in supply chain management (SCM) has addressed various topics, but most papers lack theoretical foundations. Future research may apply more organisational theory to overcome this limitation. It is recommended that the theory be used in future studies to overcome such limitations.

This study identified that the application of blockchain technology in the Agri-product value chain is still in its infancy; it can be expected that various agri-food organisations will take more initiatives. Therefore, more research from theory and empirical perspectives is needed to check the effects of blockchain technology on the agri-product value chain, mainly to study its impact on the international agri-food trade and formulate corresponding standards based on the results of this study.

7.5.1 Future Research Predictions

- **Exploring Blockchain Adoption Across Diverse Agri-Food Sectors**

  Future studies could investigate how blockchain adoption varies across different agri-food sectors, such as beef, dairy, horticulture, and wine in Australia. Each sector faces unique challenges, such as perishability, certification requirements, or export compliance—that may shape blockchain adoption differently (Rejeb et al., 2023). Comparative studies can provide sector-specific recommendations to improve traceability and sustainability.

- **Integration of Blockchain with Other Digital Technologies**

  Further research should examine how blockchain can be integrated with emerging technologies like the Internet of Things (IoT), Artificial Intelligence (AI), and Big Data analytics. Such integration could improve data accuracy, real-time monitoring, and predictive capabilities across supply chains (Queiroz

& Wamba, 2019). Studies on hybrid digital ecosystems would provide insights into creating resilient and adaptive supply chains.

- **Consumer Perceptions and Trust in Blockchain-Based Agri-Food Systems**

  Research can be extended to explore consumer attitudes toward blockchain-enabled transparency in agri-food supply chains. Understanding consumer perceptions of food provenance, authenticity, and safety is critical for ensuring widespread acceptance and demand-driven adoption (Saberi et al., 2019). This can also guide marketing strategies that leverage blockchain for competitive advantage.

- **Policy and Regulatory Frameworks for Blockchain Implementation**

  Future studies should investigate how government policies, regulations, and international trade agreements can facilitate or hinder blockchain adoption in agri-food supply chains. Policymakers play a crucial role in setting standards for interoperability, data governance, and certification processes (Roeck et al., 2020). Research in this area can help design harmonised frameworks that encourage adoption while maintaining compliance with global standards.

- **Socio-Economic Implications for Smallholder Farmers**

  Another area for future research involves studying how blockchain adoption impacts smallholder farmers, particularly in developing and rural contexts. Blockchain can potentially improve market access, reduce exploitation by intermediaries, and ensure fair compensation (Kouhizadeh & Sarkis, 2018). However, challenges such as digital literacy and access to infrastructure must be addressed, making this a critical avenue for future inquiry.

REFERENCES

Abeyratne, S. A. & Monfared, R. P. 2016. Blockchain ready manufacturing supply chain using distributed ledger. *International Journal of Research in Engineering and Technology,* 5**,** 1–10.

Aboelmaged, M. G. 2014. Predicting e-readiness at firm-level: An analysis of technological, organizational and environmental (TOE) effects on e-maintenance readiness in manufacturing firms. *International Journal of Information Management,* 34**,** 639–651.

Aguinis, H., Villamor, I. & Ramani, R. S. 2021. MTurk research: Review and recommendations. *Journal of Management,* 47**,** 823–837.

Al-Jaroodi, J. & Mohamed, N. 2019. Blockchain in Industries: A Survey. *IEEE Access,* 7**,** 36500–36515.

Allen, D. W. E., Berg, C., Davidson, S., Novak, M. & Potts, J. 2019. International policy coordination for blockchain supply chains. *Asia and the Pacific Policy Studies*.

Allen, P., Bennett, K. & Heritage, B. 2014. *SPSS statistics version 22: A practical guide*, Cengage Learning Australia.

Anastasiadis, F., Apostolidou, I. & Tsolakis, N. 2025. Challenges and opportunities of supply chain traceability: insights from emergent agri-food sector. *Supply Chain Management: An International Journal,* 30**,** 106–126.

Anderson, J. C. & Gerbing, D. W. 1988. Structural equation modeling in practice: A review and recommended two-step approach. *Psychological bulletin,* 103**,** 411.

Apeh, O. O. & Nwulu, N. I. 2024. The water-energy-food-ecosystem nexus scenario in Africa: Perspective and policy implementations. *Energy Reports,* 11**,** 5947–5962.

Apeh, O. O. & Nwulu, N. I. 2025. Improving traceability and sustainability in the agri-food industry through blockchain technology: A bibliometric approach, benefits and challenges. *Energy Nexus,* 17**,** 100388.

Aung, M. M. & Chang, Y. S. 2014. Traceability in a food supply chain: Safety and quality perspectives. *Food control,* 39**,** 172–184.

Azzi, R., Chamoun, R. K. & Sokhn, M. 2019. The power of a blockchain-based supply chain. *Computers & industrial engineering,* 135**,** 582–592.

Babbie, E. R. 2020. *The practice of social research*, Cengage learning.

Bag, S., Rahman, M. S., Gupta, S. & Wood, L. C. 2023. Understanding and predicting the determinants of blockchain technology adoption and SMEs' performance. *The International Journal of Logistics Management,* 34**,** 1781–1807.

Bai, C. & Sarkis, J. 2020. A supply chain transparency and sustainability technology appraisal model for blockchain technology. *International Journal of Production Research,* 58**,** 2142–2162.

Baker, J. J. I. s. t. 2012. The technology–organization–environment framework. 231–245.

Bals, L., Turkulainen, V. J. J. o. P. & Management, S. 2017. Achieving efficiency and effectiveness in Purchasing and Supply Management: Organization design and outsourcing. *Journal of Purchasing Supply Management,* 23**,** 256–267.

Barclay, D., Higgins, C. & Thompson, R. 1995. *The partial least squares (PLS) approach to casual modeling: personal computer adoption ans use as an Illustration*.

Barney, J. J. J. o. m. 1991. Firm resources and sustained competitive advantage. *Journal of management,* 17**,** 99–120.

Baron, R. M. & Kenny, D. A. 1986. The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of personality and social psychology,* 51**,** 1173.

Becker, J.-M., Cheah, J.-H., Gholamzade, R., Ringle, C. M. & Sarstedt, M. 2023. PLS-SEM's most wanted guidance. *International Journal of Contemporary Hospitality Management,* 35**,** 321–346.

Becker, J.-M., Klein, K. & Wetzels, M. 2012. Hierarchical latent variable models in PLS-SEM: guidelines for using reflective-formative type models. *Long range planning,* 45**,** 359–394.

Behnke, K. & Janssen, M. 2020a. Boundary conditions for traceability in food supply chains using blockchain technology. *International Journal of Information Management,* 52**,** 101969.

Behnke, K. & Janssen, M. F. W. H. A. 2019. Boundary conditions for traceability in food supply chains using blockchain technology. *International Journal of Information Management*.

Behnke, K. & Janssen, M. F. W. H. A. 2020b. Boundary conditions for traceability in food supply chains using blockchain technology. *International Journal of Information Management,* 52**,** 101969.

Benčić, F. M., Skočir, P. & Žarko, I. P. 2019. DL-Tags: DLT and Smart Tags for Decentralized, Privacy-Preserving, and Verifiable Supply Chain Management. *IEEE access,* 7**,** 46198–46209.

Bernerth, J. B. & Aguinis, H. 2016. A critical review and best-practice recommendations for control variable usage. *Personnel psychology,* 69**,** 229–283.

Beske, P. J. I. j. o. p. d. & management, l. 2012. Dynamic capabilities and sustainable supply chain management. *International journal of physical distribution logistics management*.

Blumberg, B., Cooper, D. & Schindler, P. 2014. *EBOOK: Business research methods*, McGraw Hill.

Bollen, K. A. 2014. *Structural equations with latent variables*, John Wiley & Sons.

Bosona, T. & Gebresenbet, G. 2013a. Food traceability as an integral part of logistics management in food and agricultural supply chain. *Food control,* 33**,** 32–48.

Bosona, T. & Gebresenbet, G. 2023. The role of blockchain technology in promoting traceability systems in agri-food production and supply chains. *Sensors,* 23**,** 5342.

Bosona, T. & Gebresenbet, G. J. F. c. 2013b. Food traceability as an integral part of logistics management in food and agricultural supply chain. *Food control,* 33**,** 32–48.

Bougie, R. & Sekaran, U. 2019. *Research methods for business: A skill building approach*, John Wiley & Sons.

Boxenbaum, E. & Jonsson, S. 2017. Isomorphism, diffusion and decoupling: Concept evolution and theoretical challenges. *The Sage handbook of organizational institutionalism,* 2**,** 77–101.

Boyacı, I. H., Temiz, H. T., Uysal, R. S., Velioğlu, H. M., Yadegari, R. J. & Rishkan, M. M. 2014. A novel method for discrimination of beef and horsemeat using Raman spectroscopy. *Food chemistry,* 148**,** 37–41.

Boyer, K. K. & Verma, R. 2000. Multiple raters in survey-based operations management research: a review and tutorial. *Production and Operations Management,* 9**,** 128–140.

Bryman, A. 2016. *Social research methods*, Oxford university press.

Buckley, M. R., Cote, J. A. & Comstock, S. M. 1990. Measurement errors in the behavioral sciences: The case of personality/attitude research. *Educational and psychological measurement,* 50**,** 447–474.

Bueno, S. & Gallego, M. D. 2017. Managing top management support in complex information systems projects: An end-user empirical study. *Journal of Systems and Information Technology,* 19**,** 151–164.

Buhrmester, M. D., Talaifar, S. & Gosling, S. D. 2018. An evaluation of Amazon's Mechanical Turk, its rapid rise, and its effective use. *Perspectives on psychological science,* 13**,** 149–154.

Bumblauskas, D., Mann, A., Dugan, B. & Rittmer, J. J. I. J. o. I. M. 2020. A blockchain use case in food distribution: Do you know where your food has been? *International Journal of Information Management,* 52**,** 102008.

Burrell, G. & Morgan, G. 2019. *Sociological paradigms and organisational analysis: Elements of the sociology of corporate life*, Routledge.

Büyüközkan, G. & Göçer, F. 2018. Digital Supply Chain: Literature review and a proposed framework for future research. *Computers in Industry,* 97**,** 157–177.

Byrne, B. M. 2013. *Structural equation modeling with Mplus: Basic concepts, applications, and programming*, routledge.

Caldarelli, G., Zardini, A. & Rossignoli, C. 2021. Blockchain adoption in the fashion sustainable supply chain: Pragmatically addressing barriers. *Journal of Organizational Change Management*.

Campbell, D. T. & Fiske, D. W. 1959. Convergent and discriminant validation by the multitrait-multimethod matrix. *Psychological bulletin,* 56**,** 81.

Cao, S., Johnson, H. & Tulloch, A. 2023. Exploring blockchain-based traceability for food supply chain sustainability: Towards a better way of sustainability communication with consumers. *Procedia Computer Science,* 217**,** 1437–1445.

Carlson, K. D. & Wu, J. 2012. The illusion of statistical control: Control variable practice in management research. *Organizational research methods,* 15**,** 413–435.

Carter, C. R., Rogers, D. S. J. I. j. o. p. d. & management, l. 2008. A framework of sustainable supply chain management: moving toward new theory. *International journal of physical distribution*

logistics management.

Casado-Vara, R., Prieto, J., De la Prieta, F. & Corchado, J. M. 2018. How blockchain improves the supply chain: case study alimentary supply chain. *Procedia computer science,* 134**,** 393–398.

Casati, M., Soregaroli, C., Frizzi, G. L. & Stranieri, S. 2024. Impacts of blockchain technology in agrifood: exploring the interplay between transactions and firms' strategic resources. *Supply Chain Management: An International Journal,* 29**,** 51–70.

Casino, F., Dasaklis, T. K. & Patsakis, C. 2019. A systematic literature review of blockchain-based applications: current status, classification and open issues. *Telematics and Informatics,* 36**,** 55–81.

Casino, F., Kanakaris, V., Dasaklis, T. K., Moschuris, S., Stachtiaris, S., Pagoni, M. & Rachaniotis, N. P. 2020a. Blockchain-based food supply chain traceability: a case study in the dairy sector. *International Journal of Production Research***,** 1–13.

Casino, F., Kanakaris, V., Dasaklis, T. K., Moschuris, S., Stachtiaris, S., Pagoni, M. & Rachaniotis, N. P. J. I. J. o. P. R. 2020b. Blockchain-based food supply chain traceability: a case study in the dairy sector. *International Journal of Production Research*, 1–13.

Casler, K., Bickel, L. & Hackett, E. 2013. Separate but equal? A comparison of participants and data gathered via Amazon's MTurk, social media, and face-to-face behavioral testing. *Computers in human behavior,* 29, 2156–2160.

Catalini, C. & Gans, J. S. 2020. Some simple economics of the blockchain. *Communications of the ACM,* 63, 80–90.

Cavana, R., Delahaye, B. & Sekeran, U. 2001. *Applied business research: Qualitative and quantitative methods*, John Wiley & Sons.

Chandler, J. J. & Paolacci, G. 2017. Lie for a dime: When most prescreening responses are honest but most study participants are impostors. *Social Psychological and Personality Science,* 8, 500–508.

Chang, J., Katehakis, M. N., Melamed, B. & Shi, J. J. 2018. Blockchain design for supply chain management. *Available at SSRN 3295440*.

Chang, S. E. & Chen, Y. 2020. When Blockchain Meets Supply Chain: A Systematic Literature Review on Current Development and Potential Applications. *IEEE Access,* 8, 62478–62494.

Chang, S. E., Chen, Y.-C. & Lu, M.-F. 2019. Supply chain re-engineering using blockchain technology: A case of smart contract based tracking process. *Technological Forecasting and Social Change,* 144, 1–11.

Chang, Y., Iakovou, E. & Shi, W. 2020. Blockchain in global supply chains and cross border trade: a critical synthesis of the state-of-the-art, challenges and opportunities. *International Journal of Production Research,* 58, 2082–2099.

Chase Jr, C. W. 2016. The digital revolution is changing the supply chain landscape. *The Journal of Business Forecasting,* 35, 20.

Chatterjee, S., Chaudhuri, R., Gupta, S., Sivarajah, U. & Bag, S. 2023. Assessing the impact of big data analytics on decision-making processes, forecasting, and performance of a firm. *Technological Forecasting and Social Change,* 196, 122824.

Chiaraluce, G., Bentivoglio, D., Finco, A., Fiore, M., Contò, F. & Galati, A. 2024. Exploring the role of blockchain technology in modern high-value food supply chains: global trends and future research directions. *Agricultural and Food Economics,* 12, 6.

Chin, W. W. 1998. Commentary: Issues and opinion on structural equation modeling. JSTOR.

Chin, W. W. 2009. How to write up and report PLS analyses. *Handbook of partial least squares: Concepts, methods and applications.* Springer.

Chittipaka, V., Kumar, S., Sivarajah, U., Bowden, J. L.-H. & Baral, M. M. 2023. Blockchain Technology for Supply Chains operating in emerging markets: an empirical examination of technology-organization-environment (TOE) framework. *Annals of Operations Research,* 327, 465–492.

Choi, T.-M. 2019a. Blockchain-technology-supported platforms for diamond authentication and certification in luxury supply chains. *Transportation Research Part E:,* 128, 17–29.

Choi, T.-M. 2019b. Blockchain-technology-supported platforms for diamond authentication and certification in luxury supply chains. *Transportation Research Part E: Logistics and Transportation Review,* 128, 17–29.

Choi, T.-M., Feng, L. & Li, R. 2020a. Information disclosure structure in supply chains with rental service platforms in the blockchain technology era. *International Journal of Production Economics,* 221**,** 107473.

Choi, T.-M., Guo, S. & Luo, S. 2020b. When blockchain meets social-media: Will the result benefit social media analytics for supply chain operations management? *Transportation Research Part E: Logistics and Transportation Review,* 135**,** 101860.

Choi, T.-M., Wen, X., Sun, X., Chung, S.-H. J. T. R. P. E. L. & Review, T. 2019. The mean-variance approach for global supply chain risk analysis with air logistics in the blockchain technology era. *Transportation Research Part E,* 127**,** 178–191.

Chong, A. Y.-L. 2013. A two-staged SEM-neural network approach for understanding and predicting the determinants of m-commerce adoption. *Expert Systems with Applications,* 40**,** 1240–1247.

Chowdhury, M. M. H. 2014. *Supply chain sustainability and resilience: the case of apparel industry in Bangladesh.* Curtin University.

Chowdhury, M. M. H., Chowdhury, M., Khan, E. A. & Sajib, S. 2023. Supply chain relational capital for sustainability through governance: the moderating effect of network complexity. *Supply Chain Management: An International Journal,* 28**,** 347–362.

Chowdhury, M. M. H., Islam, M. T., Ali, I. & Quaddus, M. 2024. The role of social capital, resilience, and network complexity in attaining supply chain sustainability. *Business Strategy and the Environment,* 33**,** 2621–2639.

Chowdhury, M. M. H. & Quaddus, M. 2016. Supply chain readiness, response and recovery for resilience. *Supply Chain Management: An International Journal*.

Chowdhury, M. M. H. & Quaddus, M. 2017. Supply chain resilience: Conceptualization and scale development using dynamic capability theory. *International journal of production economics,* 188**,** 185–204.

Chowdhury, M. M. H. & Quaddus, M. 2021a. Supply chain sustainability practices and governance for mitigating sustainability risk and improving market performance: A dynamic capability perspective. *Journal of Cleaner Production,* 278**,** 123521.

Chowdhury, M. M. H. & Quaddus, M. A. J. J. o. C. P. 2021b. Supply chain sustainability practices and governance for mitigating sustainability risk and improving market performance: A dynamic capability perspective. *Journal of Cleaner Production,* 278**,** 123521.

Chowdhury, M. M. H. Q., Mohammed 2016. Supply chain readiness, response and recovery for resilience. *Supply Chain Management: An International Journal,* 21**,** 709–731.

Christodoulou, P., Christodoulou, K. & Andreou, A. 2018. A Decentralized Application for Logistics: Using Blockchain in Real-World Applications. *The Cyprus Review,* 30**,** 181–118.

Christopher, M. 2016. *Logistics & supply chain management*, Pearson Uk.

Cohen, J. 2013. *Statistical power analysis for the behavioral sciences*, routledge.

Cohen, J., Cohen, P., West, S. G. & Aiken, L. S. 2013. *Applied multiple regression/correlation analysis for the behavioral sciences*, Routledge.

Cole, R., Stevenson, M. & Aitken, J. 2019. Blockchain technology: implications for operations and supply chain management. *Supply Chain Management: An International Journal,* 24**,** 469–483.

Collis, J. & Hussey, R. 2013. *Business research: A practical guide for undergraduate and postgraduate students*, Palgrave macmillan.

Coltman, T., Devinney, T. M., Midgley, D. F. & Venaik, S. 2008. Formative versus reflective measurement models: Two applications of formative measurement. *Journal of Business research,* 61**,** 1250–1262.

Cooper, M. C., Lambert, D. M. & Pagh, J. D. 1997. Supply chain management: more than a new name for logistics. *The international journal of logistics management,* 8**,** 1–14.

Costa, C., Antonucci, F., Pallottino, F., Aguzzi, J., Sarriá, D. & Menesatti, P. 2013. A review on agri-food supply chain traceability by means of RFID technology. *Food and bioprocess technology,* 6**,** 353–366.

Cousins, P. D., Lawson, B., Petersen, K. J. & Fugate, B. 2019. Investigating green supply chain management practices and performance: The moderating roles of supply chain ecocentricity and traceability. *International Journal of Operations & Production Management,* 39**,** 767–786.

Creswell, J. W. 2018. *Qualitative, quantitative, and mixed methods approaches+ a crash course in statistics*, Sage publications.

Creswell, J. W. & Creswell, J. D. 2017. *Research design: Qualitative, quantitative, and mixed methods approaches*, Sage publications.

Creydt, M. & Fischer, M. 2019. Blockchain and more-Algorithm driven food traceability. *Food Control,* 105**,** 45–51.

Crotty, M. 1998. The foundations of social research: Meaning and perspective in the research process. Sage.

Crump, M. J., McDonnell, J. V. & Gureckis, T. M. 2013. Evaluating Amazon's Mechanical Turk as a tool for experimental behavioral research. *PloS one,* 8**,** e57410.

Dauvergne, P. & Lister, J. 2012. Big brand sustainability: Governance prospects and environmental limits. *Global Environmental Change,* 22**,** 36–45.

Dawes, J. 2008. Do data characteristics change according to the number of scale points used? An experiment using 5-point, 7-point and 10-point scales. *International journal of market research,* 50**,** 61–104.

Deephouse, D. L. & Suchman, M. 2008. Legitimacy in organizational institutionalism. *The Sage handbook of organizational institutionalism,* 49**,** 273–289.

Denzin, N. K. 1970. *The research act: A theoretical introduction to sociological methods*, Transaction publishers.

Dey, K. & Shekhawat, U. 2021. Blockchain for sustainable e-agriculture: Literature review, architecture for data management, and implications. *Journal of Cleaner Production,* 316**,** 128254.

Di Vaio, A. & Varriale, L. 2020. Blockchain technology in supply chain management for sustainable performance: Evidence from the airport industry. *International Journal of Information Management,* 52**,** 102014.

DiMaggio, P. J. & Powell, W. W. 1983. The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. *American sociological review,* 48**,** 147–160.

Ding, M. J., Jie, F., Parton, K. A. & Matanda, M. J. 2014. Relationships between quality of information sharing and supply chain food quality in the Australian beef processing industry. *The international journal of logistics management*.

Dobrovnik, M., Herold, D. M., Fürst, E. & Kummer, S. 2018. Blockchain for and in Logistics: What to Adopt and Where to Start. *Logistics,* 2.

Dolgui, A., Ivanov, D., Potryasaev, S., Sokolov, B., Ivanova, M. & Werner, F. 2020. Blockchain-oriented dynamic modelling of smart contract design and execution in the supply chain. *International Journal of Production Research,* 58**,** 2184–2199.

Dos Santos, R. B., Torrisi, N. M., Yamada, E. R. K. & Pantoni, R. P. 2019. IGR token-raw material and ingredient certification of recipe based foods using smart contracts. *Informatics,* 6.

Drescher, D. 2020. *Blockchain basics: a non-technical introduction in 25 steps*, Gildan Audio.

Duan, J., Zhang, C., Gong, Y., Brown, S. & Li, Z. 2020. A Content-Analysis Based Literature Review in Blockchain Adoption within Food Supply Chain. *International Journal of Environmental Research and Public Health,* 17**,** 1784.

Edmondson, A. C. & McManus, S. E. 2007. Methodological fit in management field research. *Academy of management review,* 32**,** 1246–1264.

Elkington, J. J. E. q. m. 1998. Partnerships from cannibals with forks: The triple bottom line of 21st-century business. *Environmental quality management,* 8**,** 37–51.

Fard, A. M. F. & Hajaghaei-Keshteli, M. J. A. S. C. 2018. A tri-level location-allocation model for forward/reverse supply chain. 62**,** 328–346.

Faul, F., Erdfelder, E., Buchner, A. & Lang, A.-G. 2009. Statistical power analyses using G* Power 3.1: Tests for correlation and regression analyses. *Behavior research methods,* 41**,** 1149–1160.

Faundez, J. 2016. Douglass North's theory of institutions: lessons for law and development. *Hague Journal on the Rule of Law,* 8**,** 373–419.

Feng, H., Wang, X., Duan, Y., Zhang, J. & Zhang, X. 2020a. Applying blockchain technology to improve agri-food traceability: A review of development methods, benefits and challenges. *Journal of Cleaner Production***,** 121031.

Feng, H., Wang, X., Duan, Y., Zhang, J. & Zhang, X. J. J. o. c. p. 2020b. Applying blockchain technology to improve agri-food traceability: A review of development methods, benefits and challenges. *Journal of Cleaner Production,* 260**,** 121031.

Fernández-Caramés, T. M., Blanco-Novoa, O., Froiz-Míguez, I. & Fraga-Lamas, P. 2019. Towards an Autonomous Industry 4.0 Warehouse: A UAV and Blockchain-Based System for Inventory and Traceability Applications in Big Data-Driven Supply Chain Management. *Sensors (Basel, Switzerland),* 19.

Field, P. & Morse, J. 1985. Qualitative nursing research: The application of qualitative approaches. *Rockville, MD: Aspen*.

Figorilli, S., Antonucci, F., Costa, C., Pallottino, F., Raso, L., Castiglione, M., Pinci, E., Del Vecchio, D., Colle, G., Proto, A. R., Sperandio, G. & Menesatti, P. 2018. A blockchain implementation prototype for the electronic open source traceability of wood along the whole supply chain. *Sensors (Switzerland),* 18.

Folinas, D., Manikas, I. & Manos, B. J. B. F. J. 2006. Traceability data management for food chains. *British Food Journal*.

Fornell, C. & Bookstein, F. L. 1982. Two structural equation models: LISREL and PLS applied to consumer exit-voice theory. *Journal of Marketing research,* 19**,** 440–452.

Fornell, C. & Larcker, D. F. 1981. Evaluating structural equation models with unobservable variables and measurement error. *Journal of marketing research,* 18**,** 39–50.

Fosso, W., Samuel, Kala Kamdjoug, J. R., Epie Bawack, R. & Keogh, J. G. 2020. Bitcoin, blockchain and fintech: a systematic review and case studies in the supply chain. *Production Planning & Control,* 31**,** 115–142.

Fotopoulos, C. V., Psomas, E. L. & Vouzas, F. K. 2010. Investigating total quality management practice's inter-relationships in ISO 9001: 2000 certified organisations. *Total Quality Management,* 21**,** 503–515.

Francisco, K. & Swanson, D. 2018. The Supply Chain Has No Clothes: Technology Adoption of Blockchain for Supply Chain Transparency. *Logistics,* 2.

Fu, Y. & Zhu, J. 2019. Big Production Enterprise Supply Chain Endogenous Risk Management Based on Blockchain. *IEEE Access,* 7**,** 15310–15319.

Garcia-Torres, S., Albareda, L., Rey-Garcia, M. & Seuring, S. 2019. Traceability for sustainability–literature review and conceptual framework. *Supply Chain Management: An International Journal*.

Gatignon, H. & Xuereb, J.-M. 1997. Strategic orientation of the firm and new product performance. *Journal of marketing research,* 34**,** 77–90.

Gatteschi, V., Lamberti, F., Demartini, C., Pranteda, C. & Santamaría, V. 2018. Blockchain and smart contracts for insurance: Is the technology mature enough? *Future Internet,* 10**,** 20.

Gefen, D., Straub, D. & Boudreau, M.-C. 2000. Structural equation modeling and regression: Guidelines for research practice. *Communications of the association for information systems,* 4**,** 7.

Geisser, S. 1975. The predictive sample reuse method with applications. *Journal of the American statistical Association,* 70**,** 320–328.

George, R. V., Harsh, H. O., Ray, P. & Babu, A. K. J. J. o. C. P. 2019. Food quality traceability prototype for restaurants using blockchain and food quality data index. *Journal of Cleaner Production,* 240**,** 118021.

Gimenez, C. & Sierra, V. J. J. o. b. e. 2013. Sustainable supply chains: Governance mechanisms to greening suppliers. *Journal of business ethics,* 116**,** 189–203.

Glass, K., McLure, A., Bourke, S., Cribb, D. M., Kirk, M. D., March, J., Daughtry, B., Smiljanic, S. & Lancsar, E. 2023. The cost of foodborne illness and its sequelae in Australia circa 2019. *Foodborne Pathogens and Disease,* 20**,** 419–426.

Golan, E. H., Krissoff, B., Kuchler, F., Calvin, L., Nelson, K. E. & Price, G. K. 2004. Traceability in the US food supply: economic theory and industry studies.

Gómez-Luciano, C. A., Domínguez, F. R. R., González-Andrés, F. & De Meneses, B. U. L. J. J. o. c. p. 2018. Sustainable supply chain management: Contributions of supplies markets. *Journal of cleaner production,* 184**,** 311–320.

Goodhue, D. L., Lewis, W. & Thompson, R. 2012. Does PLS have advantages for small sample size or non-normal data? *MIS quarterly***,** 981–1001.

Goodman, J. K., Cryder, C. E. & Cheema, A. 2013. Data collection in a flat world: The strengths and weaknesses of Mechanical Turk samples. *Journal of Behavioral Decision Making,* 26**,** 213–224.

Grable, L., Overbay, A., Osborne, J., Vasu, E. & Shattuck, D. Assessing Teachers' Technology Skills and Attitudes: Initial Findings From the North Carolina IMPACT Evaluation. Society for Information Technology & Teacher Education International Conference, 2004. Association for the Advancement of Computing in Education (AACE), 926–930.

Gray, D. E. 2013. *Doing research in the real world*, Sage.

Grover, V., Chiang, R. H., Liang, T.-P. & Zhang, D. 2018. Creating strategic business value from big data analytics: A research framework. *Journal of management information systems,* 35**,** 388–423.

Grover, V. & Malhotra, M. K. J. J. o. O. m. 2003. Transaction cost framework in operations and supply chain management research: theory and measurement. *Journal of Operations management,* 21**,** 457–473.

Guba, E. G. The paradigm dialog. Alternative paradigms conference, mar, 1989, indiana u, school of education, san francisco, ca, us, 1990. Sage Publications, Inc.

Guba, E. G. & Lincoln, Y. S. 1994. Competing paradigms in qualitative research. *Handbook of qualitative research,* 2**,** 105.

Gunasekaran, A. & Kobu, B. 2007. Performance measures and metrics in logistics and supply chain management: a review of recent literature (1995–2004) for research and applications. *International Journal of Production Research,* 45**,** 2819–2840.

Guo, X., Xia, W., Feng, T., Tan, J. & Xian, F. 2024. Blockchain technology adoption and sustainable supply chain finance: The perspective of information processing theory. *Corporate Social Responsibility and Environmental Management,* 31**,** 3614–3632.

Gurtu, A. & Johny, J. 2019a. Potential of blockchain technology in supply chain management: a literature review. *International Journal of Physical Distribution & Logistics Management, Vol. 49 No. 9, PP. 881-900.*

Gurtu, A. & Johny, J. 2019b. Potential of blockchain technology in supply chain management: a literature review. *International Journal of Physical Distribution*

Logistics Management.

Hair, J. F., Risher, J. J., Sarstedt, M. & Ringle, C. M. 2019. When to use and how to report the results of PLS-SEM. *European business review,* 31**,** 2–24.

Hair Jr, J., Page, M. & Brunsveld, N. 2019. *Essentials of business research methods*, Routledge.

Hair Jr, J. F., Sarstedt, M., Hopkins, L. & Kuppelwieser, V. G. 2014. Partial least squares structural equation modeling (PLS-SEM): An emerging tool in business research. *European business review,* 26**,** 106–121.

Halac, D. S. 2015. Multidimensional construct of technology orientation. *Procedia-Social and Behavioral Sciences,* 195**,** 1057–1065.

Hammervoll, T., Jensen, L.-M. & Beske, P. 2012a. Dynamic capabilities and sustainable supply chain management. *International journal of physical distribution*

logistics management, 42 (4), .

Hammervoll, T., Jensen, L.-M. & Beske, P. 2012b. Dynamic capabilities and sustainable supply chain management. *International journal of physical distribution logistics management,* 42 (4),.

Happy, A., Chowdhury, M. M. H., Scerri, M., Hossain, M. A. & Barua, Z. 2023. Antecedents and consequences of blockchain adoption in supply chains: a systematic literature review. *Journal of Enterprise Information Management,* 36 (2)**,** 629–654.

Happy, A., Rahman, K. W., Chowdhury, M. M. H., Chowdhury, M. & Scerri, M. 2021. Blockchain adoption challenges in supply chain. *In:* AGARWAL, R., BAJADA, C., GREEN, R. AND SKELLERN, K. (ed.) *The Routledge Companion to Global Value Chains: Reinterpreting Reimagining Megatrends in the World Economy.* Taylor & Francis Group.

Harland, C. M. J. B. J. o. m. 1996. Supply chain management: relationships, chains and networks. *British Journal of management,* 7**,** S63–S80.

Hartley, J. L., Sawaya, W. & Dobrzykowski, D. 2022. Exploring blockchain adoption intentions in the supply chain: perspectives from innovation diffusion and institutional theory. *International Journal of Physical Distribution & Logistics Management,* 52**,** 190–211.

Hasan, H. R. S., K. 2018. Blockchain-Based Proof of Delivery of Physical Assets with Single and Multiple Transporters. *IEEE Access,* 6**,** 46781–46793.

Haschka, R. E. 2022. Handling endogenous regressors using copulas: a generalization to linear panel models with fixed effects and correlated regressors. *Journal of Marketing Research,* 59**,** 860–881.

Hastig, G. M. & Sodhi, M. S. 2020. Blockchain for supply chain traceability: Business requirements and critical success factors. *Production Operations Management,* 29(4)**,** 935–954.

Hastig, G. M., Sodhi, M. S. J. P. & Management, O. 2020. Blockchain for supply chain traceability: Business requirements and critical success factors. *Production Operations Management,* 29**,** 935–954.

Helo, P. & Hao, Y. 2019. Blockchains in operations and supply chains: A model and reference implementation. *Computers and Industrial Engineering,* 136**,** 242–251.

Henseler, J., Ringle, C. M. & Sarstedt, M. 2015. A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the academy of marketing science,* 43**,** 115–135.

Henseler, J. & Sarstedt, M. 2013. Goodness-of-fit indices for partial least squares path modeling. *Computational statistics,* 28**,** 565–580.

Heugens, P. P. & Lander, M. W. 2009. Structure! Agency!(and other quarrels): A meta-analysis of institutional theories of organization. *Academy of management journal,* 52**,** 61–85.

Ho, D. C. K., Au, K. F. & Newton, E. 2002. Empirical research on supply chain management: a critical review and recommendations. *International Journal of Production Research,* 40**,** 4415–4430.

Hofmann, E. & Rüsch, M. 2017. Industry 4.0 and the current status as well as future prospects on logistics. *Computers in Industry,* 89**,** 23–34.

Hong, J., Zhang, Y. & Ding, M. 2018a. Sustainable supply chain management practices, supply chain dynamic capabilities, and enterprise performance. *Journal of cleaner production,* 172**,** 3508–3519.

Hong, J., Zhang, Y. & Ding, M. J. J. o. c. p. 2018b. Sustainable supply chain management practices, supply chain dynamic capabilities, and enterprise performance. *Journal of cleaner production,* 172**,** 3508–3519.

Hoshmand, L. T. 2003. Can lessons of history and logical analysis ensure progress in psychological science? *Theory & Psychology,* 13**,** 39–44.

Howson, P. 2020. Building trust and equity in marine conservation and fisheries supply chain management with blockchain. *Marine Policy***,** 103873.

Hsing Wu, C., Kao, S. C. & Lin, H. H. 2013. Acceptance of enterprise blog for service industry. *Internet Research,* 23**,** 260–297.

Hsu, S.-D., Tseng, Y.-T., Shrestha, S., Lin, Y.-L., Khaleel, A., Chou, C.-H., Chu, C.-F., Huang, H.-Y., Lin, C.-M. & Ho, S.-Y. 2014. miRTarBase update 2014: an information resource for experimentally validated miRNA-target interactions. *Nucleic acids research,* 42**,** D78–D85.

Hughes, L., Dwivedi, Y. K., Misra, S. K., Rana, N. P., Raghavan, V. & Akella, V. 2019. Blockchain research, practice and policy: Applications, benefits, limitations, emerging research themes and research agenda. *International Journal of Information Management,* 49**,** 114–129.

Humdan, E. A., Shi, Y., Behina, M., Chowdhury, M. M. H. & Mahmud, A. S. 2023. The role of innovativeness and supply chain agility in the Australian service industry: a dynamic capability perspective. *International Journal of Physical Distribution & Logistics Management,* 53**,** 1–25.

Hunt, N. C. & Scheetz, A. M. 2019. Using MTurk to distribute a survey or experiment: Methodological considerations. *Journal of Information Systems,* 33**,** 43–65.

Imamura, M., Chen, J., Matsubayashi, S. R., Targino, R. A., Alfieri, F. M., Bueno, D. K. & Hsing, W. T. 2013. Changes in pressure pain threshold in patients with chronic nonspecific low back pain. *Spine,* 38**,** 2098–2107.

Irani, Z., Ezingeard, J.-N., Grieve, R. & Race, P. 1999. A case study strategy as part of an information systems research methodology: a critique. *International Journal of Computer Applications in Technology,* 12**,** 190–198.

Islam, S. & Cullen, J. M. J. F. C. 2021. Food traceability: A generic theoretical framework. 107848.

Jabbour, C. J. C., Fiorini, P. D. C., Ndubisi, N. O., Queiroz, M. M. & Piato, É. L. 2020. Digitally-enabled sustainable supply chains in the 21st century: A review and a research agenda. *Science of the total environment,* 725**,** 138177.

Janssen, M., Weerakkody, V., Ismagilova, E., Sivarajah, U. & Irani, Z. 2020. A framework for analysing blockchain technology adoption: Integrating institutional, market and technical factors. *International Journal of Information Management,* 50**,** 302–309.

Jayaraman, R., Salah, K. & King, N. 2019a. Improving opportunities in healthcare supply chain processes via the internet of things and blockchain technology. *International Journal of Healthcare Information Systems and Informatics, Vol. 14, No. 2, PP. 49-65.*

Jayaraman, R., Salah, K. & King, N. 2019b. Improving opportunities in healthcare supply chain processes via the internet of things and blockchain technology. *International Journal of Healthcare Information Systems*

Informatics, 14**,** 49–65.

Jie, F., Parton, K. A. & Mustafid 2016a. Supply chain performance flexibility in the Australian beef industry. *International Journal of Logistics Research and Applications,* 19**,** 300–317.

Jie, F., Parton, K. A., Research, M. J. I. J. o. L. & Applications 2016b. Supply chain performance flexibility in the Australian beef industry. 19**,** 300–317.

Johnson, R. B. & Onwuegbuzie, A. J. 2004. Mixed methods research: A research paradigm whose time has come. *Educational researcher,* 33**,** 14–26.

Johnson, R. B., Onwuegbuzie, A. J. & Turner, L. A. 2007. Toward a definition of mixed methods research. *Journal of mixed methods research,* 1**,** 112–133.

Jolink, A. & Niesten, E. 2015. Sustainable development and business models of entrepreneurs in the organic food industry. *Business Strategy and the Environment,* 24**,** 386–401.

Kale, P. & Singh, H. 2007. Building firm capabilities through learning: the role of the alliance learning process in alliance capability and firm-level alliance success. *Strategic management journal,* 28**,** 981–1000.

Kamath, R. 2018. Food traceability on blockchain: Walmart's pork and mango pilots with IBM. *The Journal of the British Blockchain Association,* 1**,** 3712.

Kamble, S., Gunasekaran, A. & Arha, H. 2019. Understanding the Blockchain technology adoption in supply chains-Indian context. *International Journal of Production Research,* 57**,** 2009–2033.

Kamble, S. G., A.: Arha, H. 2018. Understanding the Blockchain technology adoption in supply chains-Indian context. *International Journal of Production Research*.

Kamble, S. S., Gunasekaran, A. & Gawankar, S. A. 2020a. Achieving sustainable performance in a data-driven agriculture supply chain: A review for research and applications. *International Journal of Production Economics,* 219**,** 179–194.

Kamble, S. S., Gunasekaran, A. & Sharma, R. 2020b. Modeling the blockchain enabled traceability in agriculture supply chain. *International Journal of Information Management,* 52**,** 101967.

Kamble, S. S., Gunasekaran, A. & Sharma, R. 2020c. Modeling the blockchain enabled traceability in agriculture supply chain. *International Journal of Information Management,* 52.

Kamble, S. S., Gunasekaran, A., Subramanian, N., Ghadge, A., Belhadi, A. & Venkatesh, M. 2021. Blockchain technology's impact on supply chain integration and sustainable supply chain performance: evidence from the automotive industry. *Annals of Operations Research***,** 1–26.

Kamble, S. S., Gunasekaran, A., Subramanian, N., Ghadge, A., Belhadi, A. & Venkatesh, M. 2023. Blockchain technology's impact on supply chain integration and sustainable supply chain performance: Evidence from the automotive industry. *Annals of Operations Research,* 327**,** 575–600.

Kamilaris, A., Fonts, A. & Prenafeta-Boldύ, F. X. 2019. The rise of blockchain technology in agriculture and food supply chains. *Trends in Food Science & Technology,* 91**,** 640–652.

Kaplan, D. 2008. *Structural equation modeling: Foundations and extensions*, SAGE publications.

Kapoor, K. K., Dwivedi, Y. K. & Williams, M. D. 2014. Rogers' innovation adoption attributes: A systematic review and synthesis of existing research. *Information Systems Management,* 31**,** 74–91.

Kasten, J. 2019. A Blockchain Application: The Dairy Supply Chain. *Journal of Supply Chain Management Systems,* 8**,** 45–54.

Kauppi, K. 2013. Extending the use of institutional theory in operations and supply chain management research: Review and research suggestions. *International Journal of Operations & Production Management,* 33**,** 1318–1345.

Kaur Kapoor, K., K Dwivedi, Y. & D Williams, M. 2014. Innovation adoption attributes: a review and synthesis of research findings. *European Journal of Innovation Management,* 17**,** 327–348.

Keeble, B. R. J. M. & war 1988. The Brundtland report:'Our common future'. 4**,** 17–25.

Keith, M. G., Tay, L. & Harms, P. D. 2017. Systems perspective of Amazon Mechanical Turk for organizational research: Review and recommendations. *Frontiers in psychology,* 8**,** 1359.

Kenny, M. G. 1981. Multiple personality and spirit possession. *Psychiatry,* 44**,** 337–358.

Kher, S. V., Frewer, L. J., De Jonge, J., Wentholt, M., Davies, O. H., Luijckx, N. B. L. & Cnossen, H. J. J. B. F. J. 2010. Experts' perspectives on the implementation of traceability in Europe.

Kim, H. M. & Laskowski, M. 2018. Toward an ontology-driven blockchain design for supply-chain provenance. *Intelligent Systems in Accounting, Finance and Management,* 25**,** 18–27.

Kim, S., Sturman, E. & Kim, E. S. 2015. Structural equation modeling: Principles, processes, and practices. *The Palgrave handbook of research design in business and management.* Springer.

Kim Sundtoft, H. & Kinra, A. 2019. How the blockchain enables and constrains supply chain performance. *International Journal of Physical Distribution & Logistics Management,* 49**,** 376–397.

Kittipanya-ngam, P. & Tan, K. H. 2020. A framework for food supply chain digitalization: lessons from Thailand. *Production Planning and Control,* 31**,** 158–172.

Kline, R. B. 2023. *Principles and practice of structural equation modeling*, Guilford publications.

Koopmans, T. C. J. B. J. f. t. P. o. S. 1959. Three essays on the state of economic science. 10.

Kostova, T., Beugelsdijk, S., Scott, W. R., Kunst, V. E., Chua, C. H. & van Essen, M. 2020. The construct of institutional distance through the lens of different institutional perspectives: Review, analysis, and recommendations. *Journal of International Business Studies,* 51**,** 467–497.

Kouhizadeh, M., Saberi, S. & Sarkis, J. 2021. Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers. *International journal of production economics,* 231**,** 107831.

Kouhizadeh, M. & Sarkis, J. 2018. Blockchain practices, potentials, and perspectives in greening supply chains. *Sustainability (Switzerland),* 10.

Kouhizadeh, M., Sarkis, J. & Zhu, Q. 2019. At the Nexus of Blockchain technology, the circular economy, and product deletion. *Applied Sciences,* 9**,** 1712.

Krause, D., Luzzini, D. & Lawson, B. 2018. Building the case for a single key informant in supply chain management survey research. *Journal of Supply Chain Management,* 54**,** 42–50.

Kretschmer, T., Miravete, E. J. & Pernías, J. C. 2012. Competitive pressure and the adoption of complementary innovations. *American Economic Review,* 102**,** 1540–1570.

Krysiak, F. C. J. J. o. B. E. 2009. Risk management as a tool for sustainability. 85**,** 483–492.

Kshetri, N. 2017. Blockchain's roles in strengthening cybersecurity and protecting privacy. *Telecommunications Policy,* 41**,** 1027–1038.

Kshetri, N. 2018. 1 Blockchain's roles in meeting key supply chain management objectives. *International Journal of Information Management,* 39**,** 80–89.

Kuhn, T. S. 1962. *The structure of scientific revolutions*, University of Chicago press.

Kummer, S., Herold, D. M., Dobrovnik, M., Mikl, J. & Schäfer, N. 2020. A systematic review of blockchain literature in logistics and supply chain management: identifying research questions and future directions. *Future Internet,* 12**,** 60.

Kyläheiko, K. & Sandström, J. J. J. o. M. T. M. 2007. Strategic options-based framework for management of dynamic capabilities in manufacturing firms. *Journal of Manufacturing Technology Management*.

Lambert, D. M. & Cooper, M. C. 2000. Issues in supply chain management. *Industrial marketing management,* 29**,** 65–83.

Lambert, D. M., Cooper, M. C. & Pagh, J. D. 1998. Supply chain management: implementation issues and research opportunities. *The international journal of logistics management,* 9**,** 1–20.

Leavy, P. 2017. Quantitative, Qualitative, Mixed Methods, Arts-Based and Community-Based Participatory Research Approaches United States of America. New York: The Guilford Press.

Letourneau, K. B. & Whelan, S. T. 2017. Blockchain: Staying ahead of tomorrow. *The Journal of Equipment Lease Financing (Online),* 35**,** 1–6.

Levin, K. A. 2006. Study design III: Cross-sectional studies. *Evidence-based dentistry,* 7**,** 24–25.

Leys, C., Delacre, M., Mora, Y. L., Lakens, D. & Ley, C. 2019. How to classify, detect, and manage univariate and multivariate outliers, with emphasis on pre-registration. *International Review of Social Psychology,* 32.

Li, M., Shao, S., Ye, Q., Xu, G. & Huang, G. Q. 2020. Blockchain-enabled logistics finance execution platform for capital-constrained E-commerce retail. *Robotics and Computer-Integrated Manufacturing,* 65**,** 101962.

Li, Y.-H., Huang, J.-W. J. J. o. P. & Management, S. 2017. The moderating role of relational bonding in green supply chain practices and performance. *Journal of Purchasing Supply Management,* 23**,** 290–299.

Liao, D. Y. & Wang, X. 2018. Applications of blockchain technology to logistics management in integrated casinos and entertainment. *Informatics,* 5.

Lin, H.-F. 2014. Understanding the determinants of electronic supply chain management system adoption: Using the technology–organization–environment framework. *Technological Forecasting and Social Change,* 86**,** 80–92.

Lin, Q., Wang, H., Pei, X. & Wang, J. 2019. Food Safety Traceability System Based on Blockchain and EPCIS. *IEEE Access,* 7**,** 20698–20707.

Litke, A., Anagnostopoulos, D. & Varvarigou, T. 2019. Blockchains for supply chain management: Architectural elements and challenges towards a global scale deployment. *Logistics,* 3**,** 5.

Liu, Z. & Li, Z. 2020. A blockchain-based framework of cross-border e-commerce supply chain. *International Journal of Information Management,* 52**,** 102059.

Longo, F., Nicoletti, L., Padovano, A., d'Atri, G. & Forte, M. 2019. Blockchain-enabled supply chain: An experimental study. *Computers & Industrial Engineering,* 136**,** 57–69.

Low, C., Chen, Y. & Wu, M. 2011. Understanding the determinants of cloud computing adoption. *Industrial management & data systems,* 111**,** 1006–1023.

Lowry, P. B. & Gaskin, J. 2014. Partial least squares (PLS) structural equation modeling (SEM) for building and testing behavioral causal theory: When to choose it and how to use it. *IEEE transactions on professional communication,* 57**,** 123–146.

Lucas, R. E., Diener, E. & Suh, E. 1996. Discriminant validity of well-being measures. *Journal of personality and social psychology,* 71**,** 616.

Mackey, T. K., Kuo, T. T., Gummadi, B., Clauson, K. A., Church, G., Grishin, D., Obbad, K., Barkovich, R. & Palombini, M. 2019. 'Fit-for-purpose?' - Challenges and opportunities for applications of blockchain technology in the future of healthcare. *BMC Medicine,* 17.

Mahyuni, L. P., Adrian, R., Darma, G. S., Krisnawijaya, N. N. K., Dewi, I. G. A. A. P. & Permana, G. P. L. 2020. Mapping the potentials of blockchain in improving supply chain performance. *Cogent Business and Management,* 7.

Makadok, R. J. S. m. j. 2001. Toward a synthesis of the resource-based and dynamic-capability views of rent creation. *Strategic management journal,* 22**,** 387–401.

Makhdoom, I., Abolhasan, M., Abbas, H. & Ni, W. 2019. Blockchain's adoption in IoT: The challenges, and a way forward. *Journal of Network and Computer Applications,* 125**,** 251–279.

Malhotra, M. K. & Grover, V. 1998. An assessment of survey research in POM: from constructs to theory. *Journal of operations management,* 16**,** 407–425.

Malhotra, N. K., Kim, S. S. & Patil, A. 2006. Common method variance in IS research: A comparison of alternative approaches and a reanalysis of past research. *Management science,* 52**,** 1865–1883.

Manski, S. 2017. Building the blockchain world: Technological commonwealth or just more of the same? *Strategic Change,* 26**,** 511–522.

Manupati, V. K., Schoenherr, T., Ramkumar, M., Wagner, S. M., Pabba, S. K. & Inder Raj Singh, R. 2020. A blockchain-based approach for a multi-echelon sustainable supply chain. *International Journal of Production Research,* 58**,** 2222–2241.

Maroufkhani, P., Desouza, K. C., Perrons, R. K. & Iranmanesh, M. 2022. Digital transformation in the resource and energy sectors: A systematic review. *Resources Policy,* 76**,** 102622.

Martinez, V., Zhao, M., Blujdea, C., Han, X., Neely, A. & Albores, P. 2019. Blockchain-driven customer order management. *International Journal of Operations & Production Management,* 39**,** 993–1022.

Mason, C. H. & Perreault Jr, W. D. 1991. Collinearity, power, and interpretation of multiple regression analysis. *Journal of marketing research,* 28**,** 268–280.

Mason, R. B. 2007. The external environment's effect on management and strategy: a complexity theory approach. *Management decision,* 45**,** 10–28.

Matyskevic, J. & Kremer-Matyskevic, I. 2020. THE ECONOMIC ADVANTAGES OF BLOCKCHAIN TECHNOLOGY IN E-PROCUREMENT. *Regional Formation and Development Studies,* 31**,** 17–27.

Meixell, M. J. & Luoma, P. 2015. Stakeholder pressure in sustainable supply chain management: A systematic review. *International journal of physical distribution & logistics management,* 45**,** 69–89.

Mentzer, J. T., DeWitt, W., Keebler, J. S., Min, S., Nix, N. W., Smith, C. D. & Zacharia, Z. G. 2001. Defining supply chain management. *Journal of Business logistics,* 22**,** 1–25.

Min, H. 2019. Blockchain technology for enhancing supply chain resilience. *Business Horizons,* 62**,** 35–45.

Mishra, N. K., Raj, A., Mukherjee, I. & Chakraborty, A. 2025. Blockchain adoption in the supply chain management based on technology–organization–environment framework: evidence from developing and developed economies. *Journal of Business & Industrial Marketing,* 40**,** 815–832.

Mohammed, I., Nangpiire, C., Detoh, W. M. & Fataw, Y. 2024. The effect of blockchain technology in enhancing ethical sourcing and supply chain transparency: evidence from the cocoa and agricultural sectors in Ghana. *African Journal of Empirical Research,* 5**,** 55–64.

Mohapatra, S., Sainath, B., KC, A., Lal, H., K, N. R., Bhandari, G., Nyika, J. & R, S. 2025. Application of blockchain technology in the agri-food system: a systematic bibliometric visualization analysis and policy imperatives. *Journal of Agribusiness in Developing and Emerging Economies,* 15**,** 288–310.

Mohtaramzadeh, M., Ramayah, T. & Jun-Hwa, C. 2018. B2B e-commerce adoption in Iranian manufacturing companies: Analyzing the moderating role of organizational culture. *International Journal of Human–Computer Interaction,* 34**,** 621–639.

Moktadir, M. A., Rahman, T., Rahman, M. H., Ali, S. M. & Paul, S. K. J. J. o. C. P. 2018. Drivers to sustainable manufacturing practices and circular economy: A perspective of leather industries in Bangladesh. *Journal of Cleaner Production,* 174**,** 1366–1380.

Montecchi, M., Plangger, K. & Etter, M. 2019. It's real, trust me! Establishing supply chain provenance using blockchain. *Business Horizons,* 62**,** 283–293.

Morali, O. & Searcy, C. J. J. o. b. e. 2013. A review of sustainable supply chain management practices in Canada. *Journal of business ethics,* 117**,** 635–658.

Morse, J. M. 1991. Approaches to qualitative-quantitative methodological triangulation. *Nursing research,* 40**,** 120–123.

Murtagh, F. & Heck, A. 2012. *Multivariate data analysis*, Springer Science & Business Media.

Nakamoto, S. 2008. Bitcoin: A peer-to-peer electronic cash system. *Decentralized Business Review***,** 21260.

Nayak, G. & Dhaigude, A. S. 2019. A conceptual model of sustainable supply chain management in small and medium enterprises using blockchain technology. *Cogent Economics & Finance,* 7.

Newman, D. A. 2014. Missing data: Five practical guidelines. *Organizational research methods,* 17**,** 372–411.

Nikolakis, W., John, L. & Krishnan, H. 2018. How blockchain can shape sustainable global value chains: An Evidence, Verifiability, and Enforceability (EVE) Framework. *Sustainability (Switzerland),* 10.

Nikolakis, W. J., L.: Krishnan, H. 2018. How blockchain can shape sustainable global value chains: An Evidence, Verifiability, and Enforceability (EVE) Framework. *Sustainability (Switzerland),* 10.

Norton, T., Beier, J., Shields, L., Househam, A., Bombis, E. & Liew, D. J. U. N. G. C. O. N. Y., NY, USA 2014. A guide to traceability: A practical approach to advance sustainability in global supply chains.

Nowiński, W. & Kozma, M. 2017. How Can Blockchain Technology Disrupt the Existing Business Models? *Entrepreneurial Business and Economics Review,* 5**,** 173–188.

Nudurupati, S. S., Garengo, P. & Bititci, U. S. 2021. Impact of the changing business environment on performance measurement and management practices. *International Journal of Production Economics,* 232**,** 107942.

Oliveira, T. & Martins, M. F. 2010. Understanding e-business adoption across industries in European countries. *Industrial management & data systems,* 110**,** 1337–1354.

Oliveira, T., Thomas, M. & Espadanal, M. 2014. Assessing the determinants of cloud computing adoption: An analysis of the manufacturing and services sectors. *Information & management,* 51**,** 497–510.

Ooi, K.-B., Lee, V.-H., Tan, G. W.-H., Hew, T.-S. & Hew, J.-J. 2018. Cloud computing in manufacturing: The next industrial revolution in Malaysia? *Expert Systems with Applications,* 93**,** 376–394.

Pakseresht, A., Kaliji, S. A. & Hakelius, K. 2024. Blockchain technology characteristics essential for the agri-food sector: A systematic review. *Food Control,* 165**,** 110661.

Pan, X., Oh, K.-S. & Wang, M. 2021. Strategic orientation, digital capabilities, and new product development in emerging market firms: The moderating role of corporate social responsibility. *Sustainability,* 13**,** 12703.

Pan, X., Pan, X., Song, M., Ai, B. & Ming, Y. 2020. Blockchain technology and enterprise operational capabilities: An empirical test. *International Journal of Information Management,* 52**,** 101946.

Pandey, V., Pant, M. & Snasel, V. 2022. Blockchain technology in food supply chains: Review and bibliometric analysis. *Technology in Society,* 69**,** 101954.

Park, S. & Gupta, S. 2012. Handling endogenous regressors by joint estimation using copulas. *Marketing Science,* 31**,** 567–586.

Pearson, S., May, D., Leontidis, G., Swainson, M., Brewer, S., Bidaut, L., Frey, J. G., Parr, G., Maull, R. & Zisman, A. 2019. Are Distributed Ledger Technologies the panacea for food traceability? *Global Food Security,* 20**,** 145–149.

Peer, E., Brandimarte, L., Samat, S. & Acquisti, A. 2017. Beyond the Turk: Alternative platforms for crowdsourcing behavioral research. *Journal of experimental social psychology,* 70**,** 153–163.

Perboli, G., Musso, S. & Rosano, M. 2018. Blockchain in Logistics and Supply Chain: A Lean Approach for Designing Real-World Use Cases. *IEEE Access,* 6**,** 62018–62028.

Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y. & Podsakoff, N. P. 2003. Common method biases in behavioral research: a critical review of the literature and recommended remedies. *Journal of applied psychology,* 88**,** 879.

Podsakoff, P. M. & Organ, D. W. 1986. Self-reports in organizational research: Problems and prospects. *Journal of management,* 12**,** 531–544.

Pournader, M., Shi, Y., Seuring, S. & Koh, S. L. 2019. Blockchain applications in supply chains, transport and logistics: a systematic review of the literature. *International Journal of Production Research***,** 1–19.

Pournader, M., Shi, Y., Seuring, S. & Koh, S. L. J. I. J. o. P. R. 2020. Blockchain applications in supply chains, transport and logistics: a systematic review of the literature. *International Journal of Production Research,* 58**,** 2063–2081.

Prashar, D., Jha, N., Jha, S., Lee, Y. & Joshi, G. P. 2020. Blockchain-Based Traceability and Visibility for Agricultural Products: A Decentralized Way of Ensuring Food Safety in India. *Sustainability,* 12**,** 3497.

Queiroz, M. M., Telles, R. & Bonilla, S. H. 2019a. Blockchain and supply chain management integration: A systematic review of the literature. *Supply Chain Management: An International Journal,* 25 (2)**,** 241–254.

Queiroz, M. M., Telles, R. & Bonilla, S. H. 2019b. Blockchain and supply chain management integration: A systematic review of the literature. *Supply Chain Management: An International Journal*.

Queiroz, M. M. & Wamba, S. F. 2019. Blockchain adoption challenges in supply chain: An empirical investigation of the main drivers in India and the USA. *International Journal of Information Management,* 46**,** 70–82.

Ragu-Nathan, B. S., Apigian, C. H., Ragu-Nathan, T. & Tu, Q. 2004. A path analytic study of the effect of top management support for information systems performance. *Omega,* 32**,** 459–471.

Rahman, T., Ali, S. M., Moktadir, M. A., Kusi-Sarpong, S. J. P. P. & Control 2020. Evaluating barriers to implementing green supply chain management: an example from an emerging economy. *Production Planning*

Control, 31, 673–698.

Rahmanzadeh, S., Pishvaee, M. S. & Rasouli, M. R. 2020. Integrated innovative product design and supply chain tactical planning within a blockchain platform. *International Journal of Production Research,* 58, 2242–2262.

Rainero, C. & Modarelli, G. J. B. F. J. 2021. Food tracking and blockchain-induced knowledge: a corporate social responsibility tool for sustainable decision-making. *British Food Journal*.

Ramachandran, V. & Rehermann, T. 2017. Can Blockchain Technology Address De-Risking in Emerging Markets?

Rejeb, A., Keogh, J. G. & Treiblmaier, H. 2019. Leveraging the Internet of Things and blockchain technology in Supply Chain Management. *Future Internet,* 11.

Rejeb, A., Keogh, J. G., Zailani, S., Treiblmaier, H. & Rejeb, K. 2020. Blockchain technology in the food industry: A review of potentials, challenges and future research directions. *Logistics,* 4, 27.

Remko van, H. 2019. Exploring blockchain implementation in the supply chain. *International Journal of Operations & Production Management,* 39, 829–859.

Resende-Filho, M. A. & Hurley, T. M. 2012. Information asymmetry and traceability incentives for food safety. *International Journal of Production Economics,* 139, 596–603.

Richter, N. F., Sinkovics, R. R., Ringle, C. M. & Schlägel, C. 2016. A critical look at the use of SEM in international business research. *International marketing review,* 33, 376–404.

Rindfleisch, A., Malter, A. J., Ganesan, S. & Moorman, C. 2008. Cross-sectional versus longitudinal survey research: Concepts, findings, and guidelines. *Journal of marketing research,* 45, 261–279.

Ringle, C. M., Sarstedt, M. & Straub, D. W. 2012. Editor's comments: a critical look at the use of PLS-SEM in" MIS Quarterly". *MIS quarterly*, iii–xiv.

Roberts, L. D. & Allen, P. J. 2015. Exploring ethical issues associated with using online surveys in educational research. *Educational Research and Evaluation,* 21, 95–108.

Roeck, D., Sternberg, H. & Hofmann, E. 2020. Distributed ledger technology in supply chains: A transaction cost perspective. *International Journal of Production Research,* 58, 2124–2141.

Rogers, E. M., Singhal, A. & Quinlan, M. M. 2014. *Diffusion of innovations*, Routledge.

Roy, S., Ghosh, S., Beck, C. D. & Sinha, A. P. 2023. Supply chain traceability: a case of blockchain modelling application to agro-business product in India. *International Journal of Sustainable Agricultural Management and Informatics,* 9, 295–319.

Saberi, S., Kouhizadeh, M. & Sarkis, J. 2019a. Blockchains and the supply chain: Findings from a broad study of practitioners. *IEEE Engineering Management Review,* 47, 95–103.

Saberi, S., Kouhizadeh, M., Sarkis, J. & Shen, L. 2019b. Blockchain technology and its relationships to sustainable supply chain management. *International Journal of Production Research,* 57, 2117–2135.

Safiullin, M. R., Elshin, L. A. & Abdukaeva, A. A. 2020. An empirical assessment of the impact of blockchain technologies on the effectiveness of the supply chain development. *International Journal of Supply Chain Management,* 9**,** 887–892.

Salah, K., Nizamuddin, N., Jayaraman, R. & Omar, M. 2019. Blockchain-Based Soybean Traceability in Agricultural Supply Chain. *IEEE Access,* 7**,** 73295–73305.

Salman, T., Zolanvari, M., Erbad, A., Jain, R. & Samaka, M. 2019. Security services using blockchains: A state of the art survey. *IEEE Communications Surveys and Tutorials,* 21**,** 858–880.

Saltini, R. & Akkerman, R. 2012. Testing improvements in the chocolate traceability system: Impact on product recalls and production efficiency. *Food Control,* 23**,** 221–226.

Sander, F., Semeijn, J. & Mahr, D. 2018. The acceptance of blockchain technology in meat traceability and transparency. *British Food Journal,* 120**,** 2066–2079.

Santonino III, M. D., Koursaris, C. M. & Williams, M. J. 2018. Modernizing the supply chain of airbus by integrating RFID and blockchain processes. *International Journal of Aviation, Aeronautics, and Aerospace,* 5**,** 4.

Sarstedt, M., Hair Jr, J. F., Cheah, J.-H., Becker, J.-M. & Ringle, C. M. 2019. How to specify, estimate, and validate higher-order constructs in PLS-SEM. *Australasian marketing journal,* 27**,** 197–211.

Sarstedt, M., Ringle, C. M., Cheah, J.-H., Ting, H., Moisescu, O. I. & Radomir, L. 2020. Structural model robustness checks in PLS-SEM. *Tourism Economics,* 26**,** 531–554.

Sarstedt, M., Ringle, C. M. & Hair, J. F. 2017. Treating unobserved heterogeneity in PLS-SEM: A multi-method approach. *Partial least squares path modeling: Basic concepts, methodological issues and applications***,** 197–217.

Sarstedt, M., Ringle, C. M. & Hair, J. F. 2021. Partial least squares structural equation modeling. *Handbook of market research.* Springer.

Sauer, P. C. & Seuring, S. 2019. Extending the reach of multi-tier sustainable supply chain management–insights from mineral supply chains. *International Journal of Production Economics,* 217**,** 31–43.

Saunders, M., Lewis, P. & Thornhill, A. 2007. Research methods. *Business Students 4th edition Pearson Education Limited, England,* 6**,** 1–268.

Saunders, M., Lewis, P. & Thornhill, A. 2009. *Research methods for business students*, Pearson education.

Schmidt, C. G. & Wagner, S. M. 2019. Blockchain and supply chain relations: A transaction cost theory perspective. *Journal of Purchasing and Supply Management,* 25**,** 100552.

Schuetz, S. & Venkatesh, V. 2020. Blockchain, adoption, and financial inclusion in India: Research opportunities. *International journal of information management,* 52**,** 101936.

Scott, B., Loonam, J. & Kumar, V. 2017. Exploring the rise of blockchain technology: Towards distributed collaborative organizations. *Strategic Change,* 26**,** 423–428.

Sekaran, U. 2016. Research methods for business: A skill building approach. John Wiley & Sons.

Setia, M. S. 2016. Methodology series module 3: Cross-sectional studies. *Indian journal of dermatology,* 61**,** 261–264.

Seuring, S. & Gold, S. 2012. Conducting content-analysis based literature reviews in supply chain management. *Supply Chain Management: An International Journal,* 17**,** 544–555.

Sharma, R., Kamble, S. S., Gunasekaran, A., Kumar, V. & Kumar, A. 2020. A systematic literature review on machine learning applications for sustainable agriculture supply chain performance. *Computers & Operations Research,* 119**,** 104926.

Shen, C. & Pena-Mora, F. 2018. Blockchain for Cities - A Systematic Literature Review. *IEEE Access,* 6**,** 76787–76819.

Shi, P. & Yan, B. 2016. Factors affecting RFID adoption in the agricultural product distribution industry: empirical evidence from China. *SpringerPlus,* 5**,** 1–11.

Shmueli, G. & Koppius, O. R. 2011. Predictive analytics in information systems research. *MIS quarterly***,** 553–572.

Shmueli, G., Ray, S., Estrada, J. M. V. & Chatla, S. B. 2016. The elephant in the room: Predictive performance of PLS models. *Journal of business Research,* 69**,** 4552–4564.

Shmueli, G., Sarstedt, M., Hair, J. F., Cheah, J.-H., Ting, H., Vaithilingam, S. & Ringle, C. M. 2019. Predictive model assessment in PLS-SEM: guidelines for using PLSpredict. *European journal of marketing,* 53**,** 2322–2347.

Sim, S. & Wiwanitkit, V. 2021. Food contamination, food safety and COVID-19 outbreak. *Journal of Health Research,* 35**,** 463–466.

Simon, H. A. 1957. Models of man; social and rational.

Smith, G., Tatum, J., Belk, K., Scanga, J., Grandin, T. & Sofos, J. 2005. Traceability from a US perspective. *Meat science,* 71**,** 174–193.

Spanuth, A. & Urbano, D. 2024. Exploring social enterprise legitimacy within ecosystems from an institutional approach: A systematic literature review and research agenda. *International Journal of Management Reviews,* 26**,** 211–231.

Srivastava, A. & Dashora, K. 2022. Application of blockchain technology for agrifood supply chain management: A systematic literature review on benefits and challenges. *Benchmarking: An International Journal,* 29**,** 3426–3442.

Stone, G. C. & Peeke, S. C. 1974. Relative frequency of attribute relevance and response times in visual search. *Memory & Cognition,* 2**,** 453–462.

Strang, K. 2015a. *The Palgrave handbook of research design in business and management*, Springer.

Strang, K. D. 2015b. Articulating a research design ideology. *The Palgrave handbook of research design in business and management***,** 17–30.

Streukens, S. & Leroi-Werelds, S. 2016. Bootstrapping and PLS-SEM: A step-by-step guide to get more out of your bootstrap results. *European management journal,* 34**,** 618–632.

Suchman, M. C. 1995. Managing legitimacy: Strategic and institutional approaches. *Academy of management review,* 20**,** 571–610.

Tabesh, A. R., Chowdhury, M. M. H., Quaddus, M. A., Sianaki, O. A. & Khan, E. 2024. The influence of agility on green purchasing practices: the role of supplier governance and supplier relationships. *Journal of Business & Industrial Marketing,* 39**,** 1969–1983.

Tachizawa, E. M. & Wong, C. Y. J. J. o. S. C. M. 2015. The performance of green supply chain management governance mechanisms: A supply network and complexity perspective. *Journal of Supply Chain Management Systems,* 51, 18–32.

Tan, A., Gligor, D. & Ngah, A. 2020. Applying Blockchain for Halal food traceability. *International Journal of Logistics Research and Applications*.

Tao, Q. G., C.: Wang, Z.: Rocchio, J.: Hu, W.: Yu, X. 2018. Big data driven agricultural products supply chain management: A trustworthy scheduling optimization approach. *IEEE Access,* 6, 49990–50002.

Tapscott, D. & Tapscott, A. 2017. How blockchain will change organizations. *MIT Sloan Management Review,* 58, 10.

Tashakkori, A. & Teddlie, C. 1998. *Mixed methodology: Combining qualitative and quantitative approaches*, sage.

Tashakkori, A. & Teddlie, C. 2021. *Sage handbook of mixed methods in social & behavioral research*, SAGE publications.

Teece, D. J., Pisano, G. & Shuen, A. J. S. m. j. 1997. Dynamic capabilities and strategic management. *Strategic management journal,* 18, 509–533.

Teece, D. J. J. L. r. p. 2018. Business models and dynamic capabilities. *Long range planning,* 51, 40–49.

Teece, D. J. J. S. m. j. 2007. Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. *Strategic management journal,* 28, 1319–1350.

Terrizzi, G., Marino, A., Cinici, M. C. & Baglieri, D. 2024. Blockchain applications in the agri-food sector: current insights, challenges and research avenues. *British Food Journal,* 126, 504–520.

Tian, F. An agri-food supply chain traceability system for China based on RFID & blockchain technology. Service Systems and Service Management (ICSSSM), 2016 13th International Conference on, 2016a. IEEE, 1–6.

Tian, F. An agri-food supply chain traceability system for China based on RFID & blockchain technology. 2016 13th international conference on service systems and service management (ICSSSM), 2016b. IEEE, 1–6.

Tian, F. An agri-food supply chain traceability system for China based on RFID & blockchain technology. 2016 13th International Conference on Service Systems and Service Management, ICSSSM 2016, 2016c.

Tian, X. & Sarkis, J. 2020. Expanding green supply chain performance measurement through emergy accounting and analysis. *International Journal of Production Economics,* 225, 107576.

Tönnissen, S. & Teuteberg, F. 2020. Analysing the impact of blockchain-technology for operations and supply chain management: An explanatory model drawn from multiple case studies. *International Journal of Information Management,* 52, 101953.

Treiblmaier, H. 2018. The impact of the blockchain on the supply chain: a theory-based research framework and a call for action. *Supply Chain Management,* 23, 545–559.

Treiblmaier, H. 2019. Combining Blockchain Technology and the Physical Internet to Achieve Triple Bottom Line Sustainability: A Comprehensive Research Agenda for Modern Logistics and Supply Chain Management. *Logistics,* 3.

Ullman, J. B. & Bentler, P. M. 2012. Structural equation modeling. *Handbook of Psychology, Second Edition,* 2.

Urbach, N. & Ahlemann, F. 2010. Structural equation modeling in information systems research using partial least squares. *Journal of Information Technology Theory and Application (JITTA),* 11**,** 2.

Venkatesh, V., Morris, M. G., Davis, G. B. & Davis, F. D. J. M. q. 2003. User acceptance of information technology: Toward a unified view. 425–478.

Verhoeven, P., Sinn, F. & Herden, T. T. 2018. Examples from Blockchain Implementations in Logistics and Supply Chain Management: Exploring the Mindful Use of a New Technology. *Logistics,* 2.

Vern, P., Panghal, A., Mor, R. S., Kumar, V. & Jagtap, S. 2025. Blockchain-based traceability framework for agri-food supply chain: a proof-of-concept. *Operations Management Research,* 18**,** 554–573.

Visconti, A., Murray, B., Rossi, N., Wolf, J., Ourselin, S., Spector, T. D., Freeman, E. E., Bataille, V. & Falchi, M. 2022. Cutaneous manifestations of SARS-CoV-2 infection during the Delta and Omicron waves in 348 691 UK users of the UK ZOE COVID Study app. *British Journal of Dermatology,* 187**,** 900–908.

Wallace, M. & Sheldon, N. 2015. Business research ethics: Participant observer perspectives. *Journal of Business Ethics,* 128**,** 267–277.

Wamba, S. F. & Queiroz, M. M. 2020a. Blockchain in the operations and supply chain management: Benefits, challenges and future research opportunities. *International Journal of Information Management.*

Wamba, S. F. & Queiroz, M. M. 2020b. Industry 4.0 and the supply chain digitalisation: a blockchain diffusion perspective. *Production Planning and Control, DOI: 10.1080/09537287.2020.1810756.*

Wamba, S. F., Queiroz, M. M. & Trinchera, L. 2020a. Dynamics between blockchain adoption determinants and supply chain performance: An empirical investigation. *International Journal of Production Economics***,** 107791.

Wamba, S. F., Queiroz, M. M. & Trinchera, L. 2020b. Dynamics between blockchain adoption determinants and supply chain performance: An empirical investigation. *International Journal of Production Economics,* 229**,** 107791.

Wamba, S. F., Queiroz, M. M. J. P. P. & Control 2020c. Industry 4.0 and the supply chain digitalisation: a blockchain diffusion perspective. *Production Planning Control***,** 1–18.

Wang, Y., Chen, C. H. & Zghari-Sales, A. 2021. Designing a blockchain enabled supply chain. *International Journal of Production Research,* 59**,** 1450–1475.

Wang, Y., Han, J. H. & Beynon-Davies, P. 2019a. Understanding blockchain technology for future supply chains: a systematic literature review and research agenda. *Supply Chain Management: An International Journal.*

Wang, Y., Singgih, M., Wang, J. & Rit, M. 2019b. Making sense of blockchain technology: How will it transform supply chains? *International Journal of Production Economics,* 211**,** 221–236.

Warner, K. S. & Wäger, M. 2019. Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal. *Long range planning,* 52**,** 326–349.

Wen, S., Xiong, W., Tan, J., Chen, S. & Li, Q. 2021. Blockchain enhanced price incentive demand response for building user energy network in sustainable society. *Sustainable Cities and Society,* 68.

West, S. G., Taylor, A. B. & Wu, W. 2012. Model fit and model selection in structural equation modeling. *Handbook of structural equation modeling,* 1**,** 209–231.

Westerkamp, M., Victor, F. & Küpper, A. 2019. Tracing manufacturing processes using blockchain-based token compositions. *Digital Communications and Networks*.

Wilden, R., Gudergan, S., Akaka, M., Averdung, A. & Teichert, T. J. I. M. M. 2019. The role of cocreation and dynamic capabilities in service provision and performance: A configurational study. *Industrial Marketing Management,* 78**,** 43–57.

Williamson, O. E. 1993. Opportunism and its critics. *Managerial decision economics***,** 97–107.

Williamson, O. E. J. J. o. s. c. m. 2008. Outsourcing: Transaction cost economics and supply chain management. *Journal of Supply Chain Management Systems,* 44**,** 5–16.

Williamson, O. E. J. T. A. e. r. 1973. Markets and hierarchies: some elementary considerations. *The American economic review,* 63**,** 316–325.

Williamson, O. E. J. U. o. I. a. U.-C. s. A. f. E. L. H. R. R. i. E. 1975. Markets and hierarchies: analysis and antitrust implications: a study in the economics of internal organization.

Willis, J. W., Jost, M. & Nilakanta, R. 2007. *Foundations of qualitative research: Interpretive and critical approaches*, sage.

Wilson, B. & Henseler, J. Modeling reflective higher-order constructs using three approaches with PLS path modeling: a Monte Carlo comparison. Australia-New Zealand Marketing Academy Conference, ANZMAC 2007: Reputation, Responsibility, Relevance, 2007. ANZMAC, 791–800.

Wilson, T. & Clarke, W. J. S. C. M. A. I. J. 1998. Food safety and traceability in the agricultural supply chain: using the Internet to deliver traceability. *Supply Chain Management: An International Journal*.

Wong, L.-W., Leong, L.-Y., Hew, J.-J., Tan, G. W.-H. & Ooi, K.-B. 2020a. Time to seize the digital evolution: Adoption of blockchain in operations and supply chain management among Malaysian SMEs. *International Journal of Information Management,* 52**,** 101997.

Wong, L. W., Leong, L. Y., Hew, J. J., Tan, G. W. H. & Ooi, K. B. 2020b. Time to seize the digital evolution: Adoption of blockchain in operations and supply chain management among Malaysian SMEs. *International Journal of Information Management,* 52.

Wong, L. W., Tan, G. W. H., Lee, V. H., Ooi, K. B. & Sohal, A. 2020c. Unearthing the determinants of Blockchain adoption in supply chain management. *International Journal of Production Research,* 58**,** 2100–2123.

Workman Jr, J. P. 1993. Marketing's limited role in new product development in one computer systems firm. *Journal of Marketing Research,* 30**,** 405–421.

Wu, H., Li, Z., King, B., Miled, Z. B., Wassick, J. & Tazelaar, J. 2017a. A distributed ledger for supply chain physical distribution visibility. *Information (Switzerland),* 8 (4)**,** 137.

Wu, H., Li, Z., King, B., Miled, Z. B., Wassick, J. & Tazelaar, J. 2017b. A distributed ledger for supply chain physical distribution visibility. *Information (Switzerland),* 8.

Wu, H. L., Z.: King, B.: Miled, Z. B.: Wassick, J.: Tazelaar, J. 2017. A distributed ledger for supply chain physical distribution visibility. *Information (Switzerland),* 8.

Yadav, S. & Singh, S. P. 2020a. Blockchain critical success factors for sustainable supply chain. *Resources, Conservation and Recycling,* 152**,** 104505.

Yadav, S. & Singh, S. P. 2020b. An integrated fuzzy-ANP and fuzzy-ISM approach using blockchain for sustainable supply chain. *Journal of Enterprise Information Management,* 34**,** 54–78.

Yadav, V. S., Singh, A., Raut, R. D. & Govindarajan, U. H. 2020. Blockchain technology adoption barriers in the Indian agricultural supply chain: an integrated approach. *Resources, Conservation and Recycling,* 161**,** 104877.

Yawar, S. A. & Kauppi, K. 2018. Understanding the adoption of socially responsible supplier development practices using institutional theory: Dairy supply chains in India. *Journal of Purchasing and Supply Management,* 24**,** 164–176.

Yiannas, F. 2018. A new era of food transparency powered by blockchain. *Innovations: Technology, Governance, Globalization,* 12**,** 46–56.

Yigitbasioglu, O. M. J. I. J. o. P. D. & Management, L. 2010. Information sharing with key suppliers: a transaction cost theory perspective.

Yogarajan, L., Masukujjaman, M., Ali, M. H., Khalid, N., Osman, L. H. & Alam, S. S. 2023. Exploring the hype of blockchain adoption in agri-food supply chain: a systematic literature review. *Agriculture,* 13**,** 1173.

Yoo, M. & Won, Y. 2018. A study on the transparent price tracing system in supply chain management based on blockchain. *Sustainability (Switzerland),* 10.

Yu, J., Wang, J. & Moon, T. 2022. Influence of digital transformation capability on operational performance. *Sustainability,* 14**,** 7909.

Yuan, H., Qiu, H., Bi, Y., Sheng-Hung, C. & Lam, A. 2019. Analysis of coordination mechanism of supply chain management information system from the perspective of block chain. *Information Systems and eBusiness Management***,** 1.

Zhang, X., Sun, P., Xu, J., Wang, X., Yu, J., Zhao, Z. & Dong, Y. 2020. Blockchain-based safety management system for the grain supply chain. *IEEE Access,* 8**,** 36398–36410.

Zhao, G., Liu, S., Lopez, C., Lu, H., Elgueta, S., Chen, H. & Boshkoska, B. M. 2019. Blockchain technology in agri-food value chain management: A synthesis of applications, challenges and future research directions. *Computers in Industry,* 109**,** 83–99.

Zhu, Q. & Kouhizadeh, M. 2019. Blockchain technology, supply chain information, and strategic product deletion management. *IEEE Engineering Management Review,* 47**,** 36–44.

Agriculture, Fisheries and Forestry (2023). National Agricultural Traceability Strategy 2023 to 2033. Department of Agriculture, Fisheries and Forestry, Australian Government. DAFF+4DAFF+4DAFF+4

Agriculture, Fisheries and Forestry (2023). *Implementation Plan for the National Agricultural Traceability Strategy 2023 to 2028*. Draft. Google Cloud Storage

Meat & Livestock Australia. *V.ISC.2407 – Global Review of Livestock Traceability Systems* (final report). MLA. (Discussed on MLA's environment / traceability pages) meatprojects.com+2minister.agriculture.gov.au+2

New South Wales Department of Primary Industries (2023). *Livestock Traceability Policy 2023*. NSW DPI. NSW Department of Primary Industries+2NSW Department of Primary Industries+2

NSW DPI. *National Livestock Identification System (NLIS)* (NSW). NSW Department of Primary Industries+2NSW Department of Primary Industries+2

NSW DPI. *NLIS compliance monitoring procedure / NLIS cattle procedure*. NSW Department of Primary Industries+3NSW Department of Primary Industries+3NSW Department of Primary Industries+3

Appendix 1: Ethics approval of the research

ResearchMaster

Ethics Application

Application ID :	ETH22-7579
Application Title :	Blockchain for Supply Chain Traceability and Sustainability: The case of the Australian Agri-Products
Date of Submission :	
Primary Investigator :	Dr Md Maruf Hossan Chowdhury (Chief Investigator)
Other Personnel :	Mrs Anwara Akter Happy (5Research Student)
	Dr Moira Scerri (Co-Supervisor)

Appendix 2: Ethics approval letter

Outlook

Your ethics application has been approved as low risk - ETH22-7579

From research.ethics@uts.edu.au <research.ethics@uts.edu.au>
Date Tue 12/12/2023 9:04 AM
To Md Maruf Hossan Chowdhury <Maruf.Chowdhury@uts.edu.au>; Anwara Happy <Anwara.A.Happy@student.uts.edu.au>
Cc Research Ethics <Research.Ethics@uts.edu.au>

1 attachments (378 KB)
Ethics Application.pdf;

Dear Applicant,

Re: ETH22-7579 - "Blockchain for Supply Chain Traceability and Sustainability: The case of the Australian Agri-Products"

Your local research office has reviewed your application and agreed that it now meets the requirements of the National Statement on Ethical Conduct in Human Research (2007) and has been approved on that basis. You are therefore authorised to commence activities as outlined in your application, subject to any conditions detailed in this document.

You are reminded that this letter constitutes ethics approval only. This research project must also be undertaken in accordance with all UTS policies and guidelines including the Research Management Policy.

Your approval number is UTS HREC REF NO. ETH22-7579

Approval will be for a period of five (5) years from the date of this correspondence subject to the submission of annual progress reports.

The following standard conditions apply to your approval:

- Your approval number must be included in all participant material and advertisements. Any advertisements on Staff Connect without an approval number will be removed.
- The Principal Investigator will immediately report anything that might warrant review of ethical approval of the project to the Ethics Secretariat.
- The Principal Investigator will notify the Committee of any event that requires a modification to the protocol or other project documents, and submit any required amendments prior to implementation. Instructions on how to submit an amendment application can be found here.
- The Principal Investigator will promptly report adverse events to the Ethics Secretariat. An adverse event is any event (anticipated or otherwise) that has a negative impact on participants, researchers or the reputation of the University. Adverse events can also include privacy breaches, loss of data and damage to property.
- The Principal Investigator will report to the UTS HREC or UTS MREC annually and notify the Committee when the project is completed at all sites. The Principal Investigator will

Appendix 3: The variables adopted in the model

The variables adopted in the conceptual model of the study

Variable	Title of the study	References
INDEPENDENT VARIABLE • **Market Dynamics (MDY)** • **Competitive Pressure (CPR)** • **Regulatory Support (RGS)**	Time to seize the digital evolution: Adoption of blockchain in operations and supply chain management among Malaysian SME	Wong et al. (2020)
DEPENDENT VARIABLES • Blockchain Adoption (BCAD)	Dynamics between blockchain adoption determinants and supply chain performance: An empirical investigation	Wamba et al. (2020)
MODERATOR • **Technology Orientation (TOR)**	Influence of Digital Transformation Capability on Operational Performance.	Yu et al. (2022).
MODERATOR • **Upper Management Support (UMS)**	Time to seize the digital evolution: Adoption of blockchain in operations and supply chain management among Malaysian SME	Wong et al. (2020)
MODERATOR • **Sustainability Governance (SGV)**	Supply chain sustainability practices and governance for mitigating sustainability risk and improving market performance: A dynamic capability perspective.	Chowdhury and Quaddus (2021)
MEDIATOR • **Traceability (TRA)**	Investigating green supply chain management practices and performance: The moderating roles of supply chain ecocentricity and traceability.	Cousins et al. (2019).
DEPENDENT VARIABLES • **Social (SOC)** • **Environmental (ENV)** • **Economic (ECO)**	Supply chain sustainability practices and governance for mitigating sustainability risk and improving market performance: A dynamic capability perspective.	Chowdhury and Quaddus (2021)

Appendix 4: Survey questionnaire

Questionnaire

Dear Survey Respondent

Thank you for agreeing to complete this questionnaire. Your participation in this research is voluntary. The confidentiality and anonymity of the respondents will be respected and protected. I will ensure that none of the respondents cooperating in the research will be identified or be capable of being identified in the writing up of the research for academic publication. Any data presented will be aggregated, as I am interested in general trends, not in a particular individual or organisation.

The questionnaire attempts to discover the **predominant factors influencing blockchain adoption for traceability and sustainability in Australia's Agri-products supply chain**. Your assistance in completing this questionnaire would be valuable not only to me but would also make an important contribution to the knowledge base on achieving traceability for sustainability in the Agri-products supply chain of Australia. I will value your honest response to the questionnaire, and your kind participation is greatly appreciated.

This study has been approved by the University of Technology Sydney Human Research Ethics Committee [UTS HREC]. If you have any concerns or need to verify the support of this research, please get in touch with the Ethics Secretariat at +61 2 9514 2478 or email: Research.Ethics@uts.edu.au and quote the UTS HREC reference number ETH22-7579. If you would like further information about the study, please contact me. My contact details are provided below. Alternatively, you can contact my principal supervisor, Senior Lecturer Dr Md. Maruf Hossan Chowdhury, email: Maruf.Chowdhury@uts.edu.au, phone number:

Consent to participate.

Your involvement in the research is entirely voluntary. You have the right to withdraw at any stage without affecting your rights or my responsibilities.

This survey is divided into eight sections. Please ensure you have completed all the items listed in these sections.

Thank you very much for taking the time and effort to complete this survey.

Yours sincerely,

Ms Anwara Happy

Ph.D. Candidate, UTS Business School,

University of Technology Sydney, Australia
Mobile: +61- 0430 705 517
E-mail: anwara.a.happy@student.uts.edu.au

Blockchain Adoption for Agri-Products Supply Chain Traceability and Sustainability

Section 1: Some information about you and your organisation

Some necessary information about you and your organisation will be collected in this questionnaire section. The background information will be used for statistical purposes only.

Please tick ✓ the most appropriate answer:

Name-------------Text Field------------

Your current position--------------------------

Type of operation (Agri-products)

☐ Producer ☐ Processor ☐ Transporter ☐ Wholesaler ☐ Retailer

☐ Number of employees working in your organisation

☐ 0-4 employees ☐ 5 – 19 employees

☐ 20 – 199 employees ☐ More than 199 employees

☐ Number of years since the company was established

☐ Less than 5 years. ☐ +15 to 20 years. ☐ +5 to 10 years. ☐ +20 to 25 years

☐ +10 to 15 years. ☐ Other (please specify) ________________

Section 2-A: Questionnaire about business environmental factors (Market Dynamics)

Market Dynamics refer to the rapidly changing business environment, which is competitive and complex. Such an environment may influence organisations to adopt blockchain technology to sustain competitive advantage (bargaining power of suppliers; bargaining power of buyers; potential new entrants; industry competition; substitutes) over their competitors. With respect to the environmental factor, ***Market Dynamics***, please read each statement carefully, then indicate the extent **to which you disagree or agree** by checking the appropriate number on a scale of 1 (Strongly Disagree) to 7 (Strongly Agree).	**Strongly Disagree**	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
	1	2	3	4	5	6	7
Customer preferences or requirements are always changing in our firm							
Our firm is sensitive to changes in the marketplace							
In our firm, change is difficult to predict							

Section 2-B: Questionnaire about business environmental factors (Competitive Pressure)

Competitive Pressure is a situation in which a company typically faces pressure due to its competitors. With respect to the environmental factor, ***Competitive Pressure***, please read each statement carefully, then indicate the extent **to which you disagree or agree** by checking the appropriate number on a scale of 1 (Strongly Disagree) to 7 (Strongly Agree).	**Strongly Disagree**	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
	1	2	3	4	5	6	7
Our firm believes that we may lose customers if we do not adopt blockchain							
Our firm believes that other firms in our industry have recently begun to explore blockchain in their operations							
Social features such as customs and cultures force our firm to look into blockchain adoption in supply chain operations							
Competitive pressures force our firm to look into blockchain adoption in supply chain operations							

Section 2-C: Questionnaire about business environmental factors (Regulatory Support)

Regulatory Support, such as regulatory bodies/ government initiatives, to frame the policies and laws that directly or indirectly impact blockchain adoption for organisations in the changing business environment. With respect to the environmental factor, ***Regulatory Support,*** please read each statement carefully, then indicate the extent **to which you disagree or agree** by checking the appropriate number on a scale of 1 (Strongly Disagree) to 7 (Strongly Agree).	**Strongly Disagree** 1	**Disagree** 2	**Somewhat Disagree** 3	**Neutral** 4	**Somewhat Agree** 5	**Agree** 6	**Strongly Agree** 7
Our government introduce relevant policies to boost blockchain-based organisational development.							
Our firm receives financial support from the government or relevant authorities to adopt blockchain							
The laws and regulations that exist nowadays are sufficient to protect the use of blockchain in our firm							
There is legal support for the use of blockchain in our firm							

Section 3: Questionnaire about blockchain adoption

Blockchain is a distributed ledger technology. It enables connecting a chain of computer terminal participants ("nodes") through a key access system for sharing information in a decentralised manner. The statements below reflect blockchain regarding supply chain operations, distributions, traceability, transparency, and immutability. Please read each statement carefully, then indicate the extent **<u>to which you disagree or agree</u>** by checking the appropriate number on a scale of 1 (Strongly Disagree) to 7 (Strongly Agree).	**Strongly Disagree**	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
	1	2	3	4	5	6	7
Our firm invests resources in blockchain-enabled supply chain applications.							
Business activities/operations in our firm require the use of blockchain technologies.							
Functional areas in our firm require the use of blockchain technologies.							

Section 4: Questionnaire about Technology Orientation

Technology orientation incorporates an organisation's product, service, production and innovation directions. The statements below reflect technology orientation regarding product, service, production and innovation in the supply chain. Please read each statement carefully, then indicate the extent **<u>to which you disagree or agree</u>** by checking the appropriate number on a scale of 1 (Strongly Disagree) to 7 (Strongly Agree).	**Strongly Disagree**	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
	1	2	3	4	5	6	7
Our firm proactively develops new technologies.							
Our firm use sophisticated technologies in new product development.							
Our new products are always at the state of the art in the level of technology.							
Technological innovation is readily accepted in our program/project management.							
Our firm accepts technological innovation.							

Section 5: Questionnaire about Upper Management Support

Upper Management Support refers "to the degree to which upper management understands the importance of and is involved" in blockchain adoption in organisations. The statements below reflect upper management support regarding new technology adoption in the supply chain. Please read each statement carefully, then indicate the extent **to which you disagree or agree** by checking the appropriate number on a scale of 1 (Strongly Disagree) to 7 (Strongly Agree).	**Strongly Disagree**	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
	1	2	3	4	5	6	7
Our upper managers actively respond and pay attention when a project is initiated.							
Our upper managers support by providing labour resources, finances and materials for BOSCM							
Our upper managers are willing to accept risks when adopting BOSCM							
Our upper management inspires employees to apply latest blockchain technologies in daily work.							
Our upper management encourages innovation.							

Section 6: Questionnaire about Traceability

Traceability means discovering information about the life cycle of products (Cambridge Dictionary). Traceability refers to food and food safety, nutrition, feed, food-producing animal health and welfare, or expected to be incorporated into a food or feed through all stages of production, processing and distribution (EU 2002). Listed below are the statements that reflect the supply chain traceability in terms of provenance (location of origin), perishability (freshness), Food Safety (verification), Food fraud (quality) & Spoilage (temperature logs). Please read each statement carefully, then indicate the extent **to which you disagree or agree** by checking the appropriate number on a scale of 1 (Strongly Disagree) to 7 (Strongly Agree).	**Strongly Disagree**	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
	1	2	3	4	5	6	7
We know the sources of our raw materials.							
We track the processes involved in producing products throughout our complete supply chain.							
We trace the origins of our purchases through the entire supply chain.							
We track the environmental performance of our complete supply chain.							
We know what chemicals or elements are in our purchased components.							

Section 6-A: Input Traceability

Input Traceability means discovering information about the source of raw materials, the chemical components or elements contained in the purchased product and tracking the environmental performance in the upstream supply chain. Listed below are the statements that reflect the supply chain traceability in terms of provenance (location of origin), perishability (freshness), Food Safety (verification), Food fraud (quality) & Spoilage (temperature logs). Please read each statement carefully, then indicate the extent **to which you disagree or agree** by checking the appropriate number on a scale of 1 (Strongly Disagree) to 7 (Strongly Agree).	**Strongly Disagree**	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
	1	2	3	4	5	6	7
We share the inventory level and production plan of food raw materials.							
We share grades, quality, place of origin and property of food raw material.							
We share information related to changes in the technology of food products.							
We share information related to changes in the technology of food products.							
We share information on demand and customer preference shifts, especially shifts on food product safety and quality.							
We share information related to market demand trends and forecasts.							

Section 6- B: Process Traceability

Process Traceability means discovering information about the source of raw materials, the chemical components or elements contained in the purchased product and tracking the environmental performance in the upstream supply chain. Listed below are the statements that reflect the supply chain traceability in terms of provenance (location of origin), perishability (freshness), Food Safety (verification), Food fraud (quality) & Spoilage (temperature logs). Please read each statement carefully, then indicate the extent **to which you disagree or agree** by checking the appropriate number on a scale of 1 (Strongly Disagree) to 7 (Strongly Agree).	**Strongly Disagree**	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
	1	2	3	4	5	6	7
We have a mechanism and tools to provide timely information.							
Our traceability documents are up to date.							
We carry out internal and external audits.							
We keep written of past traceability reviews and audits.							

Section 6-C: Output Traceability

Output Traceability means discovering information about the source of raw materials, the chemical components or elements contained in the purchased product and tracking the environmental performance in the upstream supply chain. Listed below are the statements that reflect the supply chain traceability in terms of provenance (location of origin), perishability (freshness), Food Safety (verification), Food fraud (quality) & Spoilage (temperature logs). Please read each statement carefully, then indicate the extent **to which you disagree or agree** by checking the appropriate number on a scale of 1 (Strongly Disagree) to 7 (Strongly Agree).	**Strongly Disagree**	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
	1	2	3	4	5	6	7
We share customer feedback with our customers and supply chain members on major food product innovations.							
We share customer feedback with our customers and supply chain members on major improvements needed in food product quality and safety.							
We share grades, quality, place of origin, and property of food products with our customers and supply chain members.							
We share inventory levels and logistic information about food products with our customers and supply chain members.							
We share plans regarding our key customers' market segments with our customers and supply chain members							

Section 7: Questionnaire about the Sustainability Governance factors

Sustainability Governance factors refer to the various mechanisms and approaches that organisations use to manage and monitor sustainability practices within their supply chains. These factors can help organisations assess and improve the environmental, social, and ethical impacts of their supply chain operations. The statements below reflect sustainability governance regarding Agri-products sources, processes, origin, environment, and elements in your organisational supply chain. Please read each statement carefully, then indicate the extent **to which you disagree or agree** by checking the appropriate number on a scale of 1 (Strongly Disagree) to 7 (Strongly Agree).	**Strongly Disagree**	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
	1	2	3	4	5	6	7
We monitor social compliance (e.g. fair payment, working condition, employee welfare, human rights, freedom of association etc.) of our supply chain.							
We provide incentive to supply chain members to improve social sustainability.							
We evaluate sustainability performance of our supply chain.							
We monitor environmental performance of suppliers.							
We provide incentive to supply chain members to improve environmental performance.							
We strictly comply with labor laws (e.g. no child labor, no force labor, fair wages etc.) in our organization							
We do career planning for staff development							

Section 8-A: Questionnaire about Sustainability Performance (Social)

Social Sustainability is about identifying and managing business impacts, both positive and negative, on stakeholders. In particular, from the organisational viewpoint, social sustainability influences the effects of organisational activity on stakeholders. The statements below reflect ***social sustainability*** regarding responsible sources of Agri-products, in terms of fair wages, safe work environments, other health and safety factors, the presence of child or forced labour, and employee satisfaction, among many others. Please read each statement carefully, then indicate the extent **to which you disagree or agree** by checking the appropriate number on a scale of 1 (Strongly Disagree) to 7 (Strongly Agree).	**Strongly Disagree**	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
	1	2	3	4	5	6	7
Over the last couple of years we have reduced the detrimental impacts of our business operations to the general public.							
Over the last couple of years we have improved of the occupational health and safety of employees.							
Over the last couple of years we have provided more positions (i.e. employment opportunity) in the community.							
Over the last couple of years we have improved our product image among customers.							
Over the last couple of years we have improved our firm's image in customers' eyes.							
Over the last couple of years we have improved the firm's social reputation.							

Section 8-B: Questionnaire about Sustainability Performance (Environmental)

Environmental Sustainability is an organisation's responsibility to support its operations' environmental friendliness. The environmental dimension considers stakeholder requirements such as pollution prevention, waste disposal, recycling, environmental audits, and environmental performance evaluation. The statements below reflect ***social sustainability*** regarding responsible sources of Agri-products, in terms of stakeholder requirements such as pollution prevention, waste disposal, recycling, environmental audits, and environmental performance evaluation. Please read each statement carefully, then indicate the extent **to which you disagree or agree** by checking the appropriate number on a scale of 1 (Strongly Disagree) to 7 (Strongly Agree).	**Strongly Disagree**	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
	1	2	3	4	5	6	7
Over the last couple of years we have reduced environmental pollution (e.g. air emission/wastewater/solid waste).							
Over the last couple of years we have decreased the use of hazardous/ harmful/toxic materials in our firm.							
Over the last couple of years we have reduced energy consumption.							
Over the last couple of years we have decreased the frequency of environmental accidents in our organization and supply chains.							
Over the last couple of years we have improved compliance with environmental standards.							
Over the last couple of years we have improved the ability to reuse/recycle of materials and products.							
Over the last couple of years we have improved our firm's overall environmental issues.							

Section 8-C: Questionnaire about Sustainability Performance (Economic - financial)

Economic (financial) Sustainability refers to the short and long-term economic value of organisational activities. The statements below reflect ***Economic (financial) Sustainability*** on short and long-term economic value of an organisation in terms of sales value, cost of sales and profit margin. Please read each statement carefully, then indicate the extent **to which you disagree or agree** by checking the appropriate number on a scale of 1 (Strongly Disagree) to 7 (Strongly Agree).	**Strongly Disagree**	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
	1	2	3	4	5	6	7
Over the last couple of years we have improved our market share.							
Over the last couple of years we have improved our overall profit.							
Over the last couple of years we have improved ourour return on assets.							
Over the last couple of years we have improved our return on sales.							
Over the last couple of years we have improved our return on investment.							

Appendix 5: Bibliographic details

Appendix 3: The bibliographic details of the individual articles reviewed for this study are as bellows:

Title	Authors	Journal	Methodology	Field of Study	Theories used	Year	Country of Study
1 Blockchain's roles in meeting key supply chain management objectives.	Kshetri (2018)	International Journal of Information Management	Case study	Various food SC	Grounded Theory (GT)	2018	N/A
A Blockchain Application: The Dairy Supply Chain.	Kasten (2019)	Journal of Supply Chain Management Systems	Design science research	Dairy food SC	Social Exchange Theory (SET)	219	USA
A blockchain-based approach for a multi-echelon sustainable supply chain.	Manupati et al. (2020)	International Journal of Production Research	Case study	Multi-echelon SC	No	2020	India
A blockchain implementation prototype for the electronic open source traceability of wood along the whole supply chain.	Figorilli et al. (2018)	Sensors (Switzerland)	Conceptual paper	Wood SC	No	2018	Italy
A blockchain-based framework of cross-border e-commerce supply chain.	Liu and Li (2020)	International Journal of Information Management	Case study	Cross border e-commerce SC	No	2020	China

Title	Authors	Journal	Methodology	Field of Study	Theories used	Year	Country of Study
A conceptual model of sustainable supply chain management in small and medium enterprises using blockchain technology.	Nayak and Dhaigude (2019)	Cogent Economics & Finance	Conceptual paper	Small and medium enterprise (SME) SCM	Sustainability Theory (ST)	2019	India
A Content-Analysis Based Literature Review in Blockchain Adoption within Food Supply Chain.	Duan et al. (2020)	International Journal of Environmental Research and Public Health	Literature review	Food SC	No	2020	N/A
A Decentralized Application for Logistics: Using Blockchain in Real-World Applications.	Christodoulou et al. (2018) (Christodoulou et al., 2018)	The Cyprus Review	Case study	Logistics industry	No	2018	Cyprus
A distributed ledger for supply chain physical distribution visibility.	Wu et al. (2017b)	Information (Switzerland)	Case study	SC physical distribution	No	2017	N/A
A study on the transparent price tracing system in supply chain management based on blockchain.	Yoo and Won (2018)	Sustainability (Switzerland)	Conceptual paper	Transparent price tracking system in SCM	No	2018	Korea
A supply chain transparency and	Bai and Sarkis (2020)	International Journal of	Group decision method	SC transparency sustainability	Regret Theory (RT)	2020	China

Title	Authors	Journal	Methodology	Field of Study	Theories used	Year	Country of Study
sustainability technology appraisal model for blockchain technology.		Production Research					
A systematic literature review of blockchain-based applications: current status, classification and open issues.	Casino et al. (2019)	Telematics and Informatics	Literature review	Healthcare SC,	No	2019	N/A
A Systematic Review of Blockchain Literature in Logistics and Supply Chain Management: Identifying Research Questions and Future Directions.	Kummer et al. (2020)	Future Internet	Literature review	Logistics and SCM	Organisational Theories (Agency Theory (AT), Information Theory (IT), Institutional Theory (IT); Network Theory (NT), Resource-Based View (RBV), And Transaction Cost Analysis (TCA))	2020	N/A
Achieving sustainable performance in a data-driven agriculture supply chain: A review for research and applications.	Kamble et al. (2020a)	International Journal of Production Economics	Literature review	Agri-food SC	No	2020	N/A

Title	Authors	Journal	Methodology	Field of Study	Theories used	Year	Country of Study
Analysing the impact of blockchain-technology for operations and supply chain management: An explanatory model drawn from multiple case studies.	Tönnissen and Teuteberg (2020)	International Journal of Information Management	Case study	Operations and SCM	No	2020	N/A
Analysis of coordination mechanism of supply chain management information system from the perspective of block chain.	Yuan et al. (2019)	Information Systems and eBusiness Management	Conceptual paper	Coordination mechanism of SCM	No	2019	China
Applications of blockchain technology to logistics management in integrated casinos and entertainment.	Liao and Wang (2018)	Informatics	Case study	Logistics management in integrated casinos and entertainment	No	2018	USA
Applying blockchain technology to improve agri-food traceability: A review of development methods, benefits and challenges.	Feng et al. (2020b)	Journal of Cleaner Production	Literature review	Agri-food SC traceability	No	2020	China
Are Distributed Ledger Technologies	Pearson et al. (2019)	Global Food Security	Survey	Food SC	No	2019	UK

Title	Authors	Journal	Methodology	Field of Study	Theories used	Year	Country of Study
the panacea for food traceability?							
At the Nexus of Blockchain technology, the circular economy, and product deletion.	Kouhizadeh et al. (2019)	Applied Sciences	Conceptual paper	Circular economy (macro, meso and micro level) SC	Governance Theory (GT), Economic Theory (ET), and Organisational Theory (OT)	2019	N/A
Big Production Enterprise Supply Chain Endogenous Risk Management Based on Blockchain.	Fu and Zhu (2019)	IEEE Access	Case study	SC Endogenous Risk Management	No	2019	N/A
Bitcoin, blockchain and fintech: a systematic review and case studies in the supply chain.	Fosso et al. (2020)	Production Planning & Control	Literature review and case study	SC industries	No	2020	N/A
Blockchain adoption challenges in supply chain: An empirical investigation of the main drivers in India and the USA.	Queiroz and Wamba (2019)	International Journal of Information Management,	Survey	Logistics and SC	Network Theory (NT)	2019	India and USA
Blockchain and more-Algorithm driven food traceability.	Creydt and Fischer (2019)	Food Control	Conceptual paper	food SC traceability	No	2019	Germany
Blockchain and supply chain	Queiroz et al. (2019a)	Supply Chain Management:	Literature review	SC integration	No	2019	N/A

Title	Authors	Journal	Methodology	Field of Study	Theories used	Year	Country of Study
management integration: A systematic review of the literature.		An International Journal					
Blockchain and supply chain relations: A transaction cost theory perspective.	Schmidt and Wagner (2019)	Journal of Purchasing and Supply Management	Conceptual paper	SC relations	Transaction Cost Theory (TCT)	2019	N/A
Blockchain applications in supply chains, transport and logistics: a systematic review of the literature.	Pournader et al. (2019)	International Journal of Production Research	Literature review	SC, logistics and transport management	No	2019	N/A
Blockchain critical success factors for sustainable supply chain.	Yadav and Singh (2020a)	Resources Conservation and Recycling	Literature review	SCM	No	2020	India
Blockchain design for supply chain management.	Chang et al. (2018)	Available at SSRN	Numerical study	SCM	No	2018	USA
Blockchain for and in Logistics: What to Adopt and Where to Start.	Dobrovnik et al. (2018)	Logistics	Conceptual paper	Logistics industries	No	2018	N/A

Title	Authors	Journal	Methodology	Field of Study	Theories used	Year	Country of Study
Blockchain for Cities - A Systematic Literature Review.	Shen and Pena-Mora (2018)	IEEE Access	Literature review	Urban sustainability	No	2018	N/A
Blockchain in global supply chains and cross border trade: a critical synthesis of the state-of-the-art, challenges and opportunities.	Chang et al. (2020)	International Journal of Production Research,	Literature review	Global cross border SC	No	2020	USA
Blockchain in Industries: A Survey.	Al-Jaroodi and Mohamed (2019)	IEEE Access	Survey	Various industrial domains	No	2019	USA, Canada, China, Japan
Blockchain in Logistics and Supply Chain: A Lean Approach for Designing Real-World Use Cases.	Perboli et al. (2018)	IEEE Access	Case study	Fresh food logistics and SC	No	2018	Italy
Blockchain in the operations and supply chain management: Benefits, challenges	Wamba and Queiroz (2020a)	International Journal of Information Management	Literature review	Operations and SCM	No	2020	Top 20 countries (North American countries, Asian countries, and European countries)

Title	Authors	Journal	Methodology	Field of Study	Theories used	Year	Country of Study
and future research opportunities.							
Blockchain-oriented dynamic modelling of smart contract design and execution in the supply chain.	Dolgui et al. (2020)	International Journal of Production Research,	Empirical study	Smart contracts design and execution in the SC	Dynamic Control Theory (DCT)	2020	N/A
Blockchain practices, potentials, and perspectives in greening supply chains.	Kouhizadeh and Sarkis (2018)	Sustainability (Switzerland),	Theoretical paper	Greening SC	No	2018	USA
Blockchain ready manufacturing supply chain using distributed ledger	Abeyratne and Monfared (2016)	International Journal of Research in Engineering and Technology	Literature review	Cardboard box manufacturing SC	No	2016	N/A
Blockchain research, practice and policy: Applications, benefits, limitations, emerging research themes and research agenda.	Hughes et al. (2019)	International Journal of Information Management	Literature review	Information system and information management	No	2019	N/A
Blockchain technology adoption barriers in the Indian agricultural supply chain: an integrated approach.	Yadav et al. (2020)	Resources, Conservation and Recycling	Literature review	Agricultural supply chain	Fuzzy Set Theory (FST)	2020	India

Title	Authors	Journal	Methodology	Field of Study	Theories used	Year	Country of Study
Blockchain technology and enterprise operational capabilities: An empirical test.	Pan et al. (2020)	International Journal of Information Management,	Empirical study	Enterprise and operational capabilities	No	2020	China
Blockchain technology and its relationships to sustainable supply chain management.	Saberi et al. (2019b)	International Journal of Production Research	Theoretical paper	Sustainable SCM	Information Theory (IT)	2019	N/A
Blockchain technology for enhancing supply chain resilience.	Min (2019)	Business Horizons,	Theoretical paper	Supply chain resilience	No	2019	N/A
Blockchain technology: implications for operations and supply chain management.	Cole et al. (2019)	Supply Chain Management: An International Journal,	Theoretical paper	Operations and SCM	Social Capital Theory (SCT), Transaction Cost Economics (TCE) Theory, Agency Theory (AT)	2019	N/A
Blockchain technology in agri-food value chain management: A synthesis of applications, challenges and future research directions.	Zhao et al. (2019)	Computers in Industry	Literature review	Agri-food value chain	No	2019	N/A

Title	Authors	Journal	Methodology	Field of Study	Theories used	Year	Country of Study
Blockchain technology in supply chain management for sustainable performance: Evidence from the airport industry.	Di Vaio and Varriale (2020)	International Journal of Information Management,	Literature review and case study	Sustainable SC performance for airport industries	No	2020	Italy
Blockchain technology, supply chain information, and strategic product deletion management.	Zhu and Kouhizadeh (2019)	IEEE Engineering Management Review	Theoretical paper	SC information and product deletion management	No	2019	N/A
Blockchain's adoption in IoT: The challenges, and a way forward.	Makhdoom et al. (2019)	Journal of Network and Computer Applications	Literature review and survey	IoT environment, including its security and performance issues	No	2019	N/A
Blockchain-based safety management system for the grain supply chain.	Zhang et al. (2020)	IEEE Access	Case study	Safety management for the grain SC	No	2020	China
Blockchain-Based Soybean Traceability in Agricultural Supply Chain.	Salah et al. (2019)	IEEE Access	Theoretical paper	Agricultural SC,	No	2019	N/A
Blockchain-Based Traceability and Visibility for Agricultural	Prashar et al. (2020)	Sustainability	Case study	Agricultural SC	No	2020	India

Title	Authors	Journal	Methodology	Field of Study	Theories used	Year	Country of Study
Products: A Decentralized Way of Ensuring Food Safety in India.							
Blockchain-driven customer order management.	Martinez et al. (2019)	International Journal of Operations & Production Management	Case study	Customer order management processes	Information Processing Theory (IPT), Resource-Based View (RBV) Theory	2019	UK
Blockchain-enabled logistics finance execution platform for capital-constrained E-commerce retail.	Li et al. (2020)	Robotics and Computer-Integrated Manufacturing	Case study	Logistics finance operations and e-commerce retail	No	2020	China
Blockchain-enabled supply chain: An experimental study.	Longo et al. (2019)	Computers & Industrial Engineering	Experimental study	Performance of blockchain-enabled SC	No	2019	N/A
Blockchains and the supply chain: Findings from a broad study of practitioners.	Saberi et al. (2019a)	IEEE Engineering Management Review	Survey	SCM	No	2019	USA
Blockchains for supply chain management: Architectural elements and challenges towards a global scale deployment.	Litke et al. (2019)	Logistics	Literature review	SCM-global scale development	No	2019	N/A

Title	Authors	Journal	Methodology	Field of Study	Theories used	Year	Country of Study
Blockchains in operations and supply chains: A model and reference implementation.	Helo and Hao (2019)	Computers and Industrial Engineering,	Literature review	Operations and SCM	No	2019	N/A
Blockchain-technology-supported platforms for diamond authentication and certification in luxury supply chains.	Choi (2019a)	Transportation Research Part E	Case study	Diamond authentication and certification SCM	No	2019	N/A
Boundary conditions for traceability in food supply chains using blockchain technology.	Behnke and Janssen (2019)	International Journal of Information Management	Case study	Food SC	No	2019	Netherland
Building trust and equity in marine conservation and fisheries supply chain management with blockchain.	Howson (2020)	Marine Policy	Theoretical paper	Marine conservation and fisheries in global SCM	No	2020	N/A
Combining Blockchain Technology and the	Treiblmaier (2019)	Logistics	Theoretical paper	Logistics and SCM (Triple	Principal-Agent Theory (PAT), Transaction Cost Analysis (TCA),	2019	N/A

Title	Authors	Journal	Methodology	Field of Study	Theories used	Year	Country of Study
Physical Internet to Achieve Triple Bottom Line Sustainability: A Comprehensive Research Agenda for Modern Logistics and Supply Chain Management.				Bottom Line Sustainability)	Resource-Based View (RBV), Network Theory (NT)		
Distributed ledger technology in supply chains: A transaction cost perspective.	Roeck et al. (2020)	International Journal of Production Research	Empirical study	Transaction cost perspective in the SC	Transaction Cost Economics (TCE)	2020	N/A
DL-Tags: DLT and Smart Tags for Decentralized, Privacy-Preserving, and Verifiable Supply Chain Management.	Benčić et al. (2019)	IEEE access,	Conceptual paper	Privacy-preserving and verification in SCM	No	2019	N/A
Dynamics between blockchain adoption determinants and supply chain performance: An empirical investigation.	Wamba et al. (2020a)	International Journal of Production Economics	Literature review	SC performance	No	2020	India and USA
Examples from Blockchain Implementations in Logistics and Supply Chain Management:	Verhoeven et al. (2018)	Logistics	Case study	In logistics and SCM	Grounded Theory (GT)	2018	N/A

Title	Authors	Journal	Methodology	Field of Study	Theories used	Year	Country of Study
Exploring the Mindful Use of a New Technology.							
Exploring blockchain implementation in the supply chain.	Remko van (2019)	International Journal of Operations & Production Management	Survey	SC	No	2019	USA
'Fit-for-purpose?' - Challenges and opportunities for applications of blockchain technology in the future of healthcare.	Mackey et al. (2019)	BMC Medicine	Theoretical paper	Healthcare supply chain	No	2019	N/A
Food Safety Traceability System Based on Blockchain and EPCIS.	Lin et al. (2019)	IEEE Access	Conceptual paper	Food SC	No	2019	N/A
Food traceability on blockchain: Walmart's pork and mango pilots with IBM.	Kamath (2018)	The Journal of the British Blockchain Association	Case study	Food SC	No	2018	USA
How blockchain improves the supply chain: case study alimentary supply chain.	Casado-Vara et al. (2018)	Procedia computer science,	Case study	Agricultural SC	No	2018	Spain

Title	Authors	Journal	Methodology	Field of Study	Theories used	Year	Country of Study
How the blockchain enables and constrains supply chain performance.	Kim Sundtoft and Kinra (2019)	International Journal of Physical Distribution & Logistics Management	Literature review	Performance relationship in SCM	Organisational Theory (OT)	2019	N/A
IGR token-raw material and ingredient certification of recipe based foods using smart contracts.	Dos Santos et al. (2019)	Informatics	Conceptual paper	Ingredient certification of recipe-based food product	No	2019	N/A
Improving opportunities in healthcare supply chain processes via the internet of things and blockchain technology	Jayaraman et al. (2019a)	International Journal of Healthcare Information Systems and Informatics	Conceptual paper	Healthcare supply chain processes	No	2019	N/A
Information disclosure structure in supply chains with rental service platforms in the blockchain technology era.	Choi et al. (2020a)	International Journal of Production Economics	Case study	Product information disclosure structure in SC	No	2020	China
Integrated innovative product design and supply chain tactical planning within a blockchain platform.	Rahmanzadeh et al. (2020)	International Journal of Production Research	Case study	SC product design	Fuzzy Set Theory (FST)	2020	Iran

Title	Authors	Journal	Methodology	Field of Study	Theories used	Year	Country of Study
International policy coordination for blockchain supply chains.	Allen et al. (2019)	Asia and the Pacific Policy Studies	Theoretical paper	International SC policy coordination	No	2019	Asia-Pacific region
It's real, trust me! Establishing supply chain provenance using blockchain.	Montecchi et al. (2019)	Business Horizons	Conceptual paper	SC provenance	No	2019	UK
Leveraging the Internet of Things and blockchain technology in Supply Chain Management.	Rejeb et al. (2019)	Future Internet,	Literature review	SCM	No	2019	N/A
Making sense of blockchain technology: How will it transform supply chains?	Wang et al. (2019b)	International Journal of Production Economics	Empirical study	SC transformation	Sensemaking Theory (ST)	2019	UK
Mapping the potentials of blockchain in improving supply chain performance.	Mahyuni et al. (2020)	Cogent Business and Management	Literature review	SC performance	No	2020	N/A
Modelling the blockchain enabled traceability in	Kamble et al. (2020b)	International Journal of	Literature review	Agricultural SC	No	2020	India

Title	Authors	Journal	Methodology	Field of Study	Theories used	Year	Country of Study
agriculture supply chain.		Information Management					
Modernizing the supply chain of airbus by integrating RFID and blockchain processes.	Santonino III et al. (2018)	International Journal of Aviation, Aeronautics, and Aerospace	Literature review and survey	Airbus SC	No	2018	US, Hong Kong,
Potential of blockchain technology in supply chain management: a literature review	Gurtu and Johny (2019a)	International Journal of Physical Distribution & Logistics Management	Literature review	Potential to eliminate intermediaries and to make SCM more efficient	No	2019	N/A
Security services using blockchains: A state of the art survey.	Salman et al. (2019)	IEEE Communications Surveys and Tutorials	Survey	Security service	No	2019	N/A
Supply chain re-engineering using blockchain technology: A case of smart contract-based tracking process.	Chang et al. (2019)	Technological Forecasting and Social Change	Conceptual paper	SC re-engineering	No	2019	N/A
The acceptance of blockchain technology in meat traceability and transparency.	Sander et al. (2018)	British Food Journal	Empirical study	Meat SC	No	2018	Germany, Netherlands
The Economic Advantages Of	Matyskevic and Kremer-	Regional Formation and	Literature review	E-procurement	No	2020	EU countries, USA, and UK

Title	Authors	Journal	Methodology	Field of Study	Theories used	Year	Country of Study
Blockchain Technology In E-Procurement.	Matyskevic (2020)	Development Studies					
The impact of the blockchain on the supply chain: a theory-based research framework and a call for action.	Treiblmaier (2018)	Supply Chain Management	Theoretical paper	SCM	Principal Agent Theory (PAT), Transaction Cost Analysis (TCA), Resource-Based View (RBV), Network Theory (NT)	2018	N/A
The mean-variance approach for global supply chain risk analysis with air logistics in the blockchain technology era.	Choi et al. (2019)	Transportation Research Part E	Literature review	Global SC operations	Mean Variance (MV) Theory	2019	N/A
The power of a blockchain-based supply chain.	Azzi et al. (2019)	Computers & industrial engineering,	Case study	SCM	No	2019	N/A
The rise of blockchain technology in agriculture and food supply chains.	Kamilaris et al. (2019)	Trends in Food Science & Technology	Survey	Agriculture and food SCs	No	2019	N/A
The Supply Chain Has No Clothes: Technology Adoption of Blockchain for Supply Chain Transparency.	Francisco and Swanson (2018)	Logistics	Conceptual paper	SC transparency	Behavioural Theory Unified Theory Of Acceptance And Use Of Technology (UTAUT)	2018	N/A

Title	Authors	Journal	Methodology	Field of Study	Theories used	Year	Country of Study
Time to seize the digital evolution: Adoption of blockchain in operations and supply chain management among Malaysian SMEs.	Wong et al. (2020a)	International Journal of Information Management	Empirical study	SMEs SC	Technology-Organisation-Environment (TOE) Theory	2020	Malaysia
Toward an ontology-driven blockchain design for supply-chain provenance.	Kim and Laskowski (2018)	Intelligent Systems in Accounting, Finance and Management	Case study	SC provenance	No	2018	N/A
Towards an Autonomous Industry 4.0 Warehouse: A UAV and Blockchain-Based System for Inventory and Traceability Applications in Big Data-Driven Supply Chain Management.	Fernández-Caramés et al. (2019)	Sensors (Basel, Switzerland)	Literature review	SCM traceability	No	2019	N/A
Traceability for sustainability– literature review and conceptual framework.	Garcia-Torres et al. (2019)	Supply Chain Management: An International Journal.	Literature review	Global apparel SCs	No	2019	N/A
Understanding blockchain technology for future	Wang et al. (2019a)	Supply Chain Management:	Literature review	SC	No	2019	N/A

Title	Authors	Journal	Methodology	Field of Study	Theories used	Year	Country of Study
supply chains: a systematic literature review and research agenda.		An International Journal					
Understanding the Blockchain technology adoption in supply chains-Indian context.	Kamble et al. (2019)	International Journal of Production Research	Literature review and survey	SC	Technology Acceptance Model (TAM), Theory Of Planned Behaviour (TPB) And Technology Readiness Index (TRI) Theory	2019	India
Tracing manufacturing processes using blockchain-based token compositions.	Westerkamp et al. (2019)	Digital Communications and Networks	Conceptual paper	Manufacturing process	No	2019	N/A
When blockchain meets social-media: Will the result benefit social media analytics for supply chain operations management?	Choi et al. (2020b)	Transportation Research Part E: Logistics and Transportation Review	Literature review and case study	Social media SC	No	2020	N/A
When Blockchain Meets Supply Chain: A Systematic Literature Review on Current Development and Potential Applications	Chang and Chen (2020)	IEEE. Access	Literature review	SC	Principal Agent Theory (PAT)	2020	N/A

Appendix 6: Theories applied in the literature

Appendix 2: Theories applied in the literature as per reviewed articles.

Title	Theories	Reference
The impact of the blockchain on the supply chain: a theory-based research framework and a call for action.	Principal Agent Theory (PAT), Transaction Cost Analysis (TCA), Resource-Based View (RBV), Network Theory (NT)	Treiblmaier (2018)
How the blockchain enables and constrains supply chain performance.	Organisational Theory (OT)	Kim Sundtoft and Kinra (2019)
Blockchain and supply chain relations: A transaction cost theory perspective.	Transaction Cost Theory (TCT)	Schmidt and Wagner (2019)
A conceptual model of sustainable supply chain management in small and medium enterprises using blockchain technology.	Sustainability Theory (ST)	Nayak and Dhaigude (2019)
A Blockchain Application: The Dairy Supply Chain.	Social Exchange Theory (SET)	Kasten (2019)
At the Nexus of Blockchain technology, the circular economy, and product deletion	Governance Theory (GT), Economic Theory (ET), and Organisational Theory (OT)	Kouhizadeh et al. (2019)
Blockchain adoption challenges in supply chain: An empirical investigation of the main drivers in India and the USA.	Network Theory (NT)	Queiroz and Wamba (2019)
Blockchain and supply chain relations: A transaction cost theory perspective.	Transaction Cost Theory (TCT)	Schmidt and Wagner (2019)
Blockchain-oriented dynamic modelling of smart contract design and execution in the supply chain.	Dynamic Control Theory (DCT)	Dolgui et al. (2020)
Distributed ledger technology in supply chains: A transaction cost perspective.	Transaction Cost Economics (TCE)	Roeck et al. (2020)
The mean-variance approach for global supply chain risk analysis with air logistics in the blockchain technology era.	Mean Variance (MV) Theory	Choi et al. (2019)
Examples from Blockchain Implementations in Logistics and Supply Chain Management: Exploring the Mindful Use of a New Technology.	Grounded Theory (GT)	Verhoeven et al. (2018)

Appendix 7: Blockchain adoption in food SC

Blockchain adoption in food SC as per reviewed articles

Title	Authors	Year	Journal	Field of Study
1 Blockchain's roles in meeting key supply chain management objectives.	Kshetri (2018)	2018	International Journal of Information Management	Various food SC
A Blockchain Application: The Dairy Supply Chain.	Kasten (2019)	219	Journal of Supply Chain Management Systems	Dairy food SC
A Content-Analysis Based Literature Review in Blockchain Adoption within Food Supply Chain.	Duan et al. (2020)	2020	International Journal of Environmental Research and Public Health	Food SC
Achieving sustainable performance in a data-driven agriculture supply chain: A review for research and applications.	Kamble et al. (2020a)	2020	International Journal of Production Economics	Agri-food SC
Applying blockchain technology to improve agri-food traceability: A review of development methods, benefits and challenges.	Feng et al. (2020b)	2020	Journal of Cleaner Production	Agri-food SC traceability
Are Distributed Ledger Technologies the panacea for food traceability?	Pearson et al. (2019)	2019	Global Food Security	Food SC
Blockchain and more-Algorithm driven food traceability.	Creydt and Fischer (2019)	2019	Food Control	food SC traceability
Blockchain in Logistics and Supply Chain: A Lean Approach for Designing Real-World Use Cases.	Perboli et al. (2018)	2018	IEEE Access	Fresh food logistics and SC
Blockchain technology adoption barriers in the Indian agricultural supply	Yadav et al. (2020)	2020	Resources, Conservation and Recycling	Agricultural supply chain

chain: an integrated approach.				
Blockchain technology in agri-food value chain management: A synthesis of applications, challenges and future research directions.	Zhao et al. (2019)	2019	Computers in Industry	Agri-food value chain
Blockchain-based safety management system for the grain supply chain.	Zhang et al. (2020)	2020	IEEE Access	Safety management for the grain SC
Blockchain-Based Soybean Traceability in Agricultural Supply Chain.	Salah et al. (2019)	2019	IEEE Access	Agricultural SC,
Blockchain-Based Traceability and Visibility for Agricultural Products: A Decentralized Way of Ensuring Food Safety in India.	Prashar et al. (2020)	2020	Sustainability	Agricultural SC
Boundary conditions for traceability in food supply chains using blockchain technology.	Behnke and Janssen (2019)	2019	International Journal of Information Management	Food SC
Food Safety Traceability System Based on Blockchain and EPCIS.	Lin et al. (2019)	2019	IEEE Access	Food SC
Food traceability on blockchain: Walmart's pork and mango pilots with IBM.	Kamath (2018)	2018	The Journal of the British Blockchain Association	Food SC
How blockchain improves the supply chain: case study alimentary supply chain.	Casado-Vara et al. (2018)	2018	Procedia computer science,	Agricultural SC
IGR token-raw material and ingredient certification of recipe based foods using smart contracts.	Dos Santos et al. (2019)	2019	Informatics	Ingredient certification of recipe-based food product
Modelling the blockchain enabled traceability in	Kamble et al. (2020b)	2020	International Journal of Information Management	Agricultural SC

agriculture supply chain.				
The acceptance of blockchain technology in meat traceability and transparency.	Sander et al. (2018)	2018	British Food Journal	Meat SC
The rise of blockchain technology in agriculture and food supply chains.	Kamilaris et al. (2019)	2019	Trends in Food Science & Technology	Agriculture and food SCs
A blockchain use case in food distribution: Do you know where your food has been?	Bumblauskas et al. (2020)	2020	International Journal of Information Management	Food Distribution (egg distribution)
Blockchain-based food supply chain traceability: a case study in the dairy sector	Casino et al. (2020b)	2020	International Journal of Production Research	Dairy food sector
Food quality traceability prototype for restaurants using blockchain and food quality data index	George et al. (2019)		Journal of Cleaner Production	Food (meat) supply chain of Restaurants