Food Transparency, Authenticity and Safety with Blockchain Technology

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Chapter 2 (Systematic Literature Review): Exempt from Ethics review

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This thesis contains work prepared for publication, some of which have been co-authored.

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Food transparency, authenticity, and safety are concerns for companies, governments, and consumers alike. Rising food recalls globally evidence data security problems in the supply chain traceability systems, damaging the profitability and credibility of brands. Many companies struggle to promptly identify the root causes of food incidents since their databases are structured in silos, and interoperability is challenging. Food companies may surmount paper-based and digital repositories, making it complex to track food items quickly through their already vast networks. Thus, tracing food incidents becomes a slow process, taking months and even years for companies to determine the origin of a food incident.

Blockchain digital technology presents the opportunity for food systems to remedy those deficiencies in supply chains by monitoring and auditing all operations to proactively identify and address supply chain vulnerabilities. Through an immutable digital ledger, blockchain can track the provenance of food products in real-time, providing a reliable source for all stakeholders. In addition, food brands can strengthen their supply chains whilst providing authentic and safe products to consumers through blockchain certification, establishing strategic differentiation in the market and greater collaboration with governmental bodies to start building an e-food environment.

This thesis proposes blockchain technological solutions to advance food data security by allowing full supply chain visibility to entire food systems. This thesis aims to provide the current development of blockchain in supply chain management, specifically for the food supply chain, and contribute theoretically and pragmatically with insights towards accepting and choosing food products certified by blockchain technology from real consumers in Australia. Most studies on blockchain adoption have been primarily conducted at an organisational level and fail to consider the features of blockchain that consumers potentially

value. To fill this gap, this research analyses consumer adoption of food products certified with blockchain technology. By understanding consumers’ motivation to accept and potentially value blockchain adoption, food brands can have better knowledge to initiate its implementation.

This thesis research contains a systematic literature review and two empirical studies examining consumer behavioural factors. The first study provides a blockchain landscape in supply chain management, balancing the academic and practitioner research domains and identifying blockchain adoption trends and implications. In addition, the review unveils the underlying drivers for adopting and business values achieved by blockchain and explores the application of analytical/chemical fingerprinting techniques that link the physical product to the blockchain digital ledger.

The second study of this thesis applies and adapts the theoretical framework of Consumer Acceptance and Use of Information Technology (UTAUT2) to investigate the consumers' acceptance of blockchain-certified food products via a mobile application for food provenance. Structural equation modelling and path analysis were performed to identify latent factors that can drive the adoption of blockchain-certified food products. The results indicate that *habit* followed by *social influence* are the main predictors of behavioural intention. In contrast, a non-significant effect is confirmed for performance expectancy, effort expectancy, and consumer perceived value and trust. The results from the second study also guided the development of a policy framework for blockchain awareness and initiation in the Australian food system with several strategies.

The third study of this thesis implemented a hybrid choice model comprised of discrete choice modelling and compositional data analysis to determine the factors implicated in consumers' willingness to choose and pay for blockchain-certified food products in Australia. The significant findings of this study are that consumers display positive receptiveness for blockchain technology traceability and disfavour unethical food production methods, exposing sustainability-conscious behaviour in their purchasing decision-making. Consumers also show price sensitivity as a factor that may affect choosing blockchain-certified food products. The findings reveal that gender is also relevant to the price-sensitivity. In addition, this study furthers actionable marketing implications based on the choice modelling findings.

Overall, this thesis could have omitted relevant investigations that might have affected the findings. Even thought there is relevant literature on the topic, the study of blockchain as a nascent technology presents limited literature on its adoption in food supply chains, and this could have restricted the depth of conclusions. Similarly, the evolving nature of blockchain adoption per se poses limitations. There is also a lack of comparison between academic and industry research, with scarce collaboration between both fields, which results in limited balanced insights into technology advancement.

However, these limitations pose new avenues for future research. Studies about attitudes of shoppers towards blockchain-based tools verification, identifying behavioural factors influencing consumers to pay a premium for blockchain-certified products. Developing a framework for integrating blockchain and fingerprinting in supply chains, investigating main scalability problems of blockchain in food supply chains, collecting insights on benefits and challenges of blockchain implementation, researching new or redesigned business models integrating blockchain in food companies, exploring blockchain's role in verifying sustainable practices in the wellness and beauty industry are topics worthy of investigation. Moreover, studying the cultural variations in food consumption to avoid generalisation from an Australian sample, undertaking live experiments to assess consumer reactions in a real shopping environment, conducting longitudinal studies for changing consumer behaviour in different consumer segments, understanding social influences on behavioural intention, investigating blockchain habit formation using a behavioural neuroscience approach in consumer contexts and exploring CSR deficiencies in the food supply chain and how blockchain can address them are also interesting topics of research to advance the understanding of blockchain technology implications for food supply chain provenance.

The findings presented in all studies of this thesis shed light on the transformative potential of blockchain technology in food supply chains and offer insights into its implementation for enhancing supply chain efficiency, consumer confidence, incentivising corporate sustainable and ethical practices and promoting collaboration in food systems.

Keywords: supply chain management, blockchain technology, blockchain consumer adoption, choice modelling, compositional data, UTAUT2, sustainable and ethical practices, WTP, marketing implications

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Acronym	Definition
AFP	Analytical Fingerprint
AVE	Average Variance Extracted
BI	Behavioural Intention
CA	Cronbach Alpha
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CLR	Centred Log Ratio
CMB	Common Method Bias
CMIN/DF	Ratio of Chi-Square Minimum/Degrees of Freedom
CMV	Common Method Variance
CoDa	Compositional Data
CPI	Consumer Price Index
CPTV	Consumer Perceived Value and Trust
CR	Composite Reliability
DLT	Distributed Ledger Technology
EE	Effort Expectancy
ESEM	Exploratory Structural Equation Model
FC	Facilitating Conditions
FDA	Food and Drug Administration
FSANZ	Food Standards Australia New Zealand
FSM	Food Safety Motivations
FT-IR	Fourier Transform Infrared
GFI	Goodness of Fit Index
GMO	Genetically Modified Organism
HT	Habit
HTMT	Heterotrait-Monotrait ratio of correlations
ICLV	Integrated Choice and Latent Variable
IDT	Innovation Diffusion Theory
LSR	Logistics Social Responsibility
MANOVA	Multivariate Analysis of Variance
MIR	Mid-Infrared
MLE	Maximum Likelihood Estimation
MM	Motivational Model
MNL	Multinomial Logit Model
MPCU	Model of PC Utilization
MS	Mass Spectrometry
NFC	Near Field Communications
NIR	Near-Infrared
NMR	Nuclear Magnetic Resonance

Acronym	Definition
P2P	Peer-to-Peer
PCA	Principal Component Analysis
PE	Performance Expectancy
PSR	Purchasing Social Responsibility
QR code	Quick Response code
RFID	Radio Frequency Identification
RMR	Root Mean Squared Residual
RMSEA	Root Mean Square Error of Approximation
RP-MNL	Random Parameters Multinomial Logit
SCM	Supply Chain Management
SCT	Social Cognitive Theory
SD	Standard Deviation
SEM	Structural Equation Modeling
SI	Social Influence
SKU	Stock Keeping Unit
SLR	Systematic Literature Review
TLI	Tucker-Lewis Index
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
UB	Use Behaviour
UTAUT2	Consumer Acceptance and Use of Technology
WTA	Willingness To Accept
WTC	Willingness To Choose
WTP	Willingness To Pay

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AUTHORSHIP DECLARATION: CO-AUTHORED PUBLICATIONS

This thesis contains work that has been prepared for publication, all of which have been co-authored.

Bibliographic details of Manuscript 1 Blockchain Technology for Supply Chain Provenance: Increasing Supply Chain Efficiency and Consumer Trust.
Location in thesis: Chapter 2
Student contribution to work: Chapter 2 takes the form of an article that will be submitted to the Supply Chain Management: An International Journal. Elena led the progress of this paper from formulation to the preparation of the manuscript for publication. Elena delimited the topic and the inclusion and exclusion criteria, reviewed, analysed and synthesised the literature, and established conceptual maps using Leximancer software. Elena also identified the value of incorporating a review of additional technology (fingerprinting techniques) to support the qualitative assessment. Elena mainly developed the findings, implications and future research recommendations. Elena communicated formally with the journals' editorial teams, acting as the corresponding author. Associate Professor Paul Bergey provided extensive support in improving the paper by proposing the reformulation of the topic, additional review analyses, refinement recommendations of the structure and editing of the paper. Senior Lecturer Brett Smith provided support in improving the paper by making recommendations on the structure of the review, refinement and editing.
Co-author signatures and dates: Paul Bergey: [redacted] Date: 13/06/2023 Brett Smith: [redacted] Date: 13/06/2023

Bibliographic details of manuscript 2

Predicting Consumer Behavioural Intention of Accepting Blockchain-Certified Food Products using a Mobile Application for Food Provenance and Authenticity.

Location in thesis:

Chapter 3

Student contribution to work:

Chapter 3 takes the form of an article that will be submitted to the Food Policy Journal.

Elena led the development of this paper from conceptualisation to the preparation of the manuscript for publication. Elena identified the gaps in the literature and reviewed the suitable theorethical framework to undertake further analysis. Elena developed the instrument design, discerned the proper online panel and undertook the entire process for data collection. Elena mainly conducted the data analysis, implications and future research recommendations.

Associate Professor Paul Bergey provided extensive support in improving the paper by suggesting improvement to the instrument design for the data collection, and reestructure of the hypothesis development. He reviewed the data analysis, refined, made recommendations of the structure and editing of the paper.

Senior Lecturer Brett Smith supervised model development and estimation, provided support in improving the paper by making recommendations on the structure, refinement and the editing.

Co-author signatures and dates:

Paul Bergey: [redacted] Date: 13/06/2023

Brett Smith: [redacted] Date: 13/06/2023

Bibliographic details of manuscript 3 Food provenance assurance and willingness to pay for blockchain data security: A case of Australian consumers.
Location in thesis: Chapter 4
Student contribution to work: Chapter 4 takes the form of an article that will be submitted to International Journal of Research in Marketing. Elena led the development of this paper from conceptualisation to the preparation of the manuscript for publication. Elena identified the gaps in the literature and implemented the proper instrument design and the entire process for data collection in the online panel. Elena conducted. Elena mainly structured the data for further analysis, interpretation of the findings, implications and future research recommendations. Associate Professor Paul Bergey provided support by suggesting improvement to the instrument design for the data collection, made recommendations of the structure and editing of the paper. Senior Lecturer Brett Smith provided extensive support in the development and improvement of the paper. He suggested the methods design, validated the findings, made recommendations on the structure, refinement and the editing of the paper.
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CHAPTER 1

General Introduction

1.1. Background and Objectives

Supply chains are increasingly vulnerable to unforeseen disruptions in our globalised world, ranging from natural catastrophes to social conflicts and pandemics. These disturbances can have far-reaching consequences, negatively impacting brands' reputation, corporate performance, profitability, and consumer confidence. Building resiliency requires that brands proactively pursue a managerial vision of adjusting to a competitive market, changing customer expectations and managing supply chain risks. Hence, companies need to assess how to restructure their business models rather than merely reacting to supply chain disruptions. Proactively managing potential supply chain challenges is crucial to sustaining resilience. Research demonstrates that supply chain resilience is essential for organisations to counteract vulnerabilities (Dubey et al., 2020; Li et al., 2022; Lohmer et al., 2020) and maintain business continuity.

As consumer preferences evolve, companies must adapt to meet changing demands and expectations. Consumers increasingly want to know about the provenance of the goods they purchase (Chen et al., 2020), seeking transparency and accountability throughout the supply chain. Customers expect companies to provide unique and satisfying goods and services, making their lives easier while maintaining a seamless and meaningful experience. Companies must build trust with their customers by offering value (Xu & Duan, 2022), quality in the products they purchase, and brand relationships (Rogerson & Parry, 2020; H. Wang et al., 2021; Xu & Duan, 2022). Hence, companies can enhance their brand reputation, customer loyalty, and profitability.

With the increasing focus on innovation and technological advancement, recent developments in blockchain technology offer significant potential for streamlining supply chain operations, reducing costs (Li et al., 2021), innovating current business models and enhancing resilience strategies (Lohmer et al., 2020).

Blockchain technology is widely known in the cryptocurrency sphere as the underlying technology enabling Bitcoin or any cryptocurrency network. However, besides financial applications, blockchain technology has other uses, such as business operations, international trade, taxation, governance, identity validation and supply chain management (SCM) (Kimani et al., 2020). Blockchain technology can enable greater transparency, traceability and trust in SCM mainly for its immutability, where transactions cannot be modified once they are appended to the database (Garrard & Fielke, 2020). Adopting blockchain technology in the food supply chain can enhance the information systems that ensure food safety and protect consumers. Food supply chains are particularly vulnerable to contamination and food-borne diseases, which can have severe health consequences and even death (Li et al., 2021), particularly for vulnerable populations. In the event of a food recall or outbreak, blockchain technology can give brands real-time visibility into the supply chain (Vu et al., 2021; Wang Yingli et al., 2019), allowing them to identify potential risks and respond with faster food traceability and recalls.

Food supply chains also significantly impact the environment, and many companies are taking steps to promote sustainable practices. Blockchain technology can help companies to identify ways to incentivise and validate more sustainable and ethical practices along the food supply chain, such as waste reduction, gas emissions, water use and land degradation (Friedman & Ormiston, 2022), animal welfare (Katsikouli et al., 2021) and modern human slavery (Christ & V Helliar, 2021). By granting a secure and transparent platform for data sharing, blockchain can enhance visibility and accountability throughout the supply chain, enabling companies to track and verify sustainable/ethical claims. Additionally, blockchain provides consumers access to the historical record of the products they purchase (H. Wang et al., 2021), empowering them to make more informed choices that align with their preferences and values. All these factors highlight the importance of strengthening data security in food supply chains to enhance resilience, address disruptions, and sustain fluctuating consumer demand.

The adoption of blockchain technology can potentially revolutionise food supply chains in Australia. However, the success of this technology depends on its acceptance and usage by organisations and customers alike. This motivates my research as a topic worthy of study.

The present research employs a tripartite approach. First, I conducted a systematic literature review (SLR). Second, I conducted a study about consumers' attitudes and willingness to accept (WTA) blockchain-certified food products via a simulated mobile application to access information about food provenance. Third, I carried out a study examining consumer behavioural factors involved in their decision-making, including willingness to choose (WTC) and willingness to pay (WTP) for blockchain-certified food products.

The SLR aims to bridge the gap between theoretical inquiry and real-world blockchain solutions in supply chain management by categorising the characteristics of products used in blockchain trials by real companies. I also explore fingerprinting techniques that are used to link physical products to their digital counterparts in the blockchain ledger. The SLR synthesises related concepts and exposes gaps in the literature that can lead to future research. The SLR provides empirical evidence and confirms that adopting blockchain technology can lead to more operational capabilities in the food supply chain and increase consumer trust.

Despite the positive and steady adoption of blockchain in SCM, not all emerging digital technologies are immediately embraced by society. Blockchain adoption research has been mainly focused at the organisational level but is scarce in understanding consumer behaviour. This thesis aims to offer a more comprehensive and robust outlook of blockchain adoption besides the organisational approach, including the consumers' context, by analysing the behavioural factors influencing their acceptance, selection and willingness to pay for blockchain-certified food products.

The second study examines the attitudes of consumers' acceptance of food products certified by blockchain technology within the theoretical model of Venkatesh et al. (2012) of Consumer

Acceptance and Use of Technology (UTAUT2) under factors such as Performance Expectancy, Effort Expectancy, Social Influence, Habit, and Consumer Perceived Value and Trust. The findings confirm that the antecedent drivers of the UTAUT2 model also apply to the adoption of blockchain technology by consumers.

Finally, the third study of this thesis investigates the consumers' willingness to choose and pay for blockchain-certified food products with a hybrid choice model estimation approach with compositional data as a latent variable to predict consumers' choices for blockchain-certified food products. The findings show that, in general, consumers are willing to adopt and pay a premium for products that can provide detailed label information that is accessible and verifiable on the blockchain.

All three studies provide evidence of how blockchain technology can improve supply chain efficiency and consumer trust by identifying the provenance of food products with transparency, authenticity, and safety and offering theoretical and managerial implications. Consequently, this investigation aims to aid management regarding the decision-making to adopt blockchain solutions and provide strategies in light of consumer behaviour.

Below, I provide an overview of the chapters comprised in the present thesis and outline how they contribute to the literature.

1.2. Overview of the chapters

This thesis research has been conducted as a series of papers and contains five themed chapters, including the current chapter. Chapter 1 presents a general introduction and an outline of the studies conducted. Chapters 2, 3, and 4 illustrate the three primary studies undertaken, presented in the format of journal articles prepared for publication. Finally, chapter 5 concludes the thesis by discussing the overall research findings in more detail. Next, I will discuss each chapter.

The present chapter, 1, is the general introduction to the thesis, where I present a preamble of the research in general, an outline of the studies and a summary of the contributions of the investigation. Chapter 2, titled “Blockchain Technology for Supply Chain Provenance: Increasing Supply Chain Efficiency and Consumer Trust”, follows the format of a journal manuscript prepared for submission. In the initial stage, I provide the current advancement of blockchain in supply chain management through a systematic literature review comparing the academic and practitioner research domains and recognising blockchain adoption trends and implications. The balanced outlook from academic and practitioner domains offers a sound understanding of the theory and the tangible advantages and challenges of implementing blockchain solutions in real-world supply chain contexts. The review also reveals the underlying drivers and business values achieved by early blockchain adopters in the supply chain and explores the application of analytical/molecular fingerprinting techniques that can assist in associating the physical product to the blockchain digital ledger to ensure full authenticity. The findings of this review provide ongoing research on blockchain technology for supply chain provenance, balancing theoretical and pragmatic insights that can assist practitioners in exploring blockchain adoption.

Chapter 3 of this thesis is titled “Predicting Consumer Behavioral Intention of Accepting Blockchain-Certified Food Products using a Mobile Application for Food Provenance and Authenticity.” Following the gaps identified in the literature review, in chapter 3, I employ and adapt the theoretical framework of Venkatesh et al. (2012) of Consumer Acceptance and Use of Information Technology (UTAUT2) to investigate the consumers' acceptance of blockchain-certified food products via a mobile application for food provenance. For this analysis, I applied structural equation modelling and path analysis to unfold the latent attributes that can drive the adoption of blockchain-certified food products from the consumer angle. In chapter 3, based on the study's results, I developed a policy framework for blockchain awareness and initiation in the Australian food system with several strategies.

Chapter 4 is titled "Food Provenance Assurance and Willingness to Pay for Blockchain Data Security: A case of Australian Consumers." In chapter 4 of this thesis, I implemented a hybrid choice model comprising a discrete choice model and compositional data to determine the behavioural factors in consumers' willingness to choose and pay for blockchain-certified food products in Australia. This chapter displays the receptiveness of consumers to 'blockchained' food products that have been certified with the technology and the factors involved in their purchasing decision-making. In addition, this study furthers marketing implications.

Finally, in chapter 5, I discuss the total findings of all studies of this thesis, shedding light on the potential of blockchain technology in food supply chains and offering insights into the benefits of its implementation for enhancing supply chain efficiency, consumer confidence, incentivising corporate sustainability practices and promoting collaboration in food systems.

Table 1. Outline of the studies in the thesis

Study	Research Questions/Aims	Theoretical Framework	Methodology
Study 1	RQ1. What is the present state of the academic and industry literature regarding the use of blockchain technology to enhance supply chain provenance to fulfil the customers' demand for product authenticity? RQ2. What are the driving factors and products or service characteristics that have led to blockchain's early adoption in the supply chain, and what are the business values achieved? RQ3. How can the link between physical products flowing through the supply chain and the corresponding digital records on the blockchain be assured to establish and maintain provenance?	N/A	Systematic Literature Review Content Analysis (Leximancer) Thematic Analysis
Study 2	R1. What latent factors drive usage intention (with the UTAUT2 framework) for consumers exploring a new digital technology (blockchain) to access transparent food information? R2. Do the control variables (gender, age, education, income, and parenting) exhibit differences across the groups?	Consumer Acceptance and Use of Information Technology (UTAUT2) (Venkatesh et al., 2012)	Structural Equation Modelling
Study 3	RQ1. What food attributes are the most important drivers of consumers' decision to adopt a blockchain-certified food product? RQ2. Are consumers willing to choose and pay a premium for food products that offer greater transparency and traceability via blockchain technology?	Attribute-based choice modelling (McFadden & Train, 2000)	Hybrid Choice Modelling combining Discrete Choice Model & Compositional Data

1.3. Research Methodology

This thesis comprehends three studies and their corresponding methodologies. The first study employs an SLR with text-machine learning content analysis (Leximancer) and thematic analysis (Nvivo). The SLR guidelines were based on the study of (Durach et al., 2017) to gather and synthesize existing knowledge in a structured manner, ensuring comprehensive coverage and reducing bias. The SLR structured guidelines help identify gaps in the literature and form a solid foundation for further research. Content analysis (Leximancer) is a tool to explore and extract meaningful patterns and themes from a large volume of textual data. It aids in revealing hidden patterns, key concepts, and relationships within the literature, enhancing the depth of analysis. The thematic analysis helps to identify, analyse, and report patterns within data. It brings an organised approach to discern themes and sub-themes, allowing for a deeper understanding of the subject matter, particularly in uncovering nuances within the literature.

The Second Study employs Structural Equation Modelling (SEM) to analyse complex relationships among multiple variables. It offers a comprehensive approach to test and validate theoretical models, providing insights into the interplay among latent constructs. This is particularly valuable in understanding the factors influencing consumers' acceptance of blockchain-based products in the food supply chain.

The third study employs a hybrid choice model combining discrete choice modelling and compositional data. The hybrid choice model combines various statistical models to address specific complexities in choice behaviour. This approach is suitable for investigating consumer preferences and behaviour when faced with multiple choices, especially in the context of blockchain-certified food products. It helps examine consumers' decision-making when presented with different options and enables the evaluation of consumer preferences and their willingness to choose based on specified attributes. The compositional data analysis specifically addresses data where the variables represent proportions or compositions. This technique helps understand consumer preferences by evaluating relative importance and trade-offs among attributes, especially when assessing the choice and willingness to pay for blockchain-certified food products. Each methodology brings a unique set of analytical tools and techniques tailored to the specific objectives of the individual studies. Collectively, they contribute to a comprehensive and rigorous investigation, providing valuable insights into the acceptance of blockchain technology, consumer behaviour, and its implications within the food supply chain.

1.4. Research Contribution Summary

This investigation provides several theoretical and practical contributions. On the one hand, regarding the theoretical contributions, this thesis offers a more profound understanding of blockchain adoption from the perspective of consumer behaviour research. There is a research gap in the literature for comprehensive studies examining the influential factors of blockchain adoption at the customer level. This thesis contributes with an interdisciplinary approach to the literature on supply chain management, specifically food supply chains and marketing (consumer behaviour), addressing this research gap, highlighting consumer behaviour heterogeneity, the emerging nature of blockchain technology, and the connotations related to the technology's implementation and awareness.

I present a comprehensive overview of the blockchain landscape in supply chain management by reviewing and comparing academic and industry literature advancement. The SLR study shows the synergy across academic and industry domains considering blockchain benefits and recognises such confluence on the need to reinforce data traceability in the supply chain. Insights from both research domains illustrate blockchain adoption's efficiency gains to increase consumers' perceived value and trust in brands' claims. One of the most significant findings from this review is the characteristics of the products and services that have driven blockchain technology's early adoption. The findings of the SLR study shed light on the potential of blockchain technology in reshaping various aspects of supply chain management, including product provenance, security, authenticity, accountability, safety and consumer confidence. In addition, I address the blockchain oracle issue in food supply chains. To tackle this problem, I explore the applicability of fingerprinting techniques to connect physical products with the blockchain digital ledger.

In the second study, I discern the attitudinal factors that drive consumers' adoption of new technologies. I applied and extended the Consumer Acceptance and Use of Information Technology (UTAUT2) of Venkatesh et al. (2012) to examine the latent factors that can drive consumers' adoption of blockchain-based food products. This second study is of theoretical importance to further the academic literature on technology acceptance and supply chain management from a customer's stance, fitting the UTAUT2 customer-centric model toward accepting blockchain-certified food products (WTA) using a mobile application for food provenance. In addition, I outline a policy scheme for adopting blockchain technology centred on strengthening traceability, trust and collaboration among food supply chain stakeholders, governmental instances, and customers. This policy framework can help governmental bodies to initiate the awareness and adoption of blockchain technology.

The third study focuses on analysing the most influential food attributes for Australian consumers and their willingness to choose (WTC) and to pay (WTP) for blockchain-certified food products (eggs). The choice modelling findings pave the way to develop marketing strategies in initiating the adoption of blockchain technology.

Regarding the managerial implications, this research supports practitioners planning to attempt blockchain adoption in their food supply chains, depicting substantial knowledge in two ways. First, the results from my SLR study illustrate the importance of having a balanced literature review (academic vs. industry domains), especially when studying the adoption of new technologies that usually occur first in the industry. These outcomes enable practitioners to gain insights into the motives and gains from other companies to elucidate the viability of blockchain adoption as an initial exploration point.

This thesis analyses the behavioural factors influencing consumers' willingness to accept blockchain-certified food products. I expect the insights from this study can help supply chain stakeholders make decisions on blockchain adoption by providing the most significant factors of consumer behaviour: *habit* and *social influence*. In this manner, food businesses can have better information for blockchain implementation.

Based on choice modelling, the final study predicts consumers' receptiveness and WTP pay for blockchain-certified food products. The positive blockchain receptiveness to the utilitarian value of blockchain can aid food companies in designing better marketing strategies to push blockchain awareness in consumers. Further, I propose marketing implications to facilitate brand resilience and agility in food companies initiating the adoption of blockchain technology. The findings of this thesis inform ways that firms may work with consumers in Australia to understand the value of blockchain in ensuring food provenance and traceability.

1.5. Research Significance

The thesis presents a significant contribution in both theoretical and practical dimensions within the domain of blockchain adoption in supply chain management. The research bridges a notable gap in the literature by offering an in-depth understanding of influential factors driving blockchain adoption from an organisational and consumer-centric perspective, emphasizing the interdisciplinary nature of blockchain technology in supply chain management, particularly in the food industry. Through a comprehensive review of academic and industry literature, the thesis elucidates the synergies and implications of adopting blockchain technology. It highlights its efficiency gains in reinforcing data traceability, increasing perceived value, and establishing consumer trust in brand claims. Noteworthy findings are presented, particularly delineating the characteristics driving early blockchain adoption and the potential of blockchain in reshaping supply chain facets, such as product provenance, security, authenticity, and consumer confidence.

Furthermore, the research evaluates attitudinal factors influencing consumer acceptance of blockchain-certified food products, laying the foundation for marketing strategies and managerial implications in facilitating blockchain adoption in the food supply chain. The study foresees assisting decision-making among supply chain stakeholders and offers insights into the factors influencing consumer behaviour, particularly habit and social influences. The final segment of the thesis anticipates consumer responsiveness and willingness to pay for blockchain-certified food products, paving the way for enhanced marketing strategies and aiding food companies in comprehending the utilitarian value of blockchain.

Overall, the thesis provides comprehensive insights beneficial for practitioners planning to integrate blockchain technology in food supply chains, offering strategic guidance and managerial insights based on consumer behaviour, market responses, and the potential for blockchain technology in ensuring food provenance and traceability.

Next, this thesis undertakes a systematic literature review, thoroughly exploring the blockchain's role in supply chain management, combining perspectives from academic and industry sources.

CHAPTER 2

Blockchain Technology for Supply Chain Provenance. Increasing Supply Chain Efficiency and Consumer Trust: A Systematic Literature Review

Foreword

The main objective of this thesis is to understand blockchain technology's implications for food transparency, authenticity and safety in the supply chain. A systematic literature review (SLR) was conducted at the initial stage of this research to develop a comprehensive understanding of the application of blockchain technology for supply chain provenance. This review extensively evaluates the relevant literature and thoroughly analyses the current state-of-the-art of blockchain technology and supply chain management to identify research gaps. The review follows the guidelines outlined by (Durach et al., 2017), with established inclusion and exclusion criteria to ensure blockchain and supply chain provenance was considered the central topic. An algorithmic-driven content analysis was performed on all the articles collected from academic and industry literature to offer a reliable and reproducible review. The resulting conceptual maps provide insight into the themes, concepts, and relationships represented in the literature and a comparative analysis of the research conducted in both domains. This chapter analyses the differences and similarities between the academic and industry literature on the topic and provides an overview of the trends identified in the literature. Next, the implications of adopting blockchain for supply chain provenance are discussed, focusing on early pioneer companies and their business experiences with blockchain technology. The drivers behind the adoption of blockchain, the business values achieved, and the types of products and industries involved were categorised in detail in the analysis, and the geographical areas of greater adoption are examined. Additionally, the chapter explores fingerprinting techniques to tie physical products to the blockchain ledger in a supply chain to prevent counterfeiting. Finally, this chapter offers managerial implications, a conclusion, research limitations, and guidelines for future research.

N.B: Please note that the standard American spelling is used in the following chapter due to the journal's requirements, and for the purposes of publication, I use “we” instead of ‘I”.

Blockchain Technology for Supply Chain Provenance. Increasing Supply Chain Efficiency and Consumer Trust: A Systematic Literature Review.

Abstract

Purpose – This review comprehensively examines the blockchain landscape in supply chain management, drawing insights from academic and industry literature. The research aims to identify the key drivers, categorize the products involved, and highlight the business values achieved by early adopters of blockchain technology within the supply chain domain. Additionally, we explore fingerprinting techniques to establish a robust connection between physical products and the blockchain ledger. The findings shed light on the transformative potential of blockchain technology and offer valuable insights into its implementation for optimizing supply chain operations.

Design/methodology/approach – We use a comprehensive methodology to study the current body of knowledge on blockchain technology's potential in reshaping supply chain management. This methodology combines a systematic literature review (interpretive sensemaking), content analysis (using Leximancer text mining software) for concept mapping and qualitative thematic analysis for data categorization (NVivo).

Findings – The algorithmic concept mapping of the combined corpus of academic and industry literature on blockchain research for supply chain provenance reveals several crucial components: value, quality, authenticity, transparency, and consumer trust. Furthermore, the main drivers for the early adoption of blockchain technology are perishable goods, high-value products, long-chain custody merchandise, and sustainability claims. The research also highlights the importance of provenance information to consumers, with blockchain technology offering certainty and increasing customer loyalty toward brands that prioritize transparency. Nevertheless, the study acknowledges that while blockchain technology provides a secured digital trace of transactions, it does not guarantee a physical product's linkage to the ledger. To address this limitation, we propose using product fingerprinting techniques that directly tag physical products rather than packaging methods like RFID.

Originality/value – This study contributes significantly to the existing literature by consolidating current knowledge on blockchain's capacity to increase consumer trust and deliver competitive advantages to early adopters in the supply chain domain. Unlike previous manuscripts focusing on blockchain's financial aspects, this analysis identifies specific drivers and business values associated with early blockchain adoption in supply chain management. Furthermore, the study underscores the critical role of product fingerprinting techniques in supporting blockchain for supply chain provenance, paving the way for more robust and efficient supply chain operations in the future.

Key Words: Blockchain, Supply Chain Provenance, Value, Transparency, Authenticity, Early Adoption, Consumer Trust, Product Fingerprinting

2. Introduction

Global supply chains have become increasingly complex as supply networks grow to meet the needs of an expanding global population. For instance, large corporations like Total Energies and Walmart now rely on approximately 100,000 suppliers each (TotalEnergies, 2022; Walmart, 2022), making supply chain visibility and management a crucial concern. The COVID-19 crisis exacerbated the fragility of these supply chains, underscoring the need for better solutions. A key issue lies in the lack of visibility within supply chains, which hinders proactive disruption management and presents opportunities for substituting genuine goods with substandard or counterfeit products.

Many existing supply chain data systems are ill-equipped to validate synchronized and authenticated shipment tracking throughout the logistics cycle. Common technologies like radio frequency identification (RFID) tags and barcodes, though widely used for product identification, suffer from limitations in data storage and supply chain interoperability (Basole & Nowak, 2018; Bokolo, 2022). In addition, the maintenance of data systems and reliance on paper-based records for sharing information with third parties contribute to operational inefficiencies (Yiannas, 2018).

In response to these challenges, blockchain technology emerges as a promising solution, offering a platform for accurate and secured transactional records across multiple parties to facilitate supply chain traceability (Kamble et al., 2020). By leveraging the blockchain's secure custody chain, all parties can access critical data for precise product identification, location tracking, and proper handling (Hughes et al., 2019). By integrating a network of physical sensors with the transactional data layer, blockchain-powered supply chains validate product provenance and enhance track and trace capabilities (Laskowski & Kim, 2018). Blockchain technology secures the supply chain network using encryption to record transaction data on the ledger. It also combines automated sensor data with smart contracts to verify product milestones, such as location or temperature, allowing businesses to efficiently monitor biophysical conditions in the cold chain, such as the temperature and humidity of perishable goods (Pournader et al., 2020).

Blockchain technology can reduce costs by minimizing stockouts and tightening inventory control (Liu & Li, 2019; Queiroz & Fosso Wamba, 2019). Blockchain can tighten inventory control by decreasing the average annual inventory carried and thus reducing holding costs. Blockchain can also mitigate product shortfalls by enhancing visibility to all participants (Falcone et al., 2021), enabling improved response times and/or shorter lead times. Through trusted and reliable data sharing across multiple supply network tiers (Jain et al., 2020; Yavaprabhas et al., 2022), blockchain reshapes business-to-business and business-to-consumer relationships (Queiroz et al., 2019) by enabling all parties to trace product provenance, certify authenticity, and monitor custody and integrity (Montecchi et al., 2019). Blockchain technology empowers companies to meet customer demands efficiently by lowering costs and improving supply chain flexibility. As a result, all stakeholders become interdependent on blockchain technology once adopted, driving holistic changes in value creation (Witt & Schoop, 2023). This systematic literature review provides a comprehensive overview of blockchain technology applications for supply chain provenance. We scrutinize academic and industry literature domains through algorithmic-driven content and thematic analysis, examining early pioneer companies and their use cases of blockchain technology implementation. We also categorize the type of products, business drivers, and business values associated with the adoption of blockchain technology. Furthermore, we explore fingerprinting techniques to link physical products to the blockchain ledger in supply chains, offering a robust defense against counterfeiting and fraud.

2.1. Purpose and Research Questions

This paper examines peer-reviewed academic and editorial-reviewed business literature to analyze the commercial justifications of early adopters who integrated blockchain technology into their supply chains. The main objectives are to uncover the business values attained through blockchain adoption, identify specific product characteristics that justified the innovation efforts of actual companies, and explore associated fingerprinting methods to establish a connection between tangible goods and their corresponding digital counterparts. Through this investigation, the study seeks to enhance the understanding of blockchain's role in supply chain management and its potential to deliver tangible benefits. It also synthesizes the current state of academic and industrial investigations, identifies related concepts, and pinpoints gaps in the literature, paving the way for future research directions. To guide our investigation, we formulated three research questions:

RQ1. What is the current state of academic and industry literature concerning the use of blockchain technology to enhance supply chain provenance and meet customer demand for product authenticity?

RQ2. What are the driving factors, product characteristics, or service attributes that prompted the early adoption of blockchain technology in the supply chain, and what are the business values achieved through this adoption?

RQ3. How can the link between physical products flowing through the supply chain and their corresponding digital records on the blockchain be assured to establish and maintain provenance?

2.1.1. Blockchain: Traceability, Transparency, Trust

Blockchain technology, initially introduced in the well-known Bitcoin white paper by Satoshi Nakamoto (2008), revolutionized electronic transactions, eliminating the need for trust by using a peer-to-peer network and proof-of-work to record a public history of transactions. Blockchain evolved from database technologies, encompassing a distributed ledger (DLT) that appends records with timestamped transactions bolstered by cryptographic techniques and consensus mechanisms to preserve data integrity (Chang & Chen, 2020; Falcone et al., 2021). Originally conceived as a new form of digital currency, blockchain's applications have expanded beyond monetary transactions. As a DLT, blockchain can update and validate end-to-end product traceability data in the supply chain. Cryptographic hash functions ensure the integrity and completeness of records, with each network node verifying the information's accuracy (Pournader et al., 2020; Queiroz & Fosso Wamba, 2019). Blockchain's immutability feature allows for real-time, tamperproof records, facilitating efficient communication in complex and fragmented supply chains (Garrard & Fielke, 2020; Kouhizadeh & Sarkis, 2018). The decentralized nature of blockchain enables instant data updates across all network participants, providing a shared data history and ownership of transactions (Catalini & Michelman, 2017; Hastig & Sodhi, 2020), making it efficient and scalable (Mahyuni et al., 2020). Blockchains were designed initially as open distributed ledgers, but differences in functionality exist between platforms, such as those of Bitcoin and Ethereum.

Blockchain ledgers can be private (closed, permissioned) or public (open, permissionless); for consistency, we only use the terms private and public blockchains instead of other similar terms. In private ledgers, participation is restricted and typically managed by a consortium of stakeholders (Sternberg et al., 2020). Most blockchain trials in supply chain management use private ledgers, often employing the 'proof of authority' algorithm consensus mechanism (O'Leary, 2017). For instance, IBM's Food Trust implemented a private blockchain consortium for supply chain traceability, with participants including Walmart, Nestlé, Carrefour, and Maersk (Carrefour, 2019a; Nestlé, 2019a; O'Leary, 2017), with database access controlled to ensure within-group privacy and control protocols. Conversely, public ledgers require substantial data processing capacity, with all transactions publicly accessible and user anonymity maintained (Li et al., 2021; Sternberg et al., 2020). Another key benefit of blockchain in supply chains is its ability to prevent the infiltration of counterfeit products or ingredients (Rogerson & Parry, 2020), improving public safety and facilitating faster detection of problems.

While collaboration and information sharing among supply chain partners are crucial, companies must protect their proprietary data from competitors. Hence, most favor private ledgers due to concerns regarding data exposure and potential leakage of business intelligence to rival companies (Hald & Kinra, 2019; O'Leary, 2017; Wang et al., 2019). The decision to implement a private or public blockchain will depend on the business environment and the specific advantages companies seek to gain over their competitors

(Chang & Chen, 2020). Organizations can evaluate the potential value of blockchain technology in minimizing paper-based processes, improving traceability methods, and securing provenance data (Chang et al., 2019). Blockchain technology is poised for further advances in proofs of concept, standardization, collaboration, and integration with other technologies in the next few years. These developments are expected to drive broader adoption of blockchain in supply chain management and unleash its transformative impact. Gartner (2019) predicts an increase in blockchain trials for food traceability and safety among the top global grocers by 2025.

2.1.2. Supply Chain Provenance

The concept of provenance draws from its traditional use in the art world, referring to the record of ownership for an art piece, serving as evidence for its authenticity and origin. Supply chain provenance goes beyond ownership, encompassing a comprehensive record of proprietary and all transactions and activities as raw materials and finished goods traverse the supply chain (MacCarthy et al., 2016). This record includes detailed information on the location, handling entities, and timing of each asset's manipulations. In this study, we define 'provenance' as the collection of all recorded activities (possibly stored in a blockchain) that verify the origin of all material inputs and the processes occurring in the supply chain (Al-Mudimigh et al., 2004). The recorded activities span various supply chain stages, including procurement and sourcing, manufacturing, packaging and assembly, warehousing, inventory management, inbound and outbound transportation, and customer relationship management (Al-Mudimigh et al., 2004). Whether in biological or digital form, the provenance information of entities involved in the supply chain (Swan, 2015) assumes great significance in our emerging digital societies. The ability to capture and validate this provenance information using blockchain technology contributes to enhanced supply chain transparency and trust in the next generation of digital ecosystems.

2.2. Literature Review Methodology

A systematic literature review (SLR) was selected as the research methodology for this study to examine the existing body of knowledge, offering a rigorous methodology to comprehensively and impartially ensure a straightforward research approach on blockchain for supply chain provenance (Durach et al., 2017). We followed Durach et al. (2017) six-step process since it was designed for supply chain management research. The six-step methodology guarantees that the research questions are well-defined, the data collection process is systematic, and the analysis is thorough and transparent (Durach et al., 2017). Contributing to the overall quality and validity of the research, making it a robust and valuable contribution to the blockchain and supply chain management field.

The SLR review protocol of Durach et al. (2017) involved (1) delineating research questions; (2) defining the characteristics of primary studies; developing a search strategy with appropriate search terms and keywords, and establishing inclusion and exclusion criteria; (3) retrieving a sample of potentially relevant literature; (4) selecting the pertinent literature; (5) synthesizing the literature; and (6) reporting the findings. The screening process involved evaluating the relevance of literature based on titles, abstracts, and keywords, focusing on the central topic of blockchain and supply chain provenance and their related concepts. The selected studies were required to address the connection between blockchain and supply chain provenance, covering concepts such as traceability, origin, and source. The data extraction and analysis were carried out by identifying key patterns and trends, synthesizing the collected information, and reporting our findings.

Three research questions were formulated to initiate the review, and a comprehensive search strategy was devised using various word strings and Boolean operators. The search was conducted across multiple online databases, including Scopus, Web of Science, Harvard Business Review, Google Scholar, and specialized industrial sites, covering literature from

January 2008 to March 2023. The search terms included the following word strings: ‘Blockchain AND Supply Chain,’ ‘Blockchain AND Supply Chain Provenance,’ ‘Blockchain AND Supply Chain Origin,’ ‘Blockchain AND Supply Chain Traceability,’ ‘Blockchain AND Supply Chain Source,’ ‘Customers AND Supply Chain Trust,’ ‘Fingerprinting Analysis,’ ‘Chemical Profiling Analysis,’ ‘Forensic Traceability,’ ‘Genetic Markers OR Geochemistry of the Environment AND Supply Chain.’

See Table 2, which summarises the study's research questions and the related search strings.

Table 2. Summary of the research questions and search strings

	Research Questions/Aims	Search String
Study 1	RQ1. What is the present state of the academic and industry literature regarding the use of blockchain technology to enhance supply chain provenance to fulfil the customers' demand for product authenticity?	‘Blockchain AND Supply Chain,’ ‘Blockchain AND Supply Chain Provenance,’ ‘Blockchain AND Supply Chain Origin,’ ‘Blockchain AND Supply Chain Traceability,’ ‘Blockchain AND Supply Chain Source’ ‘Fingerprinting Analysis,’ ‘Chemical Profiling Analysis,’ ‘Forensic Traceability,’ ‘Genetic Markers OR Geochemistry of the Environment AND Supply Chain’
	RQ2. What are the driving factors and products or service characteristics that have led to blockchain's early adoption in the supply chain, and what are the business values achieved?	
	RQ3. How can the link between physical products flowing through the supply chain and the corresponding digital records on the blockchain be assured to establish and maintain provenance?	

Cross-referencing citations in the collected literature resulted in 382 relevant articles from peer-reviewed and industry literature. The industry literature was identified from the companies’ official pages, which were comprised mainly of reports, white papers, and articles on the blockchain endeavours done by these firms.

The industry literature was used to identify 'use cases' and map key drivers and business values obtained by blockchain early adopters for supply chain management. After the screening phase, 146 articles were selected, with 60% academic and 40% industry literature.

A major contribution of our SLR study is presenting a new framework for categorizing literature reviews (inductive, contextualized explanations, theory testing, and interpretive sensemaking) by Durach et al. (2021). Specifically, our SLR belongs in the interpretive sensemaking category (explore and compare perspectives of individual actors) with some overlapping elements of contextualized explanations (integrating previous literature). This SLR approach aims to synthesize existing knowledge into one objective truth, illuminating how individual actors in supply chains (use cases in our study) 'make sense' of their realities (Durach et al., 2021). Sensemaking theory fits well in situations with limited understanding and agreement on the relevant phenomena and their connections (Durach et al., 2021), such as the evolving nature of blockchain technology in the supply chain domain.

Content and thematic analyses were conducted using Leximancer software to categorize and synthesize the articles. The software has advanced natural language processing and data visualization techniques, enabling the automatic identification of key concepts, themes, and relationships within a large corpus of textual data. We used NVivo software to classify, query, and gain insights into topics of interest. The validity of this study was established through the SLR methodology, with well-defined research questions and a structured sampling approach (consistent inclusion and exclusion criteria to ensure our predefined specifications). Researchers independently followed the SLR methodology, screening and assessing the suitability of studies based on the predefined criteria to ensure consistency and address discrepancies through consensus. Integrating Leximancer and NVivo in the analytic process increases the rigor, reliability, and flexibility of the research when dealing with large amounts of data without bias, identifies a broader span of syntactic properties, and ensures reproducibility (Penn-Edwards, 2010; Poniman et al., 2015; Sotiriadou et al., 2014). The literature review results are presented using a framework adapted from the PRISMA template, outlining the review protocol in this study (Figure 1).

Figure 1. SLR Review Protocol Outline based on Durach et al. (2017) guidelines (defining primary studies, search strategy, screening, selection and synthesis of the literature) and adapted from PRISMA template.

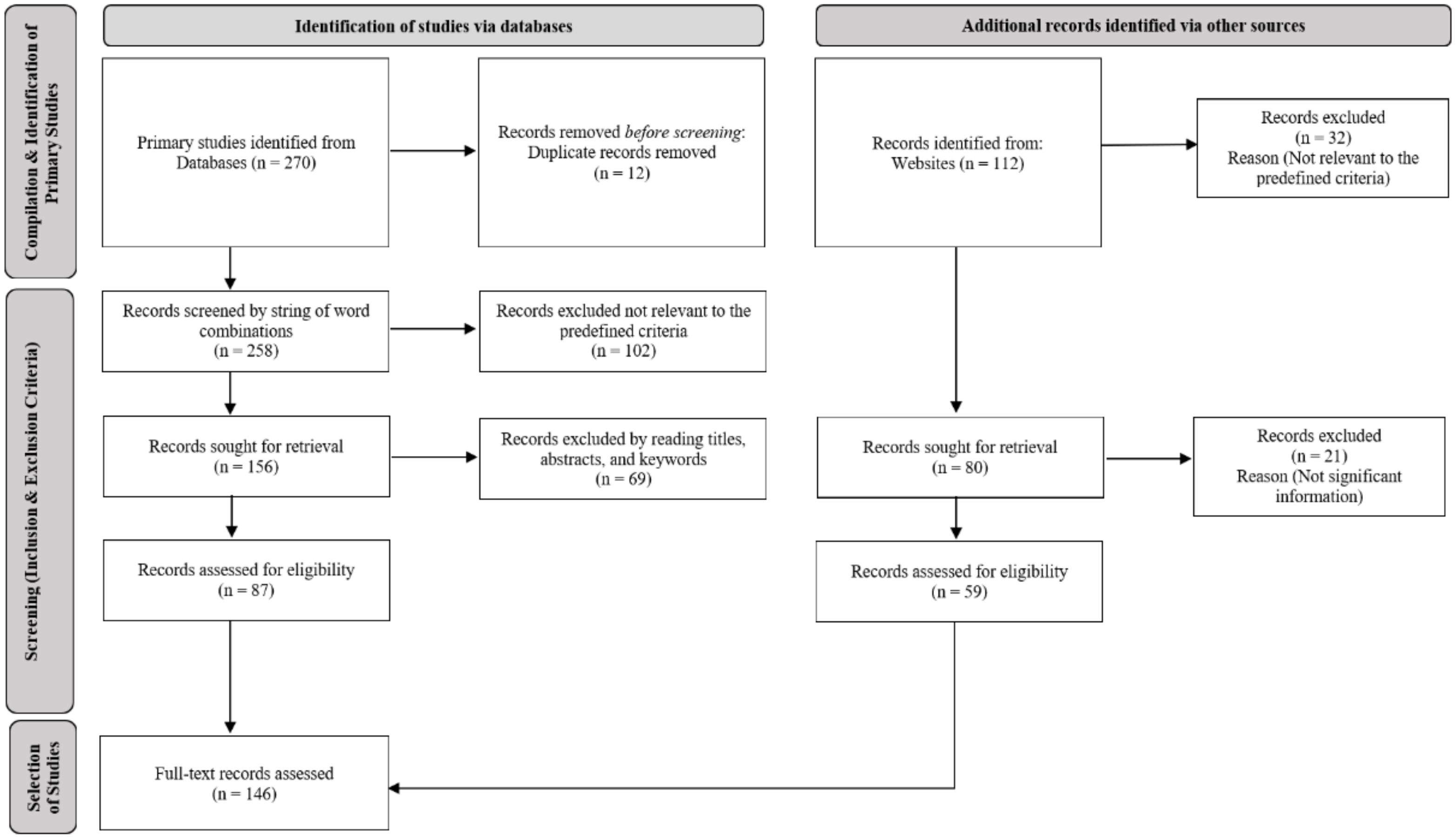


Figure 1. SLR Review Protocol Outline based on Durach et al. (2017) guidelines (defining primary studies, search strategy, screening, selection and synthesis of the literature) and adapted from the PRISMA template.

2.2.1. Literature Review Trends

In this SLR, 146 sources were analyzed, with 60% being academic and 40% non-peer-reviewed industry articles. Non-peer-reviewed articles were included to bridge the gap between academic research and industry practices and identify relevant 'use cases' to enhance the robustness of the SLR findings (Durach et al., 2017). Other studies have combined peer-reviewed and industry literature (Tranfield et al. (2003), industry papers and third-party reports (Duan et al. (2020), media pieces, and blog posts (Pournader et al. (2020) to gain insights into real-world experiences. Rogerson and Parry (2020) applied industry literature to provide empirical examples of blockchain experiments in the food supply chain. Similarly, Chang and Chen (2020) determined that academic and industry literature was valuable for examining blockchain applications. Friedman and Ormiston (2022) combined industry expert interviews and academic literature to assess difficulties with blockchain applications in the supply chain. Li et al. (2021) also analyzed industry leading blockchain platforms used in the food industry. As an emerging technology for supply chain management, blockchain trials must strike a qualitative balance between theoretical perspectives (academic inquiry) and evidence-based practices (successes by industry innovators), resulting in a well-informed and practical review of the topic. This approach can identify common key drivers for the early adoption of blockchain technology in supply chain management. Of the 87 academic sources analyzed in this SLR, 84 are peer-reviewed manuscripts published in top-tier journals (mostly in Quartile 1), of which 58 exclusively focus on blockchain applications in supply chain management.

Table 2 displays the top ten journals with the highest publications count of our peer-reviewed selected articles.

Table 3. Top ten journals with the highest count of publications

Journal	Number of articles
Business Horizons	7
International Journal of Production Research	5
IEEE Access	4
Sustainability	3
International Journal of Operations & Production Management	2
Journal of Enterprise Information Management	2
Journal of Business Logistics	2
Information Systems and e-Business Management	2
Supply Chain Management	2
Intelligent Systems in Accounting, Finance and Management	2

2.2.2. Algorithmic Content Analysis

Integrating algorithmically driven content analysis enhances the reliability and reproducibility of the SLR, providing valuable insights and complementing the qualitative assessment conducted by the researcher(s). We partitioned our literature corpus into two exhaustive and disjoint subsets to understand the key drivers of blockchain adoption for supply chain provenance in academic and industry research. This partitioning revealed differences and similarities between commercial and academic research activities. For the content analysis, we used Leximancer, a machine-learning text-data mining software developed at the University of Queensland (Leximancer, 2018). This software has been widely used in noteworthy academic publications (Goudarzi et al., 2021; Kim & Kim, 2017; Kunz et al., 2019). It applies statistical algorithms to perform text-to-data analysis, identifying related concepts and grouping them into higher-level themes. Figure 2 illustrates the outcome of the content analysis. The identified themes are represented as heat-mapped circles, each enclosing the concepts associated with each theme. The concepts are depicted as small circles connected by lines, forming a graph or spanning tree. The correlation between themes is measured through frequency counts, depicted as a Venn diagram representing the 'probability intersection' of co-occurrences. The lines connecting the nodes display the relationships between related concepts (Randhawa et al., 2016). Figure 2a presents the concept map of the themes and key concepts extracted from the academic sources, with each theme depicted as a folder. The circle size reflects each theme's relevance, and each circle's color represents a unique theme. Key concepts are represented as nodes in a network, and the proximity between nodes indicates the strength of semantic similarity. Concepts that are not connected directly imply an absence of semantic relationships (Sotiriadou et al., 2014).

1.4.2.1. Academic Literature

The analysis of academic literature revealed six prominent themes, ranked in descending order of importance based on their size: Blockchain, Data, Products, Systems, Tracking, and Innovation. Blockchain emerged as the primary theme, directly intersecting the tracking theme, indicating a semantic relationship between blockchain and supply chain traceability. This correlation implies that blockchain technology is crucial in enhancing the tracking processes within the supply chain. Within the blockchain theme, concepts related to the adoption of blockchain technology, applications, and benefits lead to an innovation theme, with the tracking theme intersecting with the blockchain and innovation themes, inferring that blockchain technology is valuable for tracking processes. The data and systems themes also intersect, highlighting the semantic association between concepts related to data (smart contracts, transactions, network, and costs) and systems (traceability, trust, transparency, and costs) themes. Data transparency and smart contracts can reduce costs and improve traceability, fostering greater trust among supply chain actors. The products theme strongly intersects the systems theme and slightly intersects the tracking theme, underscoring the importance of transparent data networks for traceability and origin identification.

1.4.2.2. Industry Literature

The analysis of industry literature yielded six prominent themes, ranked in descending order of importance based on their size: Blockchain, Data, Transparency, Systems, Process, and Provenance (Figure 2b). The central theme among industry literature is blockchain, which directly intersects the transparency, provenance, and data themes. This finding is consistent with the literature review's assertion that the industry is actively exploring and implementing blockchain technology solutions to strengthen supply chain traceability. The systems theme emphasizes the prevalence of blockchain pilots focused on data traceability, transparency, and trust, particularly within the food industry. The process theme suggests that blockchain technology is being applied to streamline network operations and reduce potential bottlenecks. The provenance theme highlights the significance of blockchain technology in tracking and authenticating the origin and history of products or materials within the supply chain, creating tamperproof and auditable records to ensure the security and reliability of provenance transactions.

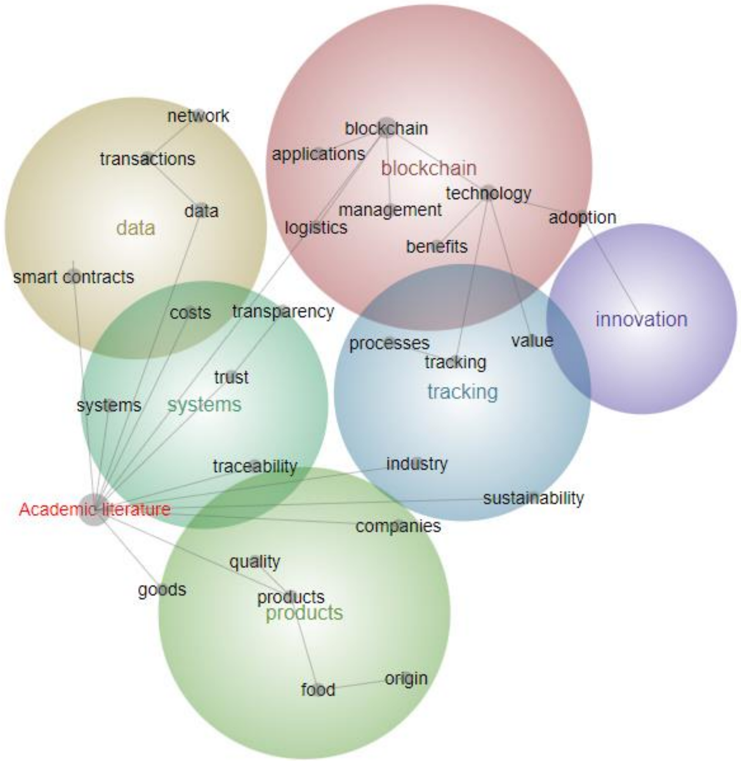


Figure 2a. Academic literature concept map

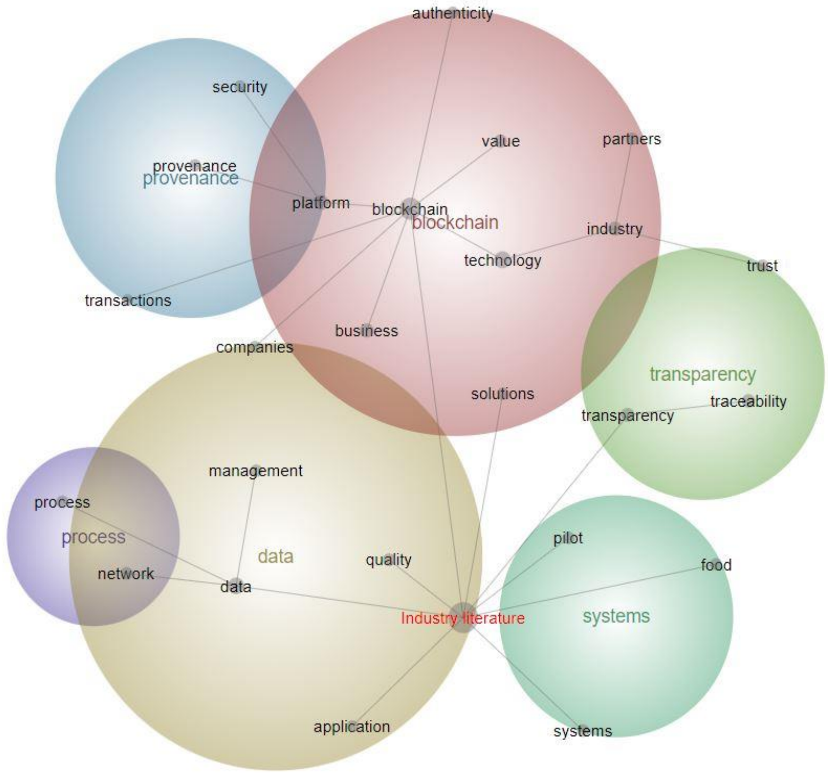


Figure 2b. Industry literature concept map

Figure 2. Concept Maps

2.2.3. Comparative Content Analysis of Academic vs. Industry Literature

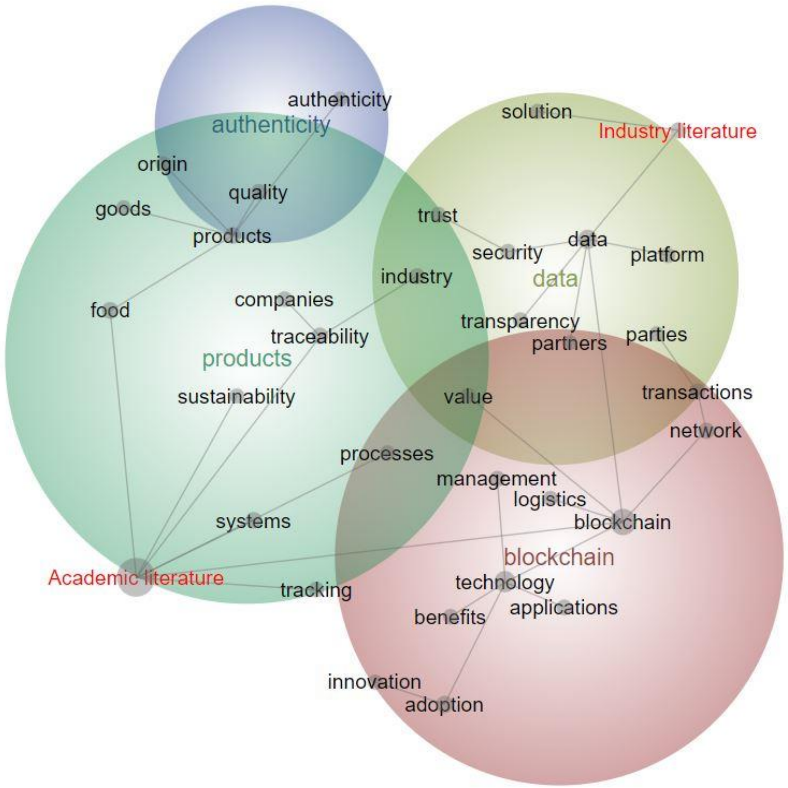


Figure 3. Theme and concept map convergence of academic and industry literature

In addition to analyzing the academic and industry literature as two distinct sets, we combined them into a single thematic analysis to develop insights into commonalities and differences (Figure 3). Table 3 shows the themes and concepts from Figures 2 and 3 in table form to support our discussion.

A cursory inspection of Table 3 reveals, unsurprisingly, that ‘Blockchain’ and ‘Data’ are the two common themes across the algorithmic presentation of the literature when analyzed separately and when merged. ‘Products’ is a common theme across the academic literature and the combined corpus but did not emerge as a theme or a concept in the industry literature. ‘Authenticity’ emerged as a major theme across the combined corpus as a single, higher-order construct for the remaining themes developed from the independent analysis: Tracking, Systems, Innovation, Transparency, and Process. The organization of the underlying network of concepts supporting each theme differs significantly between the independently developed and the combined concept maps. A detailed inspection of these differences reveals valuable insights (see the discussion section 6 later in this chapter).

Table 4. Summary of Concepts and Themes for Comparison

Academic Themes & Concepts (Figure 2a)		Industry Themes & Concepts (Figure 2b)		Combined Themes & Concepts (Figure 3)	
Blockchain	Applications, Logistics, Technology, Adoption, Benefits, Management	**Blockchain**	Authenticity, Platform, Value, Partners, Industry, Technology, Business, Solutions	**Blockchain**	Partners, Value, Transaction, Network, Processes, Management, Logistics, Technology, Benefits, Innovation, Adoption, Applications
Data	Network, Transactions, Smart Contracts, Costs	**Data**	Companies, Management, Network, Quality, Application	**Data**	Solutions, Trust, Security, Data, Platform, Industry, Transparency, Partners, Parties, Value, Transactions
Products	Goods, Qualities, Companies, Food, Origin	Provenance	Security, Platform, Transactions	Products	Origin, Goods, Quality, Trust, Food, Companies, Industry, Traceability, Sustainability, Process, Systems, Tracking
Tracking	Processes, Value, Industry	Transparency	Traceability, Trust	Authenticity	Origin, Products, Quality
Systems	Traceability, Trust, Cost, Transparency	Systems	Pilot, Food		
Innovation		Process	Network		

Insight #1. The academic literature shows that the 'value' theme is most closely associated with the 'tracking' theme, which sits uniquely within the larger theme (Figure 2a). In contrast, the industry literature shows that the ‘value’ theme is most closely associated with the ‘blockchain’ theme, which also sits uniquely within the larger theme (Figure 2b). However, combining these two bodies of knowledge reveals that the ‘value’ theme intersects the ‘blockchain,’ ‘data,’ and ‘products’ themes (Figure 3). This insight visually demonstrates the bias/focus in each body of literature. The academic map (Figure 2a) indicates that the literature focuses on ‘value’ created by tracking improvements, whereas the industry map (Figure 2b) shows that the literature focuses on ‘value’ created more generally with ‘blockchain.’ The combined literature map reveals an appealing, intuitive logic: ‘value’ cannot and should not be uniquely associated with a single theme but has profound interdependencies across themes. Importantly, those interdependencies are only exposed when the algorithms are presented with a robust academic/industry corpus.

Insight #2. The academic literature shows that the ‘quality’ theme is most closely associated with the ‘products’ theme, which sits uniquely within the larger theme (Figure 2a). In contrast, the industry literature reveals that the ‘quality’ theme is most closely associated with the ‘data’ theme, which also sits uniquely within the larger theme (Figure 2b). The combined literature map shows that the ‘quality’ theme intersects the ‘authenticity’ and ‘products’ themes (Figure 3), revealing that the academic literature focuses on product quality issues, while the industry literature focuses on data quality issues. Presenting the full body of knowledge to the algorithms reveals that the ‘quality’ theme is associated with the ‘authenticity’ and ‘products’ themes. Both the academic and industry literature emphasize the advantages of blockchain adoption in improving data traceability, particularly for supply chains in the food industry. Unsurprisingly, academia has primarily provided theoretical frameworks and a conceptual understanding of blockchain adoption, while the industry has focused on practical applications and real-world solutions.

Insight #3. The academic literature shows that the 'trust' theme is most closely associated with the 'systems' theme, which sits uniquely within the larger theme (Figure 2a). In contrast, the industry literature shows that the 'trust' theme is most closely associated with the 'transparency' theme, which also sits uniquely within the larger theme (Figure 2b). The combined literature map shows that the 'trust' theme intersects the 'data' and 'products' themes (Figure 3), revealing that the academic literature focuses on 'trust' issues in information 'systems,' while the industry literature sees 'transparency' as a larger theme that supports or leads to 'trust.' Presenting the full body of knowledge to the algorithms reveals that the 'trust' theme is associated with the 'data' and 'products' themes, with 'transparency' playing a key role in consumer perception of 'authenticity'. This insight suggests that data traceability and transparency are essential for establishing trust within the supply chain, which can enhance brand reputation and increase consumers' perceived value.

2.3. Qualitative Analysis of the Literature on Blockchain for Supply Chain Provenance

This section qualitatively reviews and assesses the corpus of literature on adopting blockchain technology for improving supply chain provenance, including blockchain applications for improving traceability and visibility, supporting sustainability and recycling, improving process efficiency, and using smart contracts to disintermediate some supply chain actors.

2.3.1. Traceability and Visibility

Ensuring traceability and visibility in supply chains is paramount, particularly in sectors such as food and pharmaceuticals, where contamination or counterfeiting can have severe consequences for public health and safety. According to the World Health Organization

(2022a), nearly 1 in 10 people contract a disease, and 420,000 die from exposure to contaminated food. Such foodborne diseases impact public health and hinder socioeconomic progress, straining healthcare systems and damaging economies.

Traditional computer systems often lack the necessary data security, leading to supply chain failures (Hastig & Sodhi, 2020; Li et al., 2021) and difficulties in identifying the source of contamination during outbreaks (Niu, Shen, et al., 2021). Blockchain offers robust traceability capacities that can enhance food safety, combat food fraud, and facilitate product recalls by auditing the entire chain of custody, which empowers brands to minimize supply chain risks and promptly trace and remove contaminated products from circulation (Duan et al., 2020; Friedman & Ormiston, 2022).

Similarly, counterfeit medical goods pose significant consumer risks and have substantial economic impacts on the pharmaceutical industry. The World Health Organization (2018) estimates that 1 in 10 medical goods is counterfeit in low-and middle-income countries. By leveraging blockchain as an anticounterfeiting solution (Casino et al., 2019), the ownership and chain of custody of medical goods can be reliably tracked to help mitigate the risks associated with fraudulent products (Hastig & Sodhi, 2020; Musamih et al., 2021; Niu, Dong, et al., 2021), ensuring consumer safety and maintaining the integrity of the pharmaceutical supply chain.

The benefits of blockchain extend beyond routine operations, particularly during crises like the COVID-19 pandemic. Blockchain technology has proven invaluable in expediting the movement of essential products, identifying alternative suppliers, and redistributing resources. For instance, Hashgraph (2021) collaborated with a National Health Service group in the UK to monitor the cold chain storage of COVID-19 vaccines using distributed ledger technology. By providing real-time monitoring and transparency, blockchain facilitated the urgent allocation and distribution of vaccines to pressing populations, ensuring their effective utilization. In high-risk environments prone to counterfeiting and supply chain vulnerabilities, companies are increasingly adopting blockchain technology to secure end-to-end security and transparency at all supply chain stages.

2.3.2. Sustainability and Recycling

By leveraging blockchain, supply chain participants can accurately measure the full lifecycle effects of products, leading to a more comprehensive understanding of their environmental impact and promoting the circular economy (make-use-recycle pattern). One innovative model in this context is the Triple Retry model proposed by Centobelli et al. (2022). This model combines blockchain technology with end-of-life goods' data, integrating three key reverse supply chain processes—recycle, redistribute, and remanufacture—with blockchain's three core architectural features: trust, traceability, and transparency. The Triple Retry model enables the implementation of circular supply chain models where manufacturers can improve the efficiency of product components and repurpose them to create novel products (Centobelli et al., 2022), contributing to resource conservation and waste reduction.

Moreover, this model enables businesses to validate sustainability claims, enhancing their credibility and acceptance in industries seeking to enhance their prestige and reputation through sustainable practices (Kouhizadeh & Sarkis, 2018). Blockchain also has the potential to influence consumer behavior and foster awareness, encouraging consumers to adopt better consumption and disposal behaviors by tracing products from their origin to the point of sale. In addition, blockchain can incentivize recycling behaviors by implementing rating and reward systems that use the same technology to motivate consumers to actively participate in recycling, rewarding them for contributing to the circular economy and promoting compliance (Centobelli et al., 2022) with recycling management strategies.

2.3.3. Process Efficiency

Blockchain technology can significantly enhance process efficiency within supply chains. Accountable businesses are increasingly interested in implementing traceability methods that guarantee sustainability, product lifecycle transparency, waste reduction, carbon footprint tracking, and promote fair trade practices. H. Wang et al. (2021) demonstrated that companies piloting blockchain technology experienced notable improvements in sales growth and reduced product returns. These positive outcomes were attributed to the improved coordination between upstream and downstream supply chain activities and enhanced channel management. A blockchain simulation study revealed a remarkable 65% reduction in processing time for placing new orders and a 60% reduction in overall operational time, reducing warehousing space utilization and improving visibility across the supply chain (Martinez et al., 2019).

2.3.4. Smart Contracts and Disintermediation

Blockchain technology can use smart contracts, with self-executing computer codes embedded within a blockchain system and governed by predefined parameters. Smart contracts are impartial mechanisms over negotiation, unlocking resources automatically, triggering notifications, and fulfilling arrangements after meeting specified conditions (Chang et al., 2019; Queiroz et al., 2019). Smart contracts generate significant advantages, including simplifying processes and payment automation, reducing the need for intermediaries, simplifying contracts, digitizing repetitive procedures involving extensive paperwork, and streamlining supply chain operations (Chang et al., 2019; Li et al., 2021; Wang et al., 2019). Using smart contracts in blockchain-based systems shifts the trust from the participants to the code, where stakeholders cannot deviate from the predetermined business logic, reducing the error rate (Markus & Buijs, 2022). Traditionally, payment settlements in supply chains involve multiple intermediaries and lengthy reconciliation procedures. Actors must gain approval through smart contract agreements and consensus before entering data into product profiles or initiating trades with other parties (Omar et al., 2022; Saberi et al., 2019). Moreover, smart contracts can integrate external data sources, such as IoT devices, to monitor and enforce the physical characteristics of products within a supply chain. For example, in a cold chain for sensitive products like vaccines, smart contracts in a blockchain can monitor temperature readings from IoT sensors and automatically execute corrective actions or alert stakeholders without human intervention (Pournader et al., 2020; Risius & Spohrer, 2017). In terms of compliance and governance, smart contracts can incentivize and penalize stakeholders in the supply chain, promoting responsible industry practices, facilitating on-time operations, and encouraging cooperation (Saberi et al., 2019; Yoon & Pishdad-Bozorgi, 2022). However, the adoption of smart contracts in supply chains depends on the maturity of blockchain technology, the adaptation of several layers of governance dimensions in virtual enterprises, and the alignment with economic processes (Bokolo, 2023; Chang et al., 2019).

2.3.5. Consumer Behavior

Consumer behavior has significantly shifted towards sustainability and eco-friendliness, with many consumers prioritizing ethical and environmentally conscious products. Many consumers want to know where products come from, but most brands cannot reveal their full history. Xu and Duan (2022) indicate that consumers have developed a high sensitivity to environmental issues, with about 20% of customers prepared to pay a premium for eco-friendly products. This finding suggests that a significant segment of consumers is willing to prioritize sustainability and ethical considerations in their purchasing decisions. Consumer preferences are also shifting toward more ethical practices, particularly in the luxury fashion sector (Cheah et al., 2016; Kshetri, 2018). However, consumers often face information asymmetry regarding product origins and production processes, leading to potential risks and health consequences (Montecchi et al., 2019). For example, a food contamination incident in China, where milk baby formula was diluted deliberately with melamine, a chemical known to cause kidney stones and damage (Ellis et al., 2012), led to widespread health consequences, including hospitalizations and, tragically, infant deaths.

Moreover, when firms market green products to consumers, incomplete product provenance information can affect consumer buying intentions (Kim et al., 2008), as consumers may associate a brand misconduct event with the entire industry (Laufer & Yijing, 2018). To counteract these negative associations, brands must proactively communicate their ethical practices, transparency initiatives, and quality control measures. Despite perceived brand misconduct, consumers may assimilate the perceived risk if they are confident the brand will be accountable for their product or service (Featherman & Pavlou, 2003). Likewise, privacy and security are crucial factors influencing consumer purchase decisions, as consumers prioritize protecting their personal information and ensuring secure transactions (Cheah et al., 2016; Kim et al., 2008). Continuous brand evaluations by consumers manifest in behavioral loyalty, involving an emotional attachment and trust in the authenticity of the brand's products. The emergence of technologies like smartphone barcode scanning empowers consumers to verify product information and trace its origins (Jain et al., 2020). A prime example is the Chinese company JD, which uses a blockchain platform to allow consumers to access detailed information such as sources, manufacturing process, packaging date, and shipment identifier tied to a single SKU by scanning a QR code (H. Wang et al., 2021).

One of the main incentives for companies to participate in blockchain traceability systems is to raise consumers' perceived trust in their brands and minimize perceived risks associated with purchasing and consumption (Montecchi et al., 2019; Westerkamp Martin et al., 2020). Blockchain challenges current business models and introduces new value exchange options for customers (Morkunas et al., 2019), allowing companies to differentiate themselves from their competitors by claiming transparent supply chain processes (Li et al., 2021; Musamih et al., 2021; H. Wang et al., 2021). H. Wang et al. (2021) report that blockchain technology can endorse companies' marketing endeavors by refining service levels and bringing brands closer to consumers, making them more responsive and customer-centric. The managers surveyed in the study reiterated that product quality, safety, and authenticity are pressing factors for building consumer trust and preference.

2.4. Use Case Analysis of Early Adopters

Blockchain applications for supply chain provenance are in the early stages and predominantly experimental (Gurtu & Johny, 2019; Li et al., 2021). Nevertheless, many companies recognize its potential for adding value to supply chain management. Our analysis, inspired by Del Castillo (2021) report in Forbes Business magazine, focused on notable firms exploring blockchain adoption. We set a threshold of at least US$1 million turnover for eligibility due to the presence of startups among the investigated companies and account for the extent of business practices related to blockchain adoption in the supply chain. Data was collected from the official web pages of 50 firms worldwide, including annual reports, official announcements, and other relevant sources. Table 4 synthesizes the most prominent blockchain pilots in the supply chain performed by early adopters. By examining blockchain adoption drivers across different industries and the products and service characteristics involved, we endeavored to understand the factors motivating firms to implement this technology and the geographical distribution of its implementation. The analysis revealed that the custody chain of products presents a significant challenge in supply chain traceability, underscoring the need for more accurate systems. For instance, the fine art market traditionally places a high value on the provenance of artworks, where the chain of custody reflects the entire ownership history, impacting its value over time.

Everledger (2021b) developed a blockchain-based platform for the art registry, providing collectors with provenance information, including details like piece condition, digital rights, and digital fingerprint. The platform also traced gems and minerals to eradicate blood diamonds and promote ethical and sustainable practices by rewarding brands investing in such activities. IBM Food Trust (2022a) consortium applied blockchain to enhance supply chain efficiency, food safety, freshness, and brand trust, aiming to reduce food fraud and waste and promote sustainability practices. Honeywell leveraged blockchain technology for digitizing aircraft records and created digital records (virtual copies of physical aircraft parts) to authenticate the supply chain and guarantee governmental compliance (Kress, 2018b).

The worldwide distribution of firms trialing blockchain for supply chain provenance showed the USA (17) is leading the way, followed by the U.K. (6), China, and Australia (4); Switzerland, France, and Germany (3); Netherlands and Japan (2); South Africa, Estonia, Ireland, Saudi Arabia, Singapore, Russia, and India (1), see Figure 4.

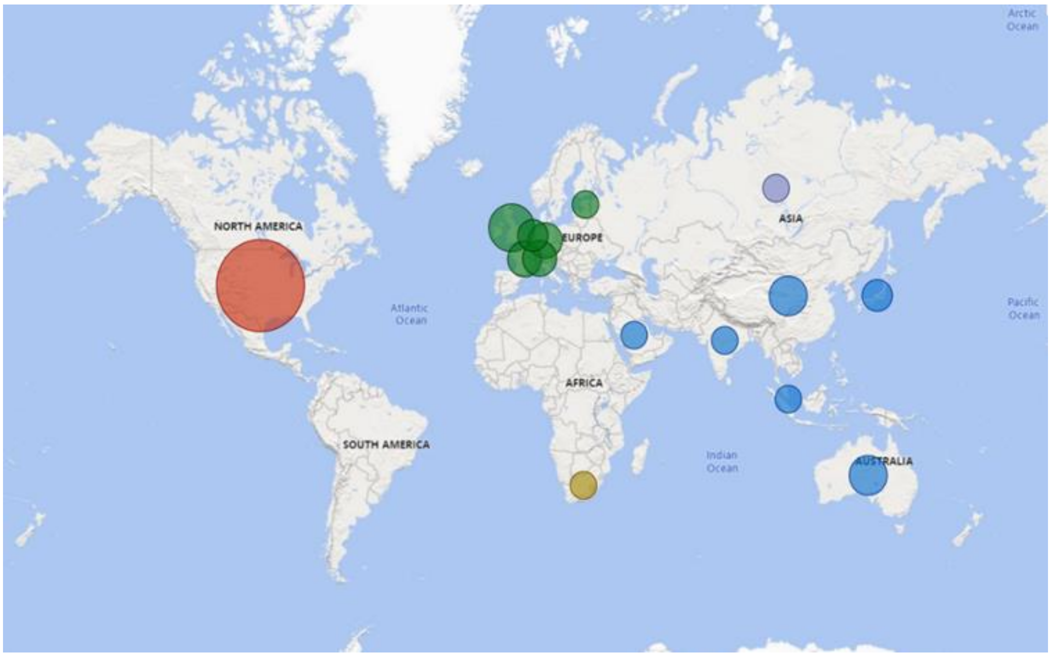


Figure 4. Worldwide distribution of trials blockchain for supply chain provenance

Our analysis also identifies the industries most actively engaged in blockchain trails. The top six include food, agriculture, logistics, luxury goods, manufacturing/automotive, and retail (see the complete type of industry in Figure 5). The food industry is the leading sector performing blockchain trails within their supply chains since combating food contamination and manipulation risks are the main drivers of applying the technology. The lack of standards for food handling makes the industry more susceptible to supply chain disruptions (Pournader et al., 2020).

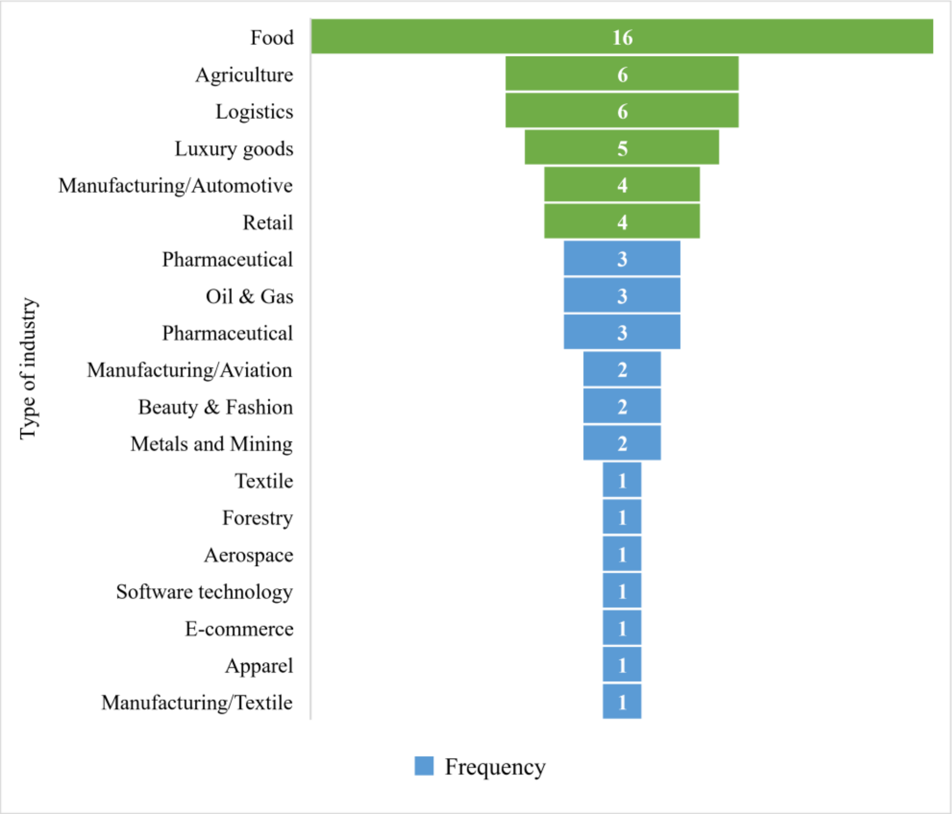


Figure 5. Frequency of blockchain trials in the supply chain by type of industry

Table 5. Early Adopters Trialing Blockchain for Supply Chain Provenance

Company	**Blockchain adoption drivers in the supply chain**	**Blockchain Type**	**Business values achieved in the supply chain**	**Year of implementation**	**Type of products**	**Type of industry applied**	**Country**
Everledger	Luxury Goods Authentication, Art, Gemstones, Minerals, Blood Diamonds Elimination, Fashion, Wines, Insurance.	Private	Traceability, Transparency, Quality, Authenticity, Ethical Sourcing, Human Rights Protection, Sustainability, Compliance, Anticounterfeiting	2015	Gemstones, Wines, Fashion, Insurance	Luxury Goods	UK
Provenance	Fish Industry Tracking, Overfishing, Fraud, Long-Term Brand Value Protection, Illegal Labor Tackling, Cease Human Rights Abuses, Sustainability Claims Proof.	Private	Traceability, Interoperability, Ethical Sourcing, Anticounterfeiting, Transparency, Human Rights Protection, Brand Prestige, Brand Loyalty, Sustainability Validation	2016	Tuna, Milk, Dog Food	Food, Beauty & Fashion	UK
Agridigital	Journey of Wheat Tracing, Real-Time Payments, Digital Escrows, Faster Deliveries	Private	Transparency, Smart Contracts Automation, Digital Payments, Simplification	2016	Grains	Agriculture	Australia
Vechain	Brand Reputation Enhancement, Supply Chain Efficiency, Consumer Confidence, High-Value Products Anticounterfeiting	Private	Brand prestige, Immutability, Transparency, Efficiency, Consumer Trust, Cost Reduction, Quality, Authenticity, Anticounterfeiting	2016	Food, Luxury Goods, Vehicles	Food, Luxury Goods, Automotive	Singapore

Company	Blockchain adoption drivers in the supply chain	Blockchain Type	Business values achieved in the supply chain	Year of implementation	Type of products	Type of industry applied	Country
Walmart	Food Safety Authentication, Faster Recalls, Prescription Drug Identification.	Consortium/ Private	Speed, Precision, Traceability, Authenticity, Compliance-Governance, Consumer Trust	2017	Mangoes, Meat & Poultry, Produce, Dairy	Retail	USA
Bext360	Transactions Timestamp in Real-Time in the Supply Chain, Crop Evaluation, Fair Price Negotiation, and Supply Chain Digitization.	Private	Transparency, Disintermediation, Buyers/Sellers Matching, Smart Image Recognition, Participants' Identification, Accountability, Fingerprinting, Traceability, Sustainability Validation	2017	Coffee Beans, Organic Cotton, Cocoa	Agriculture	USA
Cargill	Immutable Record of Processes	Consortium/ Private	Traceability, Sustainability Validation, Immutability	2017	Turkey	Food	USA
Hendrix Genetics	Animal Welfare Compliance & Standard Certification, Food Security	Private	Transparency, Efficiency, Compliance-Governance, Authenticity, Consumer Trust, Safety, Quality	2017	Turkey	Food	Netherlands
Blockchain in Transport Alliance (Bita)	Common Framework & Standards for Logistics Freight Marketplace	Private	Efficiency, Trust, Transparency	2017	Freight, Transportation	Logistics	USA
JD Blockchain Open Platform	Authenticity Certification, Property Assessment, Transaction Settlements, Digital Copyrights & Productivity Enhancement	Private	Transparency, Anticounterfeiting, Safety, Traceability, Accountability, Visibility, Sustainability Validation	2017	Food, Pharmaceuticals	Food, Agriculture & Pharmaceutical	China

Company	Blockchain adoption drivers in the supply chain	Blockchain Type	Business values achieved in the supply chain	Year of implementation	Type of products	Type of industry applied	Country
Nestle	Allow Consumers to Track Food back to the Farm	Private	Transparency, Traceability, Visibility, Accuracy	2017	Puree, Milk	Food	Switzerland
IBM Food Trust (Golden State Fruits, Walmart, Dole Food, Nestle)	Digitization, Unlocking Efficiencies, Minimizing Waste, Enhancing Brand's Reputation, Food Freshness, Food Fraud, Food Waste	Consortium/ Private	Food Safety, Efficiency, Sustainability Validation, Trust, Transparency, Integrity, Verification, Reliability, Brand Loyalty, Visibility, Interoperability, Standardization	2017	Agriculture Commodities, Fresh Produce, Restaurants, Seafood Trade	Food	USA
TradeLends (A.P. Moller-Maersk)	Container-Heavy Documentation, Real-Time Access to Shipping Documents	Consortium/ Private	Efficiency, Collaboration, Visibility, Trust, Privacy, Traceability, Friction Reduction, Simplification	2018	Trade	Container Logistics	USA
Alibaba	Lack of Data Transparency, Data Tampering, Tracing, and Recalling Obstacles. End-to-End Traceability, Anticounterfeiting.	Consortium/ Private	Traceability, Anticounterfeiting, Accuracy, Transparency, Monitoring, Auditing	2018	Dairy, Coffee, Fish, Trade	Food, Logistics, Agriculture, Healthcare	China
Agrichain	Growers' Seamless Integration, Logistics Providers, and Supply Chain Inefficiency Reduction.	Private	Productivity Improvement, Automation, Control, Speed, Cost Reduction, Efficiency, Accountability, Visibility	2018	Grains, Wine, Wool	Agriculture	Australia
Honeywell	Millions of Aviation Parts Documents Transference, Buyer Confidence	Private	Digitization, Trust, Traceability, Authentication, Anticounterfeiting, Digital Twins Creation	2018	Aircraft Parts, Label Printers	Aerospace	USA
Agroblock	Brand Integrity, Products Anticounterfeiting,	Private	Trust, Transparency, Ethical Sourcing, Visibility, Quality, Traceability, Accountability	2018	Grains	Agriculture	India

Company	Blockchain adoption drivers in the supply chain	Blockchain Type	Business values achieved in the supply chain	Year of implementation	Type of products	Type of industry applied	Country
	Growers' Revenue Assurance						
EY OpsChain Traceability	Improve Brand Equity, Revenue, and Operational Performance	Private	Traceability, Transparency, Authentication, Tokenization, Visibility, Anticounterfeiting	2018	Wines, Agribusiness, Marine Insurance	Food	UK
World Wildlife Fund	Combat Illegal Fishing and Slavery in the Tuna Industry, Sustainable Production Verification, Food Tracking, Avoid Environmental Damage and Unethical Products.	Private	Traceability, Transparency, Sustainability Validation, Collaboration, Human Rights Protection, Ethical Sourcing	2018	Tuna	Food	USA
SkyCell	Tamperproof and Storage Data Collection, Container Identity, Compliance	Private	Verification, Authenticity, Integrity, Confidentiality, Anticounterfeiting, Security, Compliance-Governance	2018	Pharmaceu-ticals	Pharmaceutical Logistics	Switzerland
Oracle	Enable Collaboration among Carriers, Terminals, Shippers, and Forwarders along the Supply Chain.	Consortium/ Private	Collaboration, Trust, Transparency, Interoperability, Productivity Improvement, Verification, Digitization, Automation	2018	Transportation	Logistics	USA
Shell	Physical Energy Commodities Management, Reduce Waste, End-to-End Efficiency Process	Private	Digitization, Collaboration, Speed, Security, Efficiency, Transparency, Verification	2018	Commodities	Oil & Gas	Netherlands

Company	Blockchain adoption drivers in the supply chain	Blockchain Type	Business values achieved in the supply chain	Year of implementation	Type of products	Type of industry applied	Country
FDA Blockchain Interoperability (IBM, KPMG, MERCK, Walmart)	Tracking Pharmaceutical Goods for Future Drug Quality and Security Act (DSCSA) Requirements	Consortium/ Private	Traceability, Visibility, Transparency, Speed, Monitoring, Interoperability, Compliance-Governance, Collaboration	2019	Pharmaceu-ticals	Pharmaceutical	USA
Toyota	Business Processes Efficiency, Traceability, Manufacturing Parts Recording, Data Sharing, Shipping.	Private	Efficiency, Traceability, Transparency, Trust, Ethical Sourcing, Sustainability Validation	2019	Vehicles	Manufacturing/Automotive	Japan
Carrefour	Trace food from farm to store.	Private	Consumer Trust, Traceability, Transparency	2019	Chicken, Tomato, Eggs, Dairy, Norwegian Salmon	Retail	France
BeefLedger	Secure Credentialed Data Provenance, Payments Streamline	Private	Integrity, Verification, Security, Accessibility, Immutability, Competitiveness	2019	Beef	Food	Australia
Starbucks	Traceability Tool to Explore the Bean-to-Cup Journey	Private	Consumer Trust, Ethical Sourcing, Traceability, Quality	2019	Coffee Beans	Food	USA
LVMH (Louis Vuitton Moët Hennessy)	Tracking High-End Products, Anticounterfeiting	Consortium/ Private	Traceability, Anticounterfeiting, Collaboration, Authenticity, Ethical Sourcing, Sustainability Validation	2019	Luxury Products	Luxury Goods	France
Oritain	Products' Origin Verification	Private	Authentication, Traceability, Verification	2019	Cotton	Textile	UK

Company	Blockchain adoption drivers in the supply chain	Blockchain Type	Business values achieved in the supply chain	Year of implementation	Type of products	Type of industry applied	Country
Techrock	Provide Consumers with Authentic Verifiable Products	Private	Authentication, Proof-of-Consumption, Fingerprinting	2019	Infant Formula	Food	China
Medileger & Chronicled (Gilead, Pfizer, Amgen, Genentech)	Product Verification	Private	Verification, Compliance-Governance	2019	Pharmaceuticals	Pharmaceutical	USA
Sappi	Materials' Provenance, Sustainable Certification	Private	Traceability, Collaboration, Sustainability Validation, Transparency, Visibility, Consumer Trust	2019	Wood, Tea	Manufacturing/Textile	South Africa
Saudi Aramco	Integration of Sensors at Oil Fields and Refineries to Ensure Asset Performance Verification	Private	Collaboration, Automation, Verification, Smart Contracts Automation	2019	Cargoes of Oil and Petroleum Products	Oil & Gas	Saudi Arabia
BMW	Supply Chain Verification	Private	Monitoring, Traceability, Visibility, Fingerprinting, Verification	2019	Minerals	Manufacturing/Automotive	Germany
De Beers Group	Provenance Assurance	Private	Trust, Traceability, Authenticity, Security, Privacy	2019	Diamonds	Luxury Goods	UK
General Electric	Additive Process Security	Private	Trust, Security, Traceability	2019	Additive Processes	Manufacturing/Aviation	USA
Boeing	Enabling the Convergence of Physical and Digital Systems	Private	Safety, Quality, Trust, Certainty, Digital Twins Creation	2019	Aircraft	Manufacturing/Aviation	USA

Company	Blockchain adoption drivers in the supply chain	Blockchain Type	Business values achieved in the supply chain	Year of implementation	Type of products	Type of industry applied	Country
Blockchain For Energy	Maximize Efficiencies, Reduce costs, Timelines Improvement, and Drive Industry Transformation.	Consortium/ Private	Collaboration, Efficiency, Traceability, Cost Reduction, Smart Contracts Automation, Efficiency, Interoperability	2019	Commodities	Oil & Gas	USA
Coke One North America (CONA)	Orders and shipments tracing, supply chain efficiency, untamperable data recording	Consortium/ Private	Traceability, Digitization, Transparency, Immutability	2020	Beverage's Bottling	Food	USA
Guardtime	Supply Chain Trade Processing and Compliance, Enabling Real-Time Anticounterfeiting Detection, Liability Management, Pharmacovigilance Post-Inoculation Visibility, Wine Authentication	Private	Traceability, Connectivity, Automation, Trust, Integrity, Identification, Authentication, Auditing	2020	Food, Retail Goods	Food, Pharmaceutical	Estonia
Daimler (Mercedes-Benz)	Procurement, CO2 Emissions Transparency in the Cobalt Supply Chain, Pursuing a Circular Economy, Human Rights, Environmental Protection, Public Safety, Compliance	Private	Traceability, Sustainability Validation, Transparency, Human Rights Protection, Ethical Sourcing, Security, Compliance-Governance	2020	Luxury Vehicles	Manufacturing/Automotive	Germany
Ant Group	Safe Cross-Border, Reliable, Efficient Trading for Buyers and Sellers	Consortium/ Private	Trust, Collaboration, Trust, Security, Transparency, Smart Contracts Automation	2020	Order Placements, Logistics	E-Commerce	China

Company	Blockchain adoption drivers in the supply chain	Blockchain Type	Business values achieved in the supply chain	Year of implementation	Type of products	Type of industry applied	Country
Breitling	Digital Security Ownership Proof, Authenticity Proof	Private	Traceability, Transparency, Authenticity	2020	Luxury Watches	Luxury Goods	Switzerland
Forest Stewardship Council	Digital Claims Assurance, Compliance, Supply Chain Integrity, Certification	Private	Verification, Security, Traceability, Compliance-Governance, Integrity	2021	Materials Trade	Forestry	Germany
Hedera (hashgraph)	Product Authenticity	Public & Private	Trust, Sustainability Validation, Integrity, Interoperability, Authentication, Traceability, Efficiency, Consumer Loyalty	2021	Vaccines, Food Items, Sneakers	Apparel, Food & Beverages, Beauty, Retail, Logistics, Pharmaceuticals	USA
Nornickel	Asset Tokenization, Carbon-Neutral Nickel Certification	Private	Sustainability Validation, Transparency, Security, Immutability, Ethical Sourcing, Tokenization	2021	Minerals (palladium, nickel, platinum, copper)	Manufacturing	Russia
PharmaLedger	Healthcare Quality Improvement	Consortium/ Private	Traceability, Anticounterfeiting, Compliance-Governance, Security, Cost Reduction, Collaboration, Trust, Quality	2021	Healthcare Solutions	Pharmaceutical	UK
Fujitsu	Reducing the Incidence of Substandard Products in the Supply Chain, Fraud, Error Prevention	Private	Transparency, Verification, Quality, Efficiency, Collaboration, Security, Traceability, Anticounterfeiting	2021	Rice	Software Technology	Japan
Renault	Productivity Gain, Costs Reduction	Private	Compliance-Governance, Traceability, Collaboration, Efficiency, Cost Reduction, Productivity Improvement	2021	Cars	Manufacturing/Automotive	France

The trend over the years of blockchain pilots in the supply chain has increased since 2015, reaching its highest point in 2019, with an abrupt decline in 2020 (possibly to the COVID-19 surge), and the post-COVID global economic perception remaining steady in 2021 (see Figure 6).

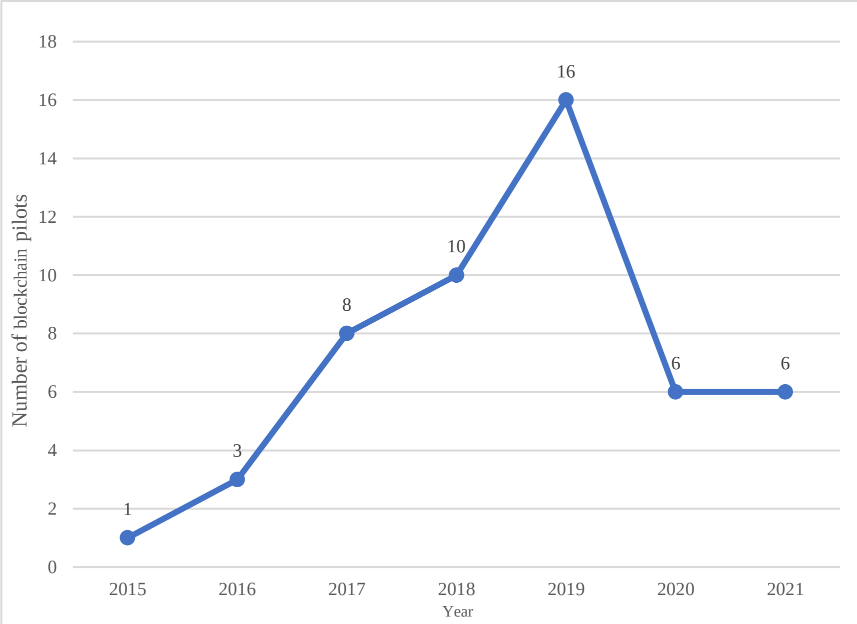


Figure 6. Number of blockchain pilots for supply chain by year

Our analysis showed that traceability is the most desired business value across the blockchain trials. The top ten business values achieved by firms are traceability, transparency, trust, collaboration, visibility, sustainability, efficiency, anticounterfeiting, authentication and quality (see Figure 7 for a complete list).

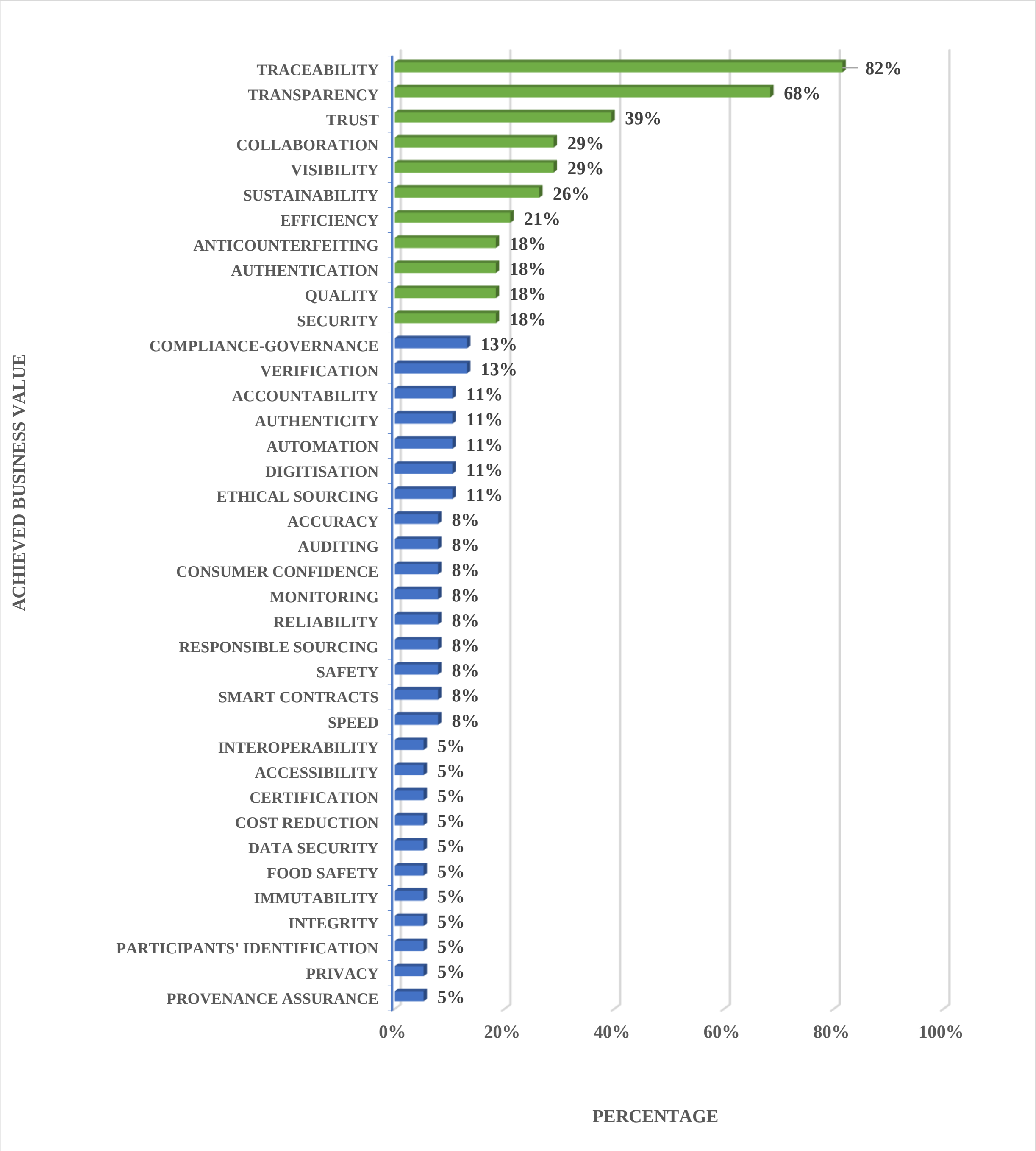


Figure 7. Frequency of achieved business values of blockchain adoption in the supply chain

2.5. Fingerprinting Traceability in a Supply Chain

Fingerprinting traceability in a supply chain can enhance the integrity of data recorded on a blockchain. While blockchain technology makes it almost impossible to falsify data in transaction logs retroactively, it does not eliminate the possibility of erroneous or deliberate data entries by humans at the transaction point.

As opportunely observed by Levine (2017), blockchain can offer the following:

> "a forceful way to make sure the signatures are in order, the ownership data is up to date, and the inspections have been done, but if you then drill a hole in the container, take out all the teddy bears, and replace them with cocaine, the blockchain will not catch that."

Thus, the historical record must be trustworthy and uncorrupted, balancing blockchain transparency and confidentiality to prove the data integrity of a firm's products (Babaei et al., 2023; Cai & Zhu, 2016; Ghode et al., 2020). Integrating fingerprinting techniques with blockchain technology is crucial to address this limitation and strengthen supply chain traceability. Fingerprinting food, for instance, offers substantial value by combating food adulteration, enhancing food security, reducing bioterrorism risks, and supporting climate change goals (Ellis et al., 2012). Various analytical fingerprinting techniques, such as chemical profiling analysis, forensic traceability, genetic markers, and environmental geochemistry, can be used to combat counterfeiting in the food supply chain (see Table 5). For example, Applied DNA Sciences provides a unique molecular inscription centered on plant DNA to create a permanent identifier in raw fibers, ensuring the authenticity of apparel products (Meraviglia, 2018).

Biochemical tracing can trace agricultural products back to their origin (farm), as the products absorb chemicals from the environment where they are grown. Notably, the method can differentiate between caged and free-range chickens residing on the same property, even if they are the same breed and receive the same feed (Bowman, 2018). The mining industry uses an analytical fingerprint (AFP) to validate mineral provenance in the supply chain, testing samples randomly from a shipment to those registered in a database (Kshetri, 2021b). Oritain (2022a) employs forensic traceability techniques to validate provenance claims of food products using chemical compound 'fingerprints' from plants and animals, which carry distinct elements and isotopes from their geographical regions. Applying forensics traceability can heighten a brand's reputation, trust, and loyalty (Oritain, 2022a). Product fingerprinting science in the supply chain will be increasingly relevant in the coming years. While integrating blockchain technology and fingerprinting techniques offers substantial advantages for supply chain traceability, some limitations persist. Firms often rely on sensors like RFID labels or barcodes to scan data from product packaging rather than the product itself, and data loggers may not always be linked to a blockchain structure. While the data on the blockchain remains immutable, it is challenging to maintain the integrity of blockchain records (Galvez et al., 2018); therefore, data entries must come from different IoT points (Tyagi, 2023).

Table 6. Analytical fingerprinting techniques used in the food supply chain.

Analytical method	**Techniques**	**Functions**	**Applications**
Vibrational spectroscopies	Fourier transform infrared (FT-IR), Raman, near-infrared (NIR), mid-infrared (MIR), NMR.	Metabolic fingerprinting to analyze carbohydrates, amino acids, fatty acids, lipids, and proteins.	Product authenticity & adulteration. Rapid identification of foodborne bacterial/spoilage contamination & food poisoning. Food ingredients authenticity analysis

Nuclear magnetic resonance (NMR)	Site Natural Isotope Fractionation (SNIF-NMR)	Provides structural information. Determines the physical & chemical properties of ingredients	Adulteration of a wide range of food (beverages)
Mass spectrometry	MS, Isotope Ratio Mass Spectrometry (IRMS)	Proteins' analysis to measure, identify & quantify molecules in simple & complex mixtures	Food pathogenic bacteria contamination detection. Food rapid packaging screening

2.5. Discussion

This research seeks to contribute to the literature on blockchain technology applications for supply chain provenance by addressing three research questions:

RQ1. What is the current state of the academic and industry literature concerning the use of blockchain technology to enhance supply chain provenance and meet customer demand for product authenticity? The current blockchain and supply chain provenance literature is relatively young but rapidly expanding. The literature, formed from a single node (Nakamoto, 2008), has blossomed into a research race for exciting new blockchain applications. Text-to-data analysis revealed commonalities and differences in the themes and concepts discussed in the literature (see Insights #1 to #3 in section 2.3). These insights established that underlying 'concepts' revealed using text-to-data algorithms are often associated with a single 'theme' if the literature base lacks diversity (i.e., the mix of industry and academic). Combining academic and industry literature using the same algorithms provided a more robust representation of themes and concepts than either literature partition alone. The qualitative review of papers revealed that academic institutions and industry actors are embracing blockchain adoption for supply chain provenance. For academia, the blockchain theme mainly relates to traceability, emphasizing the adoption benefits and importance of transparency, origin, quality, and sustainability in the supply chain. For industry, the blockchain theme mainly relates to transparency and data provenance, emphasizing the business values of trust, authenticity, and quality in the supply chain. This insight highlights the importance of collaboration and knowledge exchange between academic and industry sectors (Lepore et al., 2022), where theoretical advances from academia can inform and guide practical implementations in industry, and industry experiences can refine and validate academic frameworks based on real-world experiences, bridging the gap between theory and practice.

RQ2. What are the driving factors, product characteristics, or service attributes that prompted the early adoption of blockchain in the supply chain, and what are the business values achieved through this adoption? Our analysis reveals that blockchain adoption in the supply chain is driven by the need to digitally certify traceability in real-time, ensure product quality, enhance efficiency, verify brand claims, support ethical sourcing, and combat counterfeiting.

The product and service characteristics driving early blockchain adoption can be categorized into three groups: A, B, and C. Group A features are predominantly related to the food, pharma, and agriculture industries:

1. Perishable goods (published expiration dates).
2. Primarily for human consumption/ingestion.
3. Consumers desire a high degree of health risk mitigation (i.e., traceability, transparency, visibility, efficiency, security, and quality).

Group B features are mainly associated with the luxury and collectibles industries, including rare gems, fine wines, luxury watches, and vehicles:

1. Non-perishable goods with a long chain of ownership custody.
2. Predominantly high-value products for collection/investment purposes.
3. Consumers desire a high degree of financial risk mitigation (i.e., traceability, anticounterfeiting, authenticity, ethical sourcing, and trust).

Group C products combine attributes from both Groups A and B. This category pertains to industries that manufacture high-value physical assets, such as aircraft parts, minerals, additive ingredients, and textiles, with digital systems assuring sustainability and compliance. Group C product features include:

1. Manufacturing goods.
2. Predominantly high-value products for creating digital twins and ensuring responsible sourcing.
3. Consumers desire a high degree of confidence and sustainable certification (i.e., traceability, authentication, reliability, quality, compliance, sustainability validation, and compliance/governance).

RQ3. How can the link between physical products flowing through the supply chain and their corresponding digital records on the blockchain be assured to establish and maintain provenance? This research question examines emerging technologies to establish the provenance link between the physical product and the blockchain ledger. The use of analytical fingerprinting techniques, such as vibrational spectroscopies, mass spectroscopy, nuclear magnetic resonance, and genetic markers (Ellis et al., 2012) support tagging products in Group A, while electronic imaging, laser engraving, and molecular tagging (Meraviglia, 2018) support Group B products, and forensic traceability, biochemical markers, and environment geochemistry (AFP) support Group C products (Kshetri, 2021b; Oritain, 2022a).

We provide insights into the primary focus areas and highlight the most important aspects of blockchain technology relevant to academic and industry investigations to enable academics and practitioners to prioritize their efforts and resources accordingly.

2.6. Research Implications

2.6.1. Theoretical Implications

This SLR has important theoretical implications for advancing the understanding of blockchain technology in the context of supply chain management. The comprehensive overview of the blockchain landscape in supply chain management, comparing academic and industry articles, uses content and thematic analysis with a text-to-data algorithm to interpret and classify the literature. We contribute to understanding the early adoption of blockchain by identifying patterns and trends in the studies and unveiling the underlying drivers of blockchain technology in the supply chain domain. Our findings reveal the synergy across academic and industry domains considering blockchain benefits and recognize the need to reinforce data traceability and trust in the supply chain. The academic sources highlight a blockchain theme primarily related to traceability, stressing the adoption advantages and significance of transparency, origin, quality, and sustainability in the supply chain. Insights from both domains illustrate the efficiency gains of blockchain adoption for supply chain automation and enhancing consumers' perceived value and trust in brand claims. The study contributes to theory development in the blockchain and supply chain management field by identifying key themes that can serve as a foundation for developing conceptual frameworks and models. These insights advance the theoretical understanding and generate new perspectives for future research endeavors, guiding researchers to explore the identified themes in-depth and conduct empirical studies to gain new insights into the potential of blockchain technology in supply chains. Our findings also underscore the importance of conducting balanced literature reviews, bridging the gap between theory and practice, especially when studying emerging technologies like blockchain. This review provides valuable guidance for designing educational initiatives and training programs focused on blockchain technology and supply chain management. It allows future supply chain professionals to stay updated on blockchain's latest developments and potential applications in their field. Overall, this study highlights the game-changing potential of blockchain technology in reshaping various aspects of supply chain management, including product provenance, security, authenticity, accountability, safety, and consumer confidence.

2.6.2. Managerial Implications

The SLR on blockchain technology and supply chain management offers several managerial implications for practitioners. Practitioners recognize the potential of blockchain in addressing industry-specific challenges, such as ensuring transparency and data provenance. Understanding the benefits achieved by early adopters can serve as a starting point for companies considering blockchain adoption. Blockchain technology can verify product origin, enable truthful certifications, and comply with established standards, reinforcing trust among stakeholders and customers. Thus, implementing blockchain solutions can enhance brand reputation and consumer confidence by ensuring product authenticity and quality. Based on our results, companies can align their strategies and initiatives with their needs and expectations.

Our findings suggest that companies carefully evaluate blockchain adoption risks and start small by integrating the technology into existing or new processes before implementing a large-scale operation (Angelis & Ribeiro da Silva, 2018; Vu et al., 2021). Blockchain brings innovation to the supply chain management field –and despite the hype–it should not be considered a 'magic bullet.' Before implementing blockchain adoption for supply chain provenance, companies should carefully evaluate their requirements and goals to ensure that blockchain aligns with their managerial decisions and objectives (Niu, Dong, et al., 2021; Perboli et al., 2018). Firms exploring blockchain applications in the supply chain may encounter various supply chain challenges that need to be addressed, such as mapping supply chain processes. While the features of blockchain are compelling reasons for adoption, it is vital to conduct a comprehensive analysis combining the technical, behavioral, and organizational considerations (Oguntegbe et al., 2022). Integrating blockchain into a supply chain requires careful planning, and digitizing the supply chain (Schmidt & Wagner, 2019) beforehand is crucial to incorporate existing systems' capabilities and ensure data suitability and reliability (Azzi et al., 2019). Companies considering blockchain implementation should assess whether the consumer value proposition outweighs the set-up costs (Kumar et al. (2020). Understanding consumers' traceability awareness is essential when contemplating whether to adopt blockchain technology (Fan et al., 2022). Firms exploring blockchain solutions to foster supply chain provenance must design user-friendly interfaces that enhance customers' purchase decision-making without overwhelming them with irrelevant information (Montecchi et al., 2019).

Collaboration is crucial for successful blockchain integration in the supply chain, given its involvement of multiple stakeholders. Collaboration requires exchanging shared strategic goals (e.g., risk mitigation) and uniting resources (Min, 2019), as demonstrated in our analysis of achieved business values in the consortia blockchain trials. Top management support and influence are crucial in building an institutional vision for blockchain adoption. First-mover firms can benefit significantly from deploying the technology (Lin, 2014). The relationship between blockchain and supply chain provenance is recent, and it signals a shift in data security through enhanced efficiency drivers, prompt decision-making processes, and improved supply chain collaboration (Karakas et al., 2021; Korepin et al., 2021).

2.6.3. Research Limitations

This research has several limitations that should be acknowledged. Firstly, there is a possibility that some relevant investigations may have been missed or omitted, which could impact our findings. In addition, the limited availability of literature on blockchain adoption in supply chains may restrict the scope of our conclusions. The evolving nature of blockchain adoption in supply chains also poses a limitation. As the technology is in its infancy, we expect that a rapidly emerging body of literature will provide more extensive evidence-based general conclusions in the future. Given the rapid pace of changes and innovations in this field, there is a likelihood that some information presented in this study may become outdated over time. New developments or changes in blockchain technology, including its applications and industry integrations, may emerge after the conclusion of this research, potentially altering the understanding and implications initially derived from this study. This temporal limitation signifies the need for ongoing research and continuous monitoring of the blockchain landscape to comprehensively grasp its evolving influence on supply chain management.

Another limitation is the lack of information contrasting academic and industry research, which could have provided more balanced insights into the advancement of technology. We attributed this limitation to the scant collaborations between academia and industry in the field of blockchain for supply chain management. The absence of a comparative analysis between academic and industry research limits a well-rounded view of technology progression. This deficiency, attributed to limited collaborations between academia and industry in the blockchain domain for supply chain management, poses a setback in achieving a holistic understanding. Collaborative efforts between these sectors are crucial to bridge the gap between theoretical concepts and practical applications in the blockchain landscape.

Further collaborative research in both domains is needed to advance the literature on blockchain technology in supply chain management, bridging the gap between theory and practice. Further, while text-to-data analytics provides valuable insights that may not be extracted easily through manual analysis, it also has limitations. For instance, it may struggle to capture specialized terms in technological domains like blockchain. Despite the researchers' efforts to interpret the insights collectively, we may have missed some relevant aspects of the analysis. Despite collective efforts to interpret these insights, there might be overlooked or omitted aspects due to the intricacies of this method. Finally, this study does not claim to offer a comprehensive discussion but rather serves as an important inquiry into a subject worthy of investigation.

2.6.4. Future Research

Our literature review revealed limited peer-reviewed publications on blockchain and supply chain provenance. Future research should focus on addressing the gaps and limitations identified in the current literature. Some suggested research questions for conducting empirical studies include:

- What are the measurable attitudes of shoppers to ascertain their willingness to use a blockchain-based tool to verify the product's provenance history?
- What behavioral factors are significant for consumers to be willing to pay a premium price for a blockchain-certified product?
- Is it possible to design a theoretical framework for blockchain integration with fingerprinting techniques into a supply chain network?
- What are the main scalability problems of blockchain implementations in food supply chain networks?
- Is it possible to collect direct insights from early blockchain adopters on the benefits and challenges of the technology implementation to evaluate them quantitatively?
- What new business models can food companies create or redesign to incorporate blockchain technology?
- How can blockchain aid in verifying sustainable practices, such as responsible sourcing, carbon footprint tracking, waste reduction, or fair labor practices?

- How can blockchain benefit the provenance of the beauty supply chain and avoid business practices such as greenwashing, considering that beauty and personal care are among the most profitable industries worldwide?

2.7. Conclusion

This study reviewed and analyzed the literature on blockchain and supply chain provenance from academic and industry domains. The study highlights the importance of collaboration between academia and industry in exploring blockchain adoption for supply chain management. The findings reveal the driving factors and business values achieved through early blockchain adoption, emphasizing the need to strengthen data traceability in the supply chain. Insights from both research domains revealed efficiency gains of blockchain adoption in enhancing consumers' perceived value and trust in brand claims. We also identified the product characteristics and service attributes that drive the early adoption of blockchain technology in the supply chain, including the industries and types of products involved, business adoption rationale, and business values achieved by the blockchain trials (emphasizing ethical sourcing and sustainability practices).

Furthermore, this study explored the potential of combining blockchain with analytical fingerprinting techniques to enhance supply chain resilience by assigning unique identifiers and randomly testing the veracity of product materials. The powerful combination of blockchain technology, IoT sensors, automated smart contracts, and fingerprinting techniques will rapidly identify disruptions and certify product authenticity and quality, allowing prompt remediation actions. This approach will provide a reliable and verifiable source of information, increasing transparency throughout the supply chain network and improving supply chain resilience. These findings can assist companies in obtaining insights into the motivation and gains from other firms to elucidate the viability of blockchain adoption as an initial exploration stage. Finally, our findings complement those of earlier studies on the implications and limitations of blockchain adoption in the supply chain.

In summary, blockchain technology has the potential to revolutionize supply chain management, but its implementation should be approached with careful consideration of specific business needs and challenges. By advancing research in this area, we can unlock the full potential of blockchain in ensuring transparency, authenticity, and efficiency in supply chain processes, ultimately leading to improved consumer confidence and brand reputation.

In the next chapter, I explore the significance customers attribute to provenance information and the potential for blockchain to augment their trust. These findings paved the way for probing blockchain integration in food supply chains, revealing a research void in consumer-driven blockchain adoption. While substantial literature focused on organizational adoption, there was a lack of perspectives from the consumer point in blockchain adoption research.

CHAPTER 3

Predicting Consumer Behavioral Intention of Accepting Blockchain-Certified Food Products Using a Mobile Application for Food Provenance and Authenticity.

Foreword

The systematic literature review I carried out in the preceding chapter revealed the primary drivers of blockchain technology's early adoption in the supply chain and the business benefits accomplished by such pilots. I also identified the type of products and categorized them into three main groups after an in-depth analysis and the types of industries involved, the food industry being the most frequent one conducting blockchain experiments. Likewise, I investigated how customers place value on the availability of provenance information and how blockchain technology can enhance their confidence. These results provided the pathway to investigate blockchain adoption in food supply chains. I noticed a gap in blockchain adoption research from the consumer behavioral approach when studying this topic. There were numerous articles regarding blockchain adoption from the organisational angle but scant from the consumer outlook. Since providing a holistic approach (customer and organisational) to new technologies' adoption (Rodríguez-Ardura & Meseguer-Artola, 2010) is vital for managerial decisions, I pondered it necessary to bridge the gap in the consumer behavioural domain by adapting and extending the well-known Consumer Acceptance and Use of Information Technology (UTAUT2) theoretical framework (Venkatesh et al., 2012). This chapter advances blockchain adoption research by complementing it with the consumers' perspective by determining the key factors of intention to use a blockchain-based mobile application for food transparency and safety. I designed based on the literature (MacKenzie & Podsakoff, 2012; Podsakoff et al., 2012) and applied an online survey with real consumers across Australia for empirical data collection. The survey encompassed measurement inquiries for the model's endogenous, exogenous, and demographic variables and structural equation modelling for my data analysis. Our results indicate that habit is the main predictor of behavioral intention, followed by social influence. Finally, considering this study's findings, I contribute important theoretical and managerial implications and present an actionable policy framework for adopting blockchain technology.

N.B: Please note that the standard American spelling is used in the following chapter due to the journal's requirements, and for the purposes of publication with multiple authors, I use “we” instead of “I”.

Predicting Consumer Behavioral Intention of Accepting Blockchain-Certified Food Products Using a Mobile Application for Food Provenance and Authenticity.

Declaration of interest: none.

Abstract

Blockchain digital technology is a potential game-changer for food companies, allowing them to provide consumers with greater transparency, faster traceability, better quality label information, and superior proof of provenance for their products. This study applies and extends the Consumer Acceptance and Use of Information Technology (UTAUT2) framework to examine the consumers' acceptance of a blockchain-based mobile application for food provenance. A structural equation model and path analysis are performed using survey data gathered from consumers across Australia to investigate the latent factors that drive the adoption of blockchain-based mobile applications. Our work is significant since our results indicate that habit is the main predictor of behavioral intention, followed by social influence. In contrast, a non-significant effect is confirmed for performance expectancy, effort expectancy, and consumer perceived value and trust. These research findings have important theoretical and managerial implications and provide a policy framework for adopting new technologies such as blockchain. This study is interesting as it explores the potential of blockchain technology in revolutionizing the food industry, offering enhanced transparency, traceability, and provenance. Applying UTAUT2, it examines into consumers' acceptance of

blockchain-based applications, revealing habit and social influence as significant predictors. The findings suggest a shift in factors influencing behavioral intention, shedding light on theoretical insights and managerial strategies for adopting advanced technologies like blockchain in the food sector, making it an impactful investigation for theory and industry applications.

Keywords: Blockchain Technology, Proof of Provenance, Food Transparency, Food Safety UTAUT2, Policy Framework

3. Introduction

Blockchain technology has emerged as a powerful tool with the potential for increasing transparency, authenticity, and safety in various industries. In the food industry, blockchain-based mobile applications are increasingly being proposed to provide consumers with access to real-time information about the origin and quality of food products. Food supply chains are vulnerable to disruptions that can cause systemic supply and demand shocks directly impacting consumers' quality of life. However, despite the growing interest in blockchain-based mobile applications in the food industry, little research has been conducted on the factors influencing consumers' acceptance and intention to use such applications. To fill this gap, we examine the impact of perceived usefulness, perceived ease of use, trust, perceived risk, habit, and social influence on consumers' intention to use a blockchain-based mobile application for food transparency. The findings of this study also develop a policy framework offering valuable insights for food industry stakeholders and policymakers in designing and implementing effective strategies to promote the adoption of blockchain technology.

3.1. Food Supply Chain Disruption

There have been many food safety incidents worldwide, such as the spread of Creutzfeldt-Jacob disease (degenerative brain disorder) via contaminated meat products in the 1980s, the infant milk contaminated with melamine powder in China in 2008 (causing renal failures and death in children). The horsemeat scandal in Europe in 2013 —retailers were selling horse meat instead of beef and pork meat— (Ringsberg, 2014) and the recent food tampering with sewing needles into Australian strawberries (Food Standards Australia New Zealand, 2021b), to name a few. Food-producing companies must proactively examine worst-case product recall risks and costs to ensure food safety along the supply chain. According to Macready et al. (2020), timely transparency and openness of all food chain actors are critical for consumer trust during and after a food incident.

Unexpected disruptions in food supply chains are a continuous challenge that many economies encounter daily. Data security and the ubiquity of food supply chains are instrumental in safeguarding public health and economies worldwide. Using new digital technologies, such as blockchain, provides the pathway to strengthen the collaboration of businesses, governmental entities, and consumers for a more transparent food environment. The World Health Organization (2022b) estimates about 600 million people globally sicken from foodborne diseases, causing 420,000 deaths annually. Insecure food comprising pernicious bacteria, viruses, parasites, or chemical agents can lead to more than 200 diseases.

The Australian food supply chain is known for producing a substantial range of high-quality and premium food. Australia produces more food than it consumes, exporting around 72% of agricultural, fisheries and forestry production and importing 11% of food consumption (Department of Agriculture, 2023). Asia, notably China, has been a key market for Australian exports of meat, wine, wool, fruit, nuts, seafood, grains, and dairy. This is derived from the high-quality food products needed to supply a growing demand from the rising middle class in the mainland (Department of Foreign Affairs and Trade, 2019). After the COVID-19 pandemic, amid the trade disruptions from China, Australian exporters have diversified to new markets (Export Finance Australia, 2022) to expand their food products and combat supply chain vulnerabilities. Australia also has a reputation for rigorous governmental food regulations, making the food system relatively safe. However, Australia has not been free of compromising food incidents. For instance, approximately 4.1 million cases of food poisoning are reported annually in Australia, causing over 31,000 hospitalizations, 1 million doctor visits, and 86 deaths (Australian Institute of Food Safety, 2022a). Furthermore, as the COVID-19 pandemic shocked global supply chains, Australia was no exception, enduring shortages of several food items. COVID-19 uncertainty also affected consumer behavior and escalated stockpiling of commodities due to lockdowns and stay-at-home restrictions, triggering stock scarcity (Brown, 2020; Louie et al., 2022).

Consumers experienced recurrent empty shelves for many food products in supermarkets, and many retailers introduced provisional purchasing limits to avoid drastic food shortages. As of March 2023, there is a nationwide shortage of processed potato products in Australia, prompting retailers to limit consumer purchases. Moreover, Australian imports are mainly processed seafood, processed fruit and vegetables, and soft drinks (Hogan, 2019), which tend to be purchased by the most vulnerable Australian consumer groups. These low-income consumers were pushed to buy cheaper and less nutritious food products due to their limited resources (Louie et al., 2022). The Foodbank Australia (2021) reports multiple lockdowns and job losses caused food insecurity for the most vulnerable Australian communities, struggling to put good quality food on the table after COVID-19 due to rising costs. Australia's Consumer Price Index (CPI) rose 7.3%, mainly affecting fruit and vegetables, dairy, bread, and cereal products (Australian Bureau of Statistics, 2022b), impacting consumer demand. Finally, bad weather events, such as heavy rainfall and flooding (Australian Bureau of Statistics, 2022a), have also exacerbated food supply disruptions in Australia. All these circumstances exhibit the need to develop more resilient food supply chains since overall societal aims are enhancing food-system efficiency, food security and nutrition, and environmental sustainability (Cattaneo et al., 2021).

3.2. Provenance

All products have stories about their origins and journey to the customer, for instance, how the product was created, who was involved, and even the environmental impact of the product's journey. However, not all companies can provide an accurate account of a product's history. Provenance and traceability are the ability to follow the chronology of events (through documentation) along all production, processing, and distribution stages to consumers in associated environmental conditions (Ringsberg, 2014). Resilient food supply chains possess accurate food traceability systems with flexible labeling and fast communication (Ringsberg, 2014) among food supply chain stakeholders. The Australian consumer perceptions about food transparency enabled by blockchain technology have revealed to this study the comprehension and prediction of consumer behavior when presented with a blockchain-certified food product in the near future.

The research findings of Wang et al. (2019) showed that consumers are increasingly alert to food products' authenticity, demanding to identify how and where they were sourced and processed. Mancini et al. (2017) revealed an education effect, where well-educated people pay more attention to healthy food and tend to be more environmentally conscious. Contrarily, less educated consumers are less interested in purchasing sustainable products, even after understanding their environmental implications. A study by the Australian Department of Agriculture (2012) showed that consumers focus primarily on value, local shopping, increasing demand for convenience, product integrity, and nutritional value information.

3.3. Blockchain

According to the list of critical technologies in Australia's national interest, blockchain technology is appointed as one of the emergent technologies that significantly impact economic prosperity, national security, and social cohesion. Accordingly, the Australian government created the National Blockchain Roadmap (Department of Foreign Affairs and Trade, 2021) to foster a blockchain-empowered future. The governmental strategy involves plans to capitalize on blockchain adoption by current major players in regulation, industry, and educational research. In this context, the Australian food industry will benefit greatly since one of the priority areas includes agricultural supply chains. Blockchain is a decentralized cryptographic ledger that shares appended transactions among supply chain stakeholders. As a result, all value-added can be chronicled, tracked, and accessed much faster than the current analog systems, allowing ubiquitous real-time digital data (Kamble et al., 2020) for all food supply chain parties.

The worldwide adoption of blockchain for supply chain activities has been primarily in the private sector. There are many investigations of blockchain adoption for the supply chain at the organizational level; however, we discovered a research gap in studies from the customer's standpoint. Hence, the contribution of this study is one of the early investigations into the consumers' readiness to accept blockchained traceability as a mobile application offering handy food provenance information. If our results reveal consumers are primed and ready, this will prompt companies to focus on and improve the provenance and tracking of their products. It follows that identifying the consumers' attitudes is essential when implementing marketing strategies to introduce blockchain technology to shoppers.

3.4. Consumer Behavior

Consumers' preferences differ substantially according to diverse perceptions, needs, values, and constraints. Some consumers may perceive a product as having inadequate labeling information (i.e., ingredients, nutritional values, allergens), while others may not. Certain consumers find reading and understanding the vast quantity of label information overwhelming, while others find it most interesting. When consumers order groceries from a digital cart, they may be unable to see the food label information as if they were holding the product. Access to product labels containing details of the product's origin, ingredients, and history is meaningful in choosing products. Since blockchain technology enables transparent data storage and faster tracking processes in food supply chains (Creydt & Fischer, 2019), we propose consumers will be more confident about their purchase when given access to data beyond food product label information with this new technology.

This study examines the consumers' perceptions and aims to provide managerial insights for food producers accordingly. Specifically, on the demand side, shoppers will use a tool that automatically displays the ingredients in each item, provides nutritional value contributions, and offers better food recommendations, allowing them to make well-informed health choices. On the supply side, food companies will have the capacity to offer item-level supply chain traceability information to the consumer promptly and gain competitive advantages by marketing their food products as blockchain-based traceable, thereby improving authenticity, safety, and sustainability validation. Finally, the tracing capability offered by blockchain technology can be used to prevent, control, and expedite collaboration with governmental agencies on food investigations (food diseases or food tampering). Leading us to investigate the following research questions:

3.5. Research questions

R1. What latent factors drive usage intention (with the UTAUT2 framework) for consumers exploring a new digital technology (blockchain) to access transparent food information?

R2. Do the control variables (gender, age, education, income, and parenting) exhibit differences across the groups?

The overall structure of the study proceeds as follows: Section 2 presents the theoretical framework of this investigation, including the research model and hypothesis development. Section 3 describes the research methodology and data collection and shows descriptive statistics. Section 4 provides the results, including a discussion on model fit, common method bias, model assessment, and path analysis. Section 5 discusses the results of this study, including theoretical, managerial, and policy implications. Finally, section 6 reveals the limitations of this study, future research opportunities, and conclusions.

3.6. Theoretical Framework

Prior research has demonstrated the relevance of attitudinal factors that drive consumers' adoption of new technologies, leading to the emergence of several theories and models to explain this relationship. Several theoretical models from the fields of psychology and sociology have been derived to elucidate the behavioral aspects of technology adoption (Owusu Kwateng et al., 2019). One of the seminal models is the theory of reasoned action (TRA) by Fishbein and Ajzen (1975), who studied the importance of volition and intention to predict behavior. Following their early work in TRA, Ajzen (1985) established the theory of planned behavior (TPB), evaluating attitudes, subjective norms, and perceived behavioral control to determine behavioral intention. One of the most broadly applied models in the literature has been the technology acceptance model (TAM) by Davis (1989). TAM was designed to predict user acceptance of information technology based on perceived usefulness and ease of use.

These earlier studies led Rogers (2003) to propose the innovation diffusion theory (IDT), which incorporates the innovation process, communication channels, time, and social system effects into the model. Viswanath Venkatesh et al. (2003b) then formulated a unified theoretical model of acceptance and use of information technology (UTAUT) by comparing and integrating eight previous models: TRA, TAM, IDT, MM (Motivational Model), TPB, the combined TAM and TPB (C-TAM-TPB), the model of PC utilization (MPCU), and the social cognitive theory (SCT). The UTAUT model explained as much as 70% of the variance in usage intention decisions in an organizational environment (Viswanath Venkatesh et al., 2003a). Finally, Venkatesh et al. (2012) extended UTAUT to a consumer framework, the Consumer Acceptance and Use of Information Technology, by incorporating three new constructs: hedonic motivation, price value, and habit. This new model was referred to as UTAUT2, which forms the basis of our study. The UTAUT2 model is an extension and evolution of the original UTAUT model, maintaining a similar naming convention to signal its relation to the foundational theory. The core name (UTAUT) helps in identifying its roots and its direct connection to the established UTAUT framework, maintaining familiarity with the previous theory while signaling the improvements and advancements in the model.

3.6.1. Theoretical Model

The traditional UTAUT2 theory and model contains six independent latent constructs: performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, and habit. Prior research has included two different dependent variables with varying degrees of consistency and success. Behavioral intention (BI) is the primary dependent factor in our model because it captures the consumers' acceptance of and intention to use the target technology (blockchain). For some studies, consumers' use behavior (UB) is also considered when actual products are available to test on consumers rather than hypothetical products. When both are included in a study, most investigations have considered BI a primitive predictor of UB (Beh et al., 2019; Duarte & Pinho, 2019; El-Masri & Tarhini, 2017; Hew et al., 2015; Kamble et al., 2020; Kapser & Abdelrahman, 2020; Morosan & DeFranco, 2016; Nordhoff et al., 2020; Oliveira et al., 2016; Qasem, 2021; Shaw & Sergueeva, 2019; Sheel & Nath, 2020; Shoheib & Abu-Shanab, 2022). We sought to measure UB; however, we determined UB was immeasurable at this early stage of blockchain technology adoption for the context of our study. Considering that such a blockchain-based mobile application is not yet available to the public and participants cannot interact with the application's features (same motives for various studies examining the acceptance of new technologies), UB is not included in this study. This study also investigates the moderated effects of consumer covariates such as gender, age, education, income, and parental affiliation.

3.7. Hypothesis Development

Performance expectancy (PE) is defined as the degree to which technology will benefit consumers in performing a particular activity (Venkatesh et al., 2012). Several studies have found that PE is one of the most significant predictors of behavioral intention. For instance, Tamilmani et al. (2020) conducted a meta-analytic evaluation of 60 UTAUT2-based empirical studies —mobile banking adoption, mobile payment usage, internet banking, online shopping, broadband usage, public e-services usage, wearable technology in healthcare— with more than 122,000 observations. Merhi et al. (2019) conducted a cross-cultural study of the intention to use mobile banking between Lebanese and British consumers. They exhibited a significant relationship between PE and BI in Lebanese consumers. Since digital technology has increased tremendously in all areas of life and the term 'blockchain' is now discussed in mainstream media (mainly related to cryptocurrencies), we posit that technological barriers have been lowered. Thus, the availability of a blockchain-based mobile application to support food provenance and tracking should be less mystifying to the lay consumer. Product labels that work seamlessly with the mobile application would stimulate the consumer's acceptance of and adaptation to a new era of blockchain-certified products. Therefore, we hypothesize that:

H1: Performance Expectancy is positively related to Behavioral Intention.

Effort Expectancy (EE) is the degree of perceived effort consumers associate with using a technology (Venkatesh et al., 2012). The degree of effort could be any combination of physical or mental/cognitive load required to benefit from the technology. Tamilmani et al. (2020) revealed that EE was negatively associated with BI. Therefore, it stands to reason the greater the effort required, the less appeal a product would have to the general public and, thus, the lower the behavioral intention to adopt. Therefore, consistent with most prior studies, we posit that:

H2: Effort Expectancy is negatively related to Behavioral Intention.

Social influence (SI) is defined as the extent to which consumers perceive important others such as family, friends, colleagues, media (Merhi et al., 2019), and social media who believe they should use a particular technology (Venkatesh et al., 2012). Social influence has shown outstanding prediction in many studies. Sheel and Nath (2020) studied the intentions of blockchain adoption in the supply chain and revealed that SI is a factor that positively influences BI. Nikolopoulou et al. (2020) investigated university students' behavioral intention to use mobile phones, and SI significantly affected BI. Oliveira et al. (2016) observed that SI has a significant and positive relationship with the intention to adopt mobile payment systems. Ramírez-Correa et al. (2019) analyzed the acceptance of online games. Their results indicated that SI is significant and positively associated with BI as people shared the outcome and interactions on the games on social networks with friends. Finally, empirical studies by Tamilmani et al. (2020) demonstrated SI has one of the most robust paths for predicting BI. Therefore, we proposed that:

H3: Social Influence is positively related to Behavioral Intention.

Habit (HT) is the degree to which people tend to perform behaviors automatically and can be both conscious and unconscious (Cabrera-Sánchez et al., 2021). For example, some people repeatedly verify their mobile phones for new calls, messages, or emails, while others do not. Learning also has a pivotal role in the formation of a habit. This is because learning reflects prior experiences and reinforces sustained usage of new technology (Venkatesh et al., 2012). HT has been found in previous investigations to be one of the most significant drivers of BI. Penney et al. (2021) examined the factors that predicted users' BI to use mobile money services and determined that HT is highly significant and positively associated with BI. It is logical to reason that consumers with a strong habitual relationship with their mobile devices are likelier to embrace a blockchain-based mobile application for food provenance. Thus, we hypothesize that:

H4: Habit is positively related to Behavioral Intention.

Blockchain technology's value proposition predominately emanates as a machine (Casey & Vigna, 2018), where trust in people and relationships is shifted to trust in code via encryption and validation. Trust is people's confidence regarding a process or mechanism to produce an expected outcome. In the context of this study, trust is a measure of confidence people have in food chain actors, food information integrity, and food technology (Macready et al., 2020). According to Rupprecht et al. (2020), consumers' perception of the trustworthiness of food labels is decreasing. The variety of labels on the food market poses challenges for consumers to determine whether the information is trustworthy. Eden et al. (2008) study showed consumers become suspicious of an organization's agenda when explicit claims of trustworthiness are placed on product labels. Contrary to their findings, Atkinson and Rosenthal (2014) showed that one way to strengthen consumer trust is by using labels that present detailed explanations about specific claims related to trustworthiness. Thus, prior research is inconclusive.

Value is in the eye of the beholder, and the cliché goes. It assesses the perceived benefit and cost of obtaining a product or service (Zeithaml, 1988). It is also the extent to which people perceive utilitarian value in using some technology (Wang, 2015). In this study, perceived value is the utility of the additional provenance and tracking data delivered to the consumer via a blockchain-based mobile application. We originally conceived Consumer Perceived Value and Consumer Trust as separate constructs. However, as newly theorized constructs adapted for our purpose, we employed a mixed method of ESEM (exploratory structural equation model) by integrating exploratory factor analysis with our confirmed factors from UTAUT2. A major advantage of ESEM is it demonstrates power and flexibility to fit the data better in the observed model (Marsh et al., 2009). In doing so, we found that most of the indicators for the new constructs loaded onto a single high-order factor. Therefore, we established an aggregate construct named Consumer Perceived Value and Trust (CPVT). It is reasonable to expect that higher levels of CPTV are associated with greater motivation to adopt new technology. Therefore, we proposed that:

H5: Consumer Perceived Value and Trust is positively related to Behavioral Intention.

As CPVT is newly proposed, we were curious about its impact on the traditional UTAUT2 constructs. Since consumer perceptions of value and trust in technology can be influenced by myriad factors, such as the performance outcomes they expect and the commensurate effort required to experience them, it is reasonable to think there may be some interaction between these factors. This approach is consistent with Macready et al. (2020) recommendation to explore whether consumer trust (in our case, CPVT) moderates the link between the constructs PE, EE, SI, HT, and BI to accept blockchain-certified food products. Furthermore, social influence from friends, family members, and colleagues regarding their intentions to use technology can also have a strong psychological impact on a person's perceptions of trust and value. The psychological impact is likely to manifest as a positive or negative predisposition and/or unconscious bias to adopt the technology in question. Finally, since habits are formed through repetitive experiences that drive behaviors, subjects are often unaware that habits are ingrained in the unconscious mind. Therefore, it stands to reason that trust and value underlie the formation of unconscious repetitive behaviors. To this end, we explore, without any preconceived expectation of direction, whether CPTV moderates the relationships between the traditional UTAUT2 constructs in our model (see Figure 8):

H6a: Consumer Perceived Value and Trust plays a role in moderating the relationship between Performance Expectancy and Behavioural Intention.

H6b: Consumer Perceived Value and Trust plays a role in moderating the relationship between Effort Expectancy and Behavioural Intention.

H6c: Consumer perceived value and trust plays a role in moderating the relationship between Social Influence and Behavioural Intention.

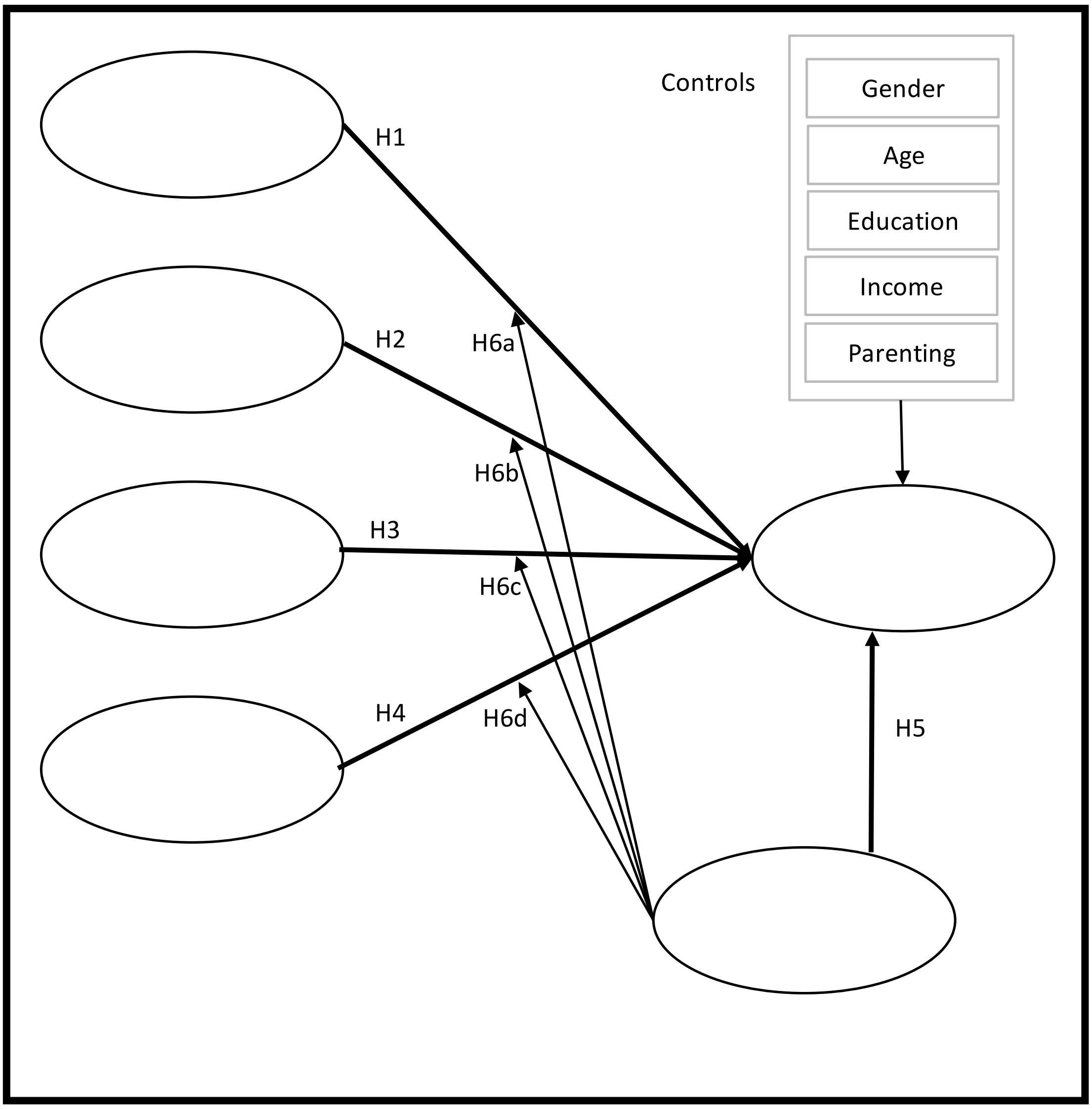


Figure 8. Proposed UTAUT2 research model

H6d: Consumer perceived value and trust plays a role in moderating the relationship between Habit and Behavioural Intention.

3.7.1. Excluded Factors

Facilitating conditions (FC) is an a priori construct of UTAUT2 that refers to consumers' perceptions of the resources and support available to perform a task (Venkatesh et al., 2012). Through the lens of this research, it would include mobile phone adequacy, network adequacy, and the ability to scan a quick response barcode. However, our preliminary analysis found that most of the indicators for FC showed poor loadings. Thus, it was omitted based on Baumgartner and Homburg (1996) (Costello & Osborne, 2005) recommendation to have at least three indicators to avoid weakness and instability. This is consistent with Morosan and DeFranco (2016) findings that the relationship between FC on BI was significant but weak and challenging to measure in their study of consumers' use of mobile applications. The decision to omit this construct is further supported by Tamilmani et al. (2020), suggesting researchers are not obliged to replicate all the constructs from UTAUT2 when operationalizing their own models.

The hedonic motivation construct was revised to food safety motivation to suit our context. Traditionally, the hedonic motivation of consumers refers to the emotional aspects of purchasing a product, such as feelings of joy or fun. We speculated it would also apply to feelings of safety and security in the context of food consumption. Food safety refers to the dangers that may make food pernicious to the consumer's health (Food and Agriculture Organization of the United Nations, 2003). Food safety guarantees that food will not injure the consumer when prepared and consumed according to its intended use. Food safety is well-studied by experts, but research investigating how consumers interpret it is scarce (Raspor, 2008). One of the few studies in this area was by Jevšnik et al. (2006), where they analyzed consumer interpretation of food safety terms such as fresh, frozen, healthy, and gluten-free. We developed indicators to attempt to capture food safety concerns. These included a desire to be informed of possible food incidents (contamination, adulteration, recalls) and information authenticity. However, our attempt to measure food safety motivation as a proxy for hedonic motivation failed to produce a viable latent construct. Therefore, it was not included in the study.

3.8. Methodology

A survey method was applied using an online questionnaire for empirical data collection. The survey comprised measurement questions for the model's endogenous, exogenous, and demographic variables. We used a five-point semantic differential scale with alternating positive/negative adjectives to minimize participants' fatigue and item ambiguity. In addition, we used reversed-scored scale items to reduce the tendency of respondents to answer the questions in a repetitive style and to maintain their attention. The semantic differential scale was more suitable for our study than the Likert scale because it prevents double-barrelled questions (i.e., ambiguities; avoidance in the task) and reduces the acquiescence bias — participants endorse responses for acceptability—without mitigating psychometric quality (MacKenzie & Podsakoff, 2012). Based on comments from Friborg et al. (2006), the semantic design is recommended to measure positive/negative psychological constructs better and shows improvements in measuring uni-dimensional loading items.

Our measurement items were adjusted from Venkatesh et al. (2012) to our food information context: Performance Expectancy, Effort Expectancy, Social Influence, Habit, and Consumer Perceived Value and Trust. The questionnaire captured the model's latent dependent variable, Behavioural Intention, and the five independent variables with 57 scaled items. In addition, the controlled variables of gender, age, education, income, and parental affiliation were also included. We modified hedonic motivation to measure food safety motivation and price value to measure perceived consumer value. We did so as we considered food safety motivation to be more relevant to consumers than hedonic motivation when evaluating their perceptions of food authenticity and safety matters. Also, real-world sample pricing is not available; perceived consumer value is a latent measure of value, whereas price value is direct. At the end of the survey, we incorporated a final open question about any feedback regarding food transparency, followed by the demographic questions (gender, age, region, education level, employment status, household income, Australian regions, and parenting).

The data was analyzed, and the above hypotheses were tested using the two-step structural equation modeling (SEM) estimation process by Anderson and Gerbing (1988), which includes a confirmatory factor analysis (CFA) followed by a path analysis of the relationships. SEM is a statistical method that simultaneously analyses the interrelated relationship dependence among multiple variables and accounts for measurement error in the estimation process (Collier, 2020). Data was analyzed using statistical software such as SPSS, Analysis of Moment Structures (AMOS SPSS 28 Graphics).

3.8.1. Data Collection Platform

The measurement instrument was pre-tested in October 2021 with a cohort of undergraduate students in an internal platform to evaluate the questionnaire's content validity and the instrument's design. We conducted a comparative analysis of the different online panels. Following the recommendations of Peer et al. (2021) for experimental research, we collected our primary data on the Prolific online platform to access real-world consumers. After we edited some questions for additional clarity, we also conducted a pilot study of ten participants, a practice recommended by the online panel, with the highest approval rate of completion in the online panel. Finally, based on the respondents' feedback, we made minor modifications regarding the wording explanation of blockchain technology's role in the food supply chain safety in the questionnaire. This received the Ethics approval number 2021/ET000375 to conduct this research.

3.8.2. Sample

In the pre-screening stage, the location was limited to participants living in Australia with a minimum age of 18. The study distribution set was a balanced sample of male and female participants consulted previously by the Australian Bureau of Statistics (2021) to determine the quota sampling by age and gender to ensure representativeness. The final data was collected in two allotments between June and July 2022. We collected 463 responses overall. After the data scrutiny, we removed 12 responses due to survey incompleteness and response bias; hence, the final sample yielded 451 complete responses to analyze. According to the metrics provided by the online panel, the participants took 22 minutes on average to complete the survey. Table 6 provides summary statistics of the sample.

3.8.3. Descriptive Analysis

The sample was gender-balanced, with males (49%), females (48.8%), non-binary/gender-diverse (1.8%), and those who preferred not to answer (0.4%). In the age category, most participants were 28-37 years old (34.8%), followed by 18-27 years (31.7 %), 38-47 years (17.7%), 48-57 years (10 %), and 58+ (5.8%). Noteworthy is that 62.1% of the participants had already heard about blockchain before participating in the survey. In contrast, 37.7% reported this type of digital technology was completely new, and only 1 person preferred not to answer. The data suggests gender may be relevant to blockchain awareness, with males (63.9%) being more aware of the technology than females (33.9%) and non-binary/gender-diverse (1.8%) respondents. In addition, blockchain awareness may also be correlated to age, as participants in the 28-37 years old (38.2%) were more aware of the technology than those in the 58+ category (3.9%).

Regarding education levels, 33.7% of the population reported having an undergraduate degree, 17.1% indicated they had a technical degree, and 15.5% had a high school diploma. Higher education levels were relatively low, with 15.1% of the population reporting having a master's degree, 8.2% indicated they had a graduate degree, and 4.4% had a PhD degree. Participants possessing secondary education and no formal qualifications accounted for 6%.

Almost half of the participants had a full-time job (43.9%) or a part-time job (22.6%), and 13.7% were students. On the other hand, 8% were not in a paid job (whether homemakers, retired, or disabled), and 11.8% were unemployed, looking, not looking for work or other. Most of the respondents' participation regions were from New South Wales and Victoria (62.1%), followed by Queensland (17.5%), and 20.4% of responses were from South Australia, Western Australia, Tasmania, and the Northern Territory. The demographic data shown in Table 6 offers a representative cross-section of Australian consumers with descriptions briefly highlighted above.

Table 7. Summary Statistics

	Category	**Frequency**	**%**
Gender	Male	221	49
	Female	220	48.8
	Non-binary/gender-diverse	8	1.8
	Prefer not to answer	2	0.4
Age	18 -27	143	31.7
	28 - 37	157	34.8
	38 - 47	80	17.7
	48 - 57	45	10
	58 +	26	5.8
Education	Doctorate/PhD	20	4.4
	Master/Professional degree	68	15.1
	Graduate degree	37	8.2
	Undergraduate degree	152	33.7
	Technical / Community college	77	17.1
	High school diploma	70	15.5
	Secondary education	26	5.8
	No formal qualifications	1	0.2
Income	More than $200,000	35	7.8
	$100,000 - $200,000	141	31.3
	$50,000 - $100,000	140	31
	$25,000 - $50,000	68	15.1
	Less than $25,000	34	7.5
	Prefer not to answer	33	7.3
Employment	Full time	198	43.9
	Part-time	102	22.6

	Unemployed, looking for work	28	6.2
	Unemployed, not looking for work	12	2.7
	Not in paid work (e.g., 'homemaker,' 'retired' or disabled)	36	8
	Student	62	13.7
	Other	13	2.9
Region	Western Australia (WA)	36	8
	Northern Territory (NT)	2	0.4
	South Australia (SA)	41	9.1
	Queensland (QLD)	79	17.5
	New South Wales (NSW)	141	31.3
	Victoria (VIC)	139	30.8
	Tasmania (TAS)	13	2.9
Blockchain Awareness	Yes	280	62.1
	No	170	37.7
	Prefer not to answer	1	0.2

3.9. Results

The results showed all the standardized regression weights had beta coefficients > 0.50 (Hair et al., 2019). However, some indicators showed poor loadings (PE1, PE5, SI4, HT1, CT1, CT2, FSM1, FMS2, and FSM3) and were subsequently removed to achieve a better data fit (Collier, 2020). When doing the CFA, the data showed multivariate non-normality despite almost all the variables exhibiting a univariate normal distribution. We used the ML Bollen-Stein bootstrapping technique as an appropriate response to address this problem (Bollen & Stine, 1992). To discern whether our model fits the data, we tested the null hypothesis that the model was correct with the Bollen-Stine bootstrap. If the null model is correct, we would expect the p-value associated with our sample dataset to be greater than 0.05. Hence, we rejected the null hypothesis and concluded the model had an acceptable fit.

Next, we analyzed the goodness of fit to determine how well the defined theoretical model mathematically reflected reality as represented by the data (Hair et al., 2019). We analyzed the goodness of fit indices with the maximum likelihood estimator, and the model fit was evaluated using the following measures: CMIN/DF (normed chi-square; $1.0 < X^2/df < 3.0$), Goodness of Fit Index (GFI ≥ 0.95), comparative fit index (CFI; ≥0.95), Tucker-Lewis index (TLI; ≥ 0.95), the Root Mean Square Error of Approximation (RMSEA; ≤ 0.07) and Root Mean Squared Residual (RMR ≤ 0.05) (Diamantopoulos & Siguaw, 2000; Hair et al., 2019; Hu & Bentler, 1999; Kline, 2005). We used a "relative chi-square" test (chi-square value divided by the degrees of freedom) to improve the robustness of our model to sample size (Kline, 2005). Overall, our model showed good measurements in all other fit statistics. See the measurement estimation assessment in Table 7.

Table 8. Goodness of fit assessment of the model

Indices	**χ2**	**df**	**CMIN/DF**	**RMSEA**	**GFI**	**TLI**	**CFI**	**Standardized RMR**
Criteria	–	–	Between 1 and 3	≤ 0.05	≥ 0.95	≥ 0.95	≥ 0.95	≤ 0.05
Model	471.315	254	1.856	0.044	0.922	0.962	0.968	0.0475

Construct reliability and validity of the measurement model were tested using the composite reliability, Cronbach Alpha (Hair et al., 2019), and average variance extracted (AVE). Composite reliability is a measure of internal consistency of the constructs in the model, and a construct is considered reliable if the Alpha (α) value is greater than 0.70 (Hair et al., 2013). The results exhibited all constructs were found reliable (CR > .70 and α > .70), supporting internal consistency (see Table 8). Furthermore, convergent validity is estimated with average variance extracted (>0.5), showing that all constructs met this threshold value except for *habit* (.469). However, as a rule of thumb, if composite reliability is greater than 0.6 and AVE is close to 0.5, the construct validity is still adequate (Fornell & Larcker, 1981), ergo, establishing convergent validity.

Table 9. Construct loadings, factor reliability, AVE, item means, and standard deviation

Construct	No Items	Item	Factor loading	CR	Cronbach's Alpha	AVE	Mean	SD
Performance Expectancy	3	PE4	0.688	0.805	0.798	0.581	4.02	1.00
		PE3	0.830				3.68	1.08
		PE2	0.762				3.48	1.13
Effort Expectancy	4	EE4	0.560	0.831	0.831	0.558	4.67	0.64
		EE3	0.770				4.66	0.67
		EE2	0.905				4.49	0.71
		EE1	0.712				3.92	0.91
Social Influence	3	SI3	0.836	0.913	0.912	0.779	3.44	0.99
		SI2	0.905				3.71	0.95
		SI1	0.905				3.66	0.97
Habit	3	HT4	0.781	0.724	0.760	0.469	3.11	1.29
		HT3	0.593				3.68	1.22
		HT2	0.668				3.12	1.23
Consumer Perceived Value & Trust	8	CPV5	0.648	0.894	0.901	0.516	3.81	0.97
		CPV4	0.762				3.83	1.02
		CPV3	0.818				3.88	1.02
		CPV2	0.727				3.99	0.98
		CPV1	0.685				3.58	1.01
		CT4	0.656				3.89	0.93
		CT3	0.672				4.16	0.80

Construct	No Items	Item	Factor loading	CR	Cronbach's Alpha	AVE	Mean	SD
		FSM4	0.759				3.78	0.99
Behavioral Intention	4	BI1	0.678	0.852	0.847	0.593	2.41	1.06
		BI2	0.675				4.03	0.98
		BI3	0.845				3.34	1.01
		BI4	0.860				3.20	1.15
Note: CR = composite reliability; AVE = average variance extracted; SD = standard deviation.								

Finally, discriminant validity was analyzed with the heterotrait-monotrait ratio of correlations (HTMT< 0.90), denoting no issues of discriminant validity (Hair et al., 2019; Henseler et al., 2015); see Table 9.

Table 10. Discriminant Validity (HTMT Ratio)

	CPVT	**HT**	**BI**	**SI**	**EE**
CPVT					
HT	0.721				
BI	0.747	0.800			
SI	0.777	0.710	0.807		
EE	0.124	0.206	0.072	0.073	
PE	0.862	0.743	0.773	0.795	0.103

Note: HTMT = heterotrait-monotrait ratio; CPVT= consumer perceived value and trust; HT = habit; BI = behavioral intention; SI = social influence; EE = Effort Expectancy; PE = performance expectancy.

3.9.1. Common Method Bias

To minimize the effects of common method bias, we followed the active intervention techniques described in MacKenzie and Podsakoff (2012) and Podsakoff et al. (2012). We created a psychological separation task between the survey sections where participants answered questions related to independent and dependent variables. The task was to watch a short video on the Fourth Industrial Revolution unrelated to our research topic. The aim is to reduce the salience of the connection between the predictor and criterion variables (Podsakoff et al., 2012) in the respondents' short-term memory. We achieved an adequate temporal separation (Jordan & Troth, 2019) of 1:26 minutes, balancing the length of the temporal delay to avoid respondent attrition and/or sense of purposeless separation.

Moreover, we designed the questionnaire based on a semantic differential style, with a random question sequence, maintaining clear and simple questions to prevent double-meaning comprehension (MacKenzie & Podsakoff, 2012). Subsequently, we asked a couple of psychological questions related to the video to eliminate familiar retrieval cues and reduce the perceived relevance of the formerly recalled information from the dependent variables (Podsakoff et al., 2012). Then, we conducted the post-data collection recommendation of MacKenzie and Podsakoff (2012) for the common method variance (CMV) estimation. Finally, we performed Harman's single factor test (in SPSS and AMOS) and the common latent factor test in AMOS to increase our confidence in our results. Harman's one-factor test loads all indicators from each construct into a single factor, denoting CMV problems if the factor reports a large amount of shared variance among the variables (Jordan & Troth, 2019). Table 10 shows the percentage of total variance is 43%, meeting the acceptable threshold of half (<.50) of the variation attributable to one factor (Aguirre-Urreta & Hu, 2019). Even though Harman's one-factor test has been criticized as insensitive, it provides a handy procedure for disclosing CMB likelihood (Hair et al., 2019; Jordan & Troth, 2019). We also undertook the same test in AMOS by comparing the model fit summaries from the restricting one-factor model and our analyzed SEM model (Collier, 2020). The test showed that our model had no significant issues with CMV.

Table 11. Harman's Single Factor Test

Component	**Initial Eigenvalues**	**% of variance**	**Cumulative %**	**Extraction Sums of Squared Loadings**	**% of variance**	**Cumulative %**
	Total			Total		
1	10.753	43.011	43.011	10.753	**43.011**	43.011

Finally, we constructed a common latent factor adjusted model by adding a first-order factor with a direct relationship with each construct's indicators, allowing them to share a common source of variance (Collier, 2020; Podsakoff et al., 2012). Next, we performed a chi-square difference test with the common latent factor to resolve if bias exists (Collier, 2020). When comparing the difference in chi-square estimates (Williams et al., 2003), we observed a 53.43 chi-square difference between the models at 1 degree of freedom. Next, we identified two indicators from *Effort Expectancy* where the standardized regression weights had values larger than .2 (.27 and .32, respectively), meaning there was a low-level issue of CMB (Malhotra et al., 2006). Subsequently, we performed a data imputation for the CMV post-remedy in the SEM analysis (Collier, 2020) and compared the results. The adjusted model had a better fit when comparing both models (see Table 11). The evidence in total indicates CMB is not a major concern; by weighing only two items from one construct displayed a slight amount of CMV, and Harmon's one-factor test was 43%. The adjusted model had a good fit overall to move forward with high confidence (Collier, 2020; Hair et al., 2019).

Table 12. Original vs. adjusted model CFA comparison assessment

Indices	**$\chi 2$**	**df**	**CMIN/DF**	**RMSEA**	**GFI**	**TLI**	**CFI**	**Standardized RMR**
Criteria	–	–	Between 1 and 3	≤ 0.05	≥ 0.95	≥ 0.95	≥ 0.95	≤ 0.05
Original model	471.315	254	1.856	0.044	0.922	0.962	0.968	0.0475
Adjusted model (CMV post-remedy)	417.890	253	1.652	0.038	0.932	0.971	0.976	0.0419

3.9.2. Model Assessment

We used SEM for our path analysis because it uses a structural equation modeling multivariate technique integrating factor analysis and multiple regression features to estimate dependence relationships and computational power (Hair et al., 2019). The covariance-based model facilitated our research objective of testing the UTAUT2 theory. Therefore, we tested the structural relationships between constructs and assessed the model fit (see Table 12).

A good fitting model is accepted if the value of the CMIN/DF is <5 (Hair et al., 2013); with the Goodness of Fit (GFI), the Tucker and Lewis (1973) index (TLI), the confirmatory fit index (CFI) (Bentler, 1990) are all >0.90 (Hair et al., 2013). A good-fitting model is also confirmed if the measured value of the standardized root mean square residual (RMR) < 0.05 and the root mean square error approximation (RMSEA) is between 0.05 and 0.08 (Hair et al., 2013). The fit indices result of our structural model assessment in Table 12 (Anderson & Gerbing, 1988) demonstrated a good model fit (CMIN/DF=1.652; GFI=0.932; TLI=0.971; CFI=0.976; Standardized RMR= 0.0419; RMSEA=0.038). The squared multiple correlation was 0.74 for behavioral intention, indicating the five factors (*PE*, *EE*, *SI*, *HT*, and *CPVT*) account for 74% of the variation in behavioral intention.

Table 13. SEM Model Assessment

Indices	**$\chi 2$**	**df**	**CMIN/DF**	**RMSEA**	**GFI**	**TLI**	**CFI**	**Standardized RMR**
Criteria	–	–	Between 1 and 3	≤ 0.05	≥ 0.95	≥ 0.95	≥ 0.95	≤ 0.05
Results	417.890	253	1.652	.038	0.932	0.971	0.976	.0419

Having discussed the model assessment, we delineate the model with path coefficients, significance, and structural model fit in Figure 9

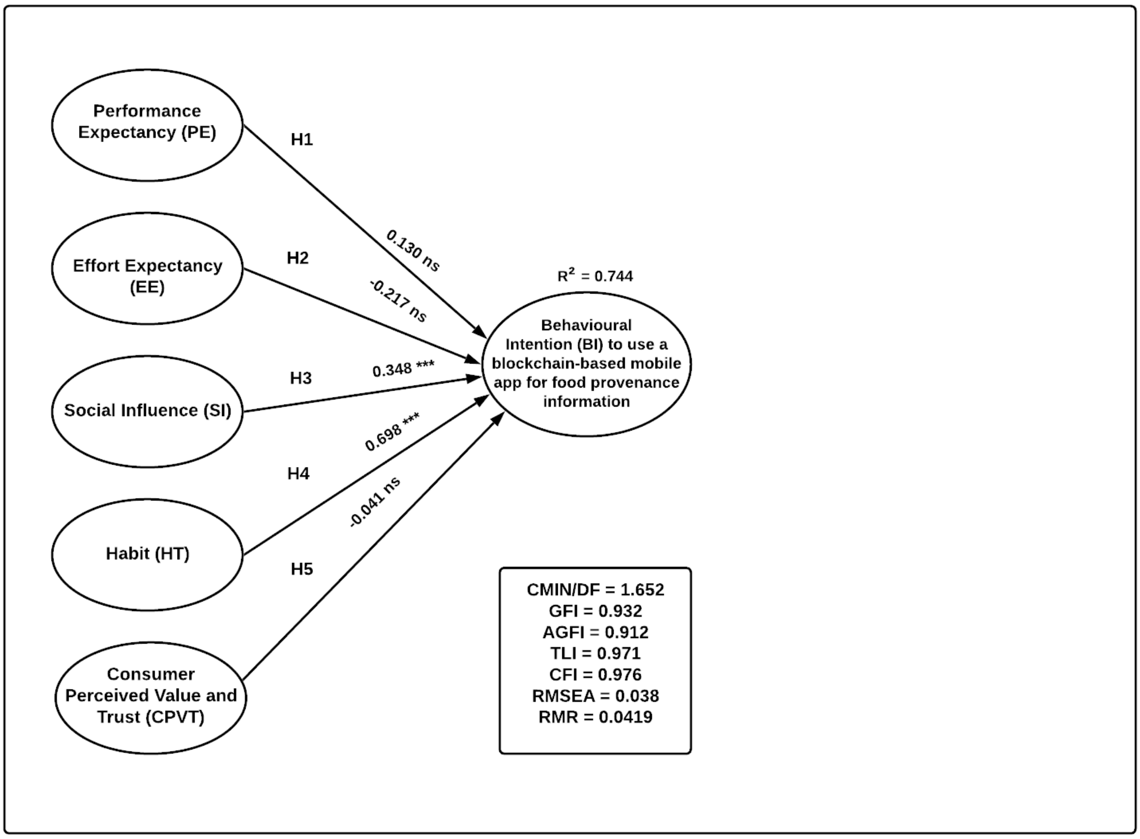


Figure 9. Path coefficients, significance, and structural model fit

Note: ns = not significant; *p<0.05; ***p<0.001

3.9.3. Structural relationships

The pathway analysis revealed only two of the five hypotheses could be supported (see Table 13). H1 proposed a positive relationship between PE and BI, which was not supported (b= 0.013, t= 1.122, p= 0.262). H2 proposed a negative relationship between EE and BI, which was not supported (b= -0.217, t= -1.849, p=0.064). H3 proposed a positive relationship between SI and BI, which was supported (b= 0.348, t= 3.750, **p<0.001**). H4 proposed a positive relationship between HT and BI, which was supported (b= 0.698, t= 4.630, **p< 0.001**). Finally, H5 proposed a positive relationship between CPVT and BI, which was not supported (b= -0.041, t= -0.242, p= 0.809).

Table 14. Summary of findings of structural relationships

Hypothesis	**Path**	**Proposed effect**	**β**	**t-value**	**Significance**	**Result**
H1	PE → BI	+	0.130	1.122	0.262	Rejected
H2	EE → BI	−	-0.217	-1.849	0.064	Rejected
H3	**SI → BI**	+	**0.348**	**3.750**	**< 0.001**	**Supported**
H4	**HT → BI**	+	**0.698**	**4.630**	**< 0.001**	**Supported**
H5	CPVT → BI	+	-0.041	-0.242	0.809	Rejected

3.9.4. Analysis of Control Variables

Next, we ran a multi-group SEM analysis in AMOS to examine consistency with UTAUT2 using control variables (gender, age, education, income, and parenting) to determine if differences exist across the groups. In the first stage, we examined all the relationships in the model (structural weights) to determine if the groups were different as a whole. If we found significant differences (p-value<0.05) in any of the paths, we formed a new constrained model (constraining the specific relationship). We observed which group had a stronger or weaker effect on the relationships by comparing the standardized regression weights (Collier, 2020). There were no significant differences among the gender, age, education, and income groups regarding *PE*, *EE*, *SI*, or *CPTV* relationship to *BI*. However, there was a significant difference in the relationship between *HT* on *BI* for the groups that are parents or caretakers of children and those that are not. Those who are **not** parents or caretakers are more favorably predisposed to using a blockchain-based mobile application for food provenance. Therefore, all the control variables were found insignificant except for not being a parent regarding *HT* on *BI* (see Table 14).

Accordingly, although not being a parent was found significant in *HT* on *BI*, incorporating the control variables does not modify any of the significance levels of the path's coefficients in our structural model. Overall, our model's confluence of independent factors explained 74% of the variance in behavioral intention.

Table 15. SEM Multi-Group Analysis

Groups	**Paths (β)**					**Results**
Gender	PE→BI	EE→BI	SI→BI	HT→BI	CPVT→BI	Significance between the groups
Male	0.220	-0.034	0.325	0.386	0.060	No significant difference for all paths
Female	0.036	-0.109	0.345	0.704	-0.129	
Age						
18-27	0.292	-0.040	0.376	0.460	-0.214	No significant difference for all paths
28-37	-0.088	-0.046	0.335	0.681	0.043	No significant difference for all paths
38-47	-0.157	-0.260	0.310	0.851	0.057	No significant difference for all paths
48-57	3.731	-0.156	0.423	-0.810	-2.479	No significant difference for all paths
58 +	1.397	-1.148	-0.433	1.372	0.028	No significant difference for all paths
Education						
No formal qualifications	0.156	0.217	0.125	0.081	0.223	No significant difference for all paths
Secondary education	0.102	0.046	-0.115	0.141	0.807	No significant difference for all paths
High school diploma	0.146	-0.027	0.365	0.677	-0.266	No significant difference for all paths
Technical/Community College	0.068	-0.143	0.13	0.443	0.481	No significant difference for all paths
Undergraduate degree	0.587	-0.022	0.125	0.505	-0.204	No significant difference for all paths
Graduate degree	-0.033	0.089	0.597	0.268	0.058	No significant difference for all paths

Groups	Paths (β)					Results
Master	-0.089	0.006	0.180	0.585	0.314	No significant difference for all paths
PhD	-0.173	-0.098	0.597	0.59	0.485	No significant difference for all paths
Household Income (Annual)						
Less than $25,000	-0.119	-0.097	0.141	0.290	0.592	No significant difference for all paths
$25,000 - $50,000	0.308	-0.169	0.252	0.498	0.020	No significant difference for all paths
$50,000 - $100,000	0.112	-0.142	0.388	0.757	-0.262	No significant difference for all paths
$100,000 - $200,000	0.304	0.119	0.742	0.104	-0.223	No significant difference for all paths
More than $200,000	-0.458	-0.162	0.334	1.006	0.324	No significant difference for all paths
Parent or caretaker of children						
Yes	-1.321	-0.544	-0.263	1.709	1.018	No significant difference for all paths
No	0.268	-0.077	0.352	0.435	-0.070	Significant HT→BI (**0.021**) <0.05

Note: PE = performance expectancy; EE = effort expectancy; SI = social influence; HT = habit; CPVT = consumer perceived value and trust.

3.9.5. Moderation Effect

The technique used for the moderation assessment was an interaction term created by a product term of the independent variable and the moderator (see Figure 10). The interaction term reveals if the presence of the moderator has a significant impact on the relationships from the predictors to the criterion variable (Collier, 2020). We first mean-centered the composite variables to account for potential collinearity issues and easier interpretation of outcomes (Dawson, 2014).

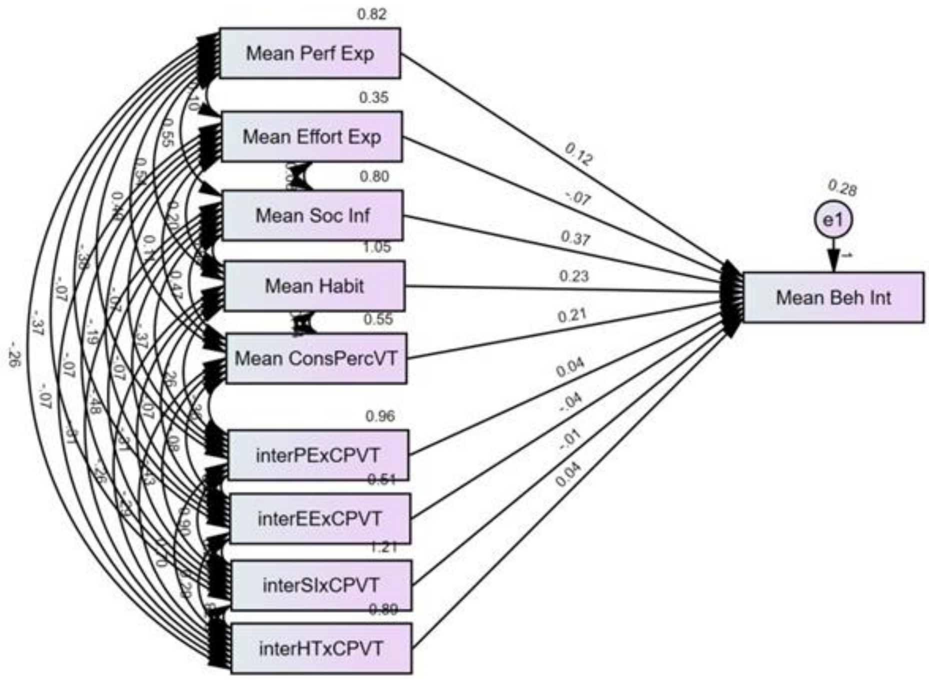


Figure 10. SEM Interaction Term Model for Moderation Assessment

Overall, there is no evidence of moderation when including the new factor (CPVT) in any of the relationships (see Table 15).

Table 16. Moderation Estimation and Significance between the relationships

Hypothesis	Interaction	Estimates	Significance	Result
H6a	PExCPVT	0.041	0.421	Rejected
H6b	EExCPVT	-0.045	0.315	Rejected
H6c	SIxCPVT	-0.008	0.869	Rejected
H6d	HTxCPVT	0.039	0.380	Rejected

PE = performance expectancy; EE = effort expectancy; SI = social influence; HT = habit; CPVT = consumer perceived value and trust.

3.10. Discussion, policy implications, and conclusion

In this study, we examined the key factors that advance or hinder consumers' acceptance of a blockchain-based mobile application for food provenance, which can transform the food supply chain to make it more efficient, transparent, safer, and customer-centric. Generally, in our study participants responded positively to the proposition. This study has provided several observations and further support for some of the UTAUT2 constructs. We examined the answers to our two research questions:

RQ1. What latent factors drive usage intention (with the UTAUT2 framework) for consumers exploring a new digital technology (blockchain) to access transparent food information? The data revealed the significant factors of usage intention according to the relationship strengths (beta-coefficients), such as *habit,* which has proven to be the most significant and positive factor in our study, followed by *social influence,* which is also positive and significant. We anticipated that *effort expectancy* would be significant, negatively affecting *behavioral intention* to use the blockchain-based application. However, this was not the case in our study. Furthermore, *performance expectancy* had an insignificant effect on *behavioral intention.* Finally, our newly added construct, the *consumer perceived value and trust,* had an insignificant impact on *behavioral intention* to use the application.

Our empirical results show that *habit* is the most significant predictor of behavioral intention. This outcome is consistent with previous findings from mobile applications use research (Merhi et al., 2019; Nikolopoulou et al., 2020; Oliveira et al., 2016; Penney et al., 2021; Ramírez-Correa et al., 2019; Venkatesh et al., 2012). S*ocial influence* also plays a significant role in the acceptance and use of the technology, which also confirms previous findings of Cabrera-Sánchez et al. (2021); (Morosan & DeFranco, 2016; Venkatesh et al., 2012). This outcome demonstrated that participants could be substantially influenced by their peers' views, whether family members, colleagues, or people on social media. Tamilmani et al. (2020) reported that *effort expectancy* tends to yield the most inconsistent results in prior studies deploying the UTAUT2 framework, which was the case in our study. We also introduced a new composite construct, *consumer perceived value and trust*, and proposed a positive relationship for our study. However, our results showed an insignificant relationship with *behavioral intention*. Finally, we theorized the moderating influence of *CPVT* on the relationships between the previous constructs (*PE, EE, SI,* and *HT*) and *BI*. However, there were no significant moderation effects to report.

R2. Do the control variables (gender, age, education, income, and parenting) exhibit differences across the groups?

When we conducted a multi-group analysis with the control variables, we found no significant differences among the groups except parents or children's caretakers vs. those who were not. However, regarding the influence of *habit* on *behavioral intention*, there is a significant difference in those that are not parents or do not take care of children—implying that for the *habit* factor, not being a parent positively affects *behavioral intention*, contrary to what we expected. We theorized being a parent was positively associated with primal concerns about the health and welfare of their children. Thus, we expected a robust attitude toward using a blockchain-mobile app to support more transparent and safer food choices. Yet, the effect is the opposite. A possible explanation of this outcome is that most participants were 18-37 years old, and participants in our study who were not yet parents (i.e., younger generations) embraced digital technologies more readily (digital natives).

3.11. Policy Implications

Our previous study grants us the proficiency to formulate a food policy framework based on our research analysis and the Food Standards Australia New Zealand (FSANZ) regulatory information. FSANZ is part of the Australian Government's health portfolio and develops food standards with advice from other government agencies and stakeholder input (Food Standards Australia New Zealand, 2016). Our food policy framework offers guidelines for cooperation among governmental bodies, the food industry, and the consumer, incorporating four strategic interdependent pillars to embrace blockchain adoption: food provenance, collaboration, compliance, and trust (see Figure 11). The food provenance pillar refers to the critical necessity of accurately tracing a food product back to its origin, leading to the implementation of blockchain technology providing transparent instant traceability in the food industry. Thereby, with the technology adoption, the possibility of embedding smart contracts into the ledger will streamline supply chain operations contributing to faster food recalls and protection for the consumer. The collaboration pillar refers to uniting efforts among the food industry, governmental bodies and the consumer to initiate blockchain adoption by observing shared goals and updating food regulations in terms of compliance. The compliance pillar refers to aligning food policies with established regulations and standards in a new blockchain environment. It comprises six main strategies, strengthening food transparency, safeguarding food safety, collaboration among supply chain stakeholders, developing food policies and fostering international partnerships. The final pillar of our food policy framework for blockchain adoption is trust, which refers to gaining the trust of consumers and among all food supply chain stakeholders achieving food supply chain efficiency. Next, the six strategies for food policies are explained in more detail.

3.11.1. Strengthening Food Transparency

Initiating the adoption of blockchain technology in food supply chains requires cooperation among all stakeholders, such as governmental agencies, food companies, and consumers. To achieve this, government agencies must identify the proper communication channels to enable collaboration among all parties. Since key digital technologies strengthen auditing and support integrated analytics across databases (Ehlers et al., 2021), when training and understanding the companies' requirements, policymakers should initiate context-specific studies of supply chains to identify the most effective points of intervention (Cattaneo et al., 2021) for blockchain technology adaptation.

Based on the findings of this investigation, government agencies must coordinate with food companies to target *habit* formation and *social influence* to actively create incentives to digitize paper-based processes in food supply chains and to create an e-food environment that guarantees continuity of information. By mapping and standardizing processes in food supply chains using blockchain technology, companies will be more efficient in recording and sharing data on food provenance. One important aspect of standardization can involve employing a unified label format for the entire food industry and affixing it to the item(s) and the package. Also, promoting the use of unique product identifiers or QR codes on food packaging is pivotal so consumers can scan them to access information about the food product's journey. Finally, it is vital to constantly monitor the ongoing standardization processes and food supply chains' gradual adoption of blockchain.

3.11.2. Safeguarding Food Safety

The main goals of implementing blockchain-based systems in the food supply chain focus on food transparency, monitoring, and faster detection of food safety incidents. The aim is to attain faster location of contamination sources, earlier containment actions, and boost food recalls' responsiveness. A key strategy can be to initiate trials of blockchain-enabled smart contracts to automate and enforce compliance with food safety and standard regulations, ensuring timely corrective actions, minimizing risks, reducing administrative burdens, and improving supply chain automation. Using smart contracts will help enforce food businesses to report any safety issues promptly and maintain an immutable record of declared incidents to assist investigations and attribute responsibilities.

3.11.3. Collaboration

All stakeholders in the food supply chain need to plan collaborative initiatives to raise awareness and educate all participants on the advantages and applications of blockchain technology in the food supply chain. By sharing insights, stakeholders can formulate a general understanding of blockchain's potential and its importance to the food industry. Collaborative efforts can recognise use cases where blockchain implementation can generate substantial value for the food industry. Collaboration can involve shared agreements of interoperability exploration using sandboxes to test food supply chain processes beforehand going to real blockchain proof-of-concepts production to examine the feasibility of implementing the technology in the food supply chain. Forming consortia is encouraged to jointly finance and perform the blockchain projects as the blockchain experiments worldwide have shown as an effective cooperation strategy. Collaboration is essential to determine interoperability and standards, data accessibility, data privacy, data sharing and data security. Close collaboration with consumers is imperative to gather feedback and design user-friendly interfaces to access transparent and reliable food product information and progress continuous improvement.

3.11.4. Food Policies and Food Standards

Launching a multidisciplinary council comprised of academics, government food regulatory bodies, food businesses, and consumers is indispensable in assessing the food policies required to comply within a blockchain-based food environment. Food supply chain stakeholders can collaborate with regulators to align goals and provisions and review compliance difficulties related to blockchain adoption, such as liability and conflict resolution. Government agencies can offer regulation guidance, promote incentives, and regulatory sandboxes where food businesses can contribute with their insights to establish food policies and standards and modify the regulatory system accordingly. The established council should constantly monitor the performance of the blockchain food integration and assess whether it is functioning accordingly with the food policies and standards previously set.

3.11.5. Compliance Reinforcement

The coordination of a council comprised of government regulatory bodies, academics, food businesses, and consumers is required to develop food policies and standards to comply with blockchain-based certification in food products. Government regulatory bodies will delegate powers to enforce compliance with food safety standards and opportunity areas for improvement throughout the supply chains.

3.11.6. Fostering International Partnerships

Collaborating with international counterparts is also central to exploring standards and regulations for blockchain-enabled food systems aiming to complement standardization over time. Sharing best practices, experiences, and lessons learned by implementing blockchain technology in the food industry via international forums and partnerships will be valuable. For instance, The Produce Traceability Initiative (2023) was created to support the food industry in optimizing traceback procedures while developing a standardized industry approach to promote the efficiency of traceability systems for the future. By exchanging knowledge and expertise can initiate interoperability among blockchain supply chain networks facilitating international cooperation.

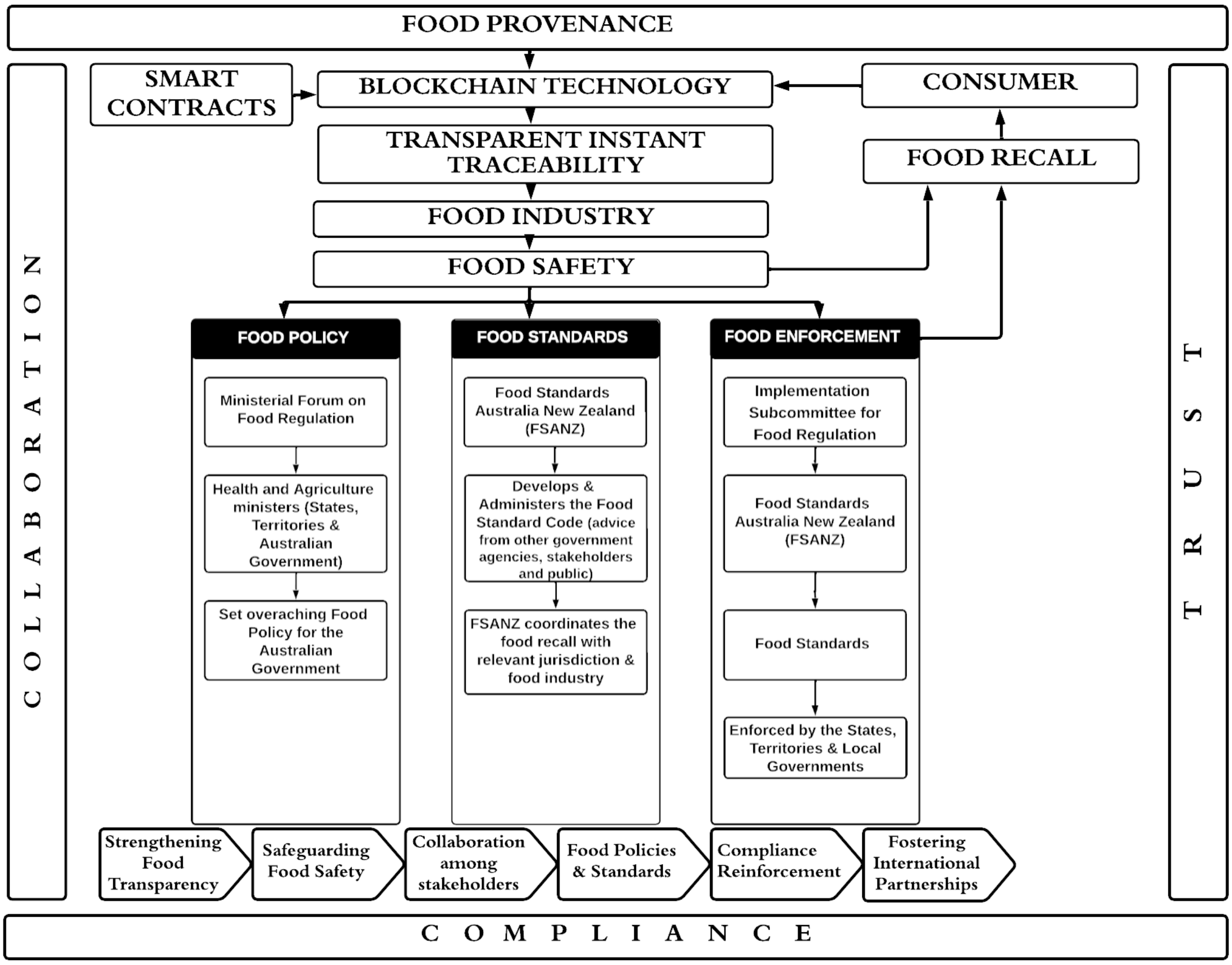


Figure 11. Policy Framework for a Blockchain Food Environment

3.12. Theoretical Contributions

This study advances the academic literature on technology acceptance and supply chain management from a costumers' perspective. From a theoretical outlook, this is the first study investigating user acceptance of a blockchain-based mobile application by utilizing the costumer-centric technology acceptance model (UTAUT2). By adjusting the theoretical framework to a consumer-centric food provenance approach, we provide a novel context for this widely studied framework. Lastly, although

UTAUT2 was established to research the acceptance of technology in a consumer environment, no similar study has been conducted in Australia's cultural setting, which we are aware of.

3.13. Managerial Implications

From a practical standpoint, this study provides guidance for food companies. First, businesses have better information about the factors influencing consumer behavior (habit and social influence). This increases food practitioners' managerial confidence in where to focus their resources for consumers' acceptance of blockchain-certified food products strategically. Second, practitioners can improve their labeling content and design decisions to differentiate themselves in the market. Companies can differentiate from other brands in terms of sustainability, ethical sourcing, and ingredient authenticity, especially for high-end food products providing a substantial market competitive advantage. Third, with *habit* as the most significant driver of consumers' behavioral intention, technology providers must design more user-friendly and visually attractive applications to reinforce the impact of *habit* on BI. Perhaps gamification will provide such an opportunity. Fourth, marketing managers can craft improved social media campaigns with the insight that *social influence* is the second most important factor driving market uptake. They could employ celebrities, opinion leaders, or influencers to push the image of the modern-technologically competent consumer. Thus, companies should emphasize the utilitarian value of the blockchain-based mobile application in their marketing campaigns, perhaps by creating kiosks that provide easy access to select products. This may appeal to the less technologically savvy consumer. Placing those food products with a displayed blockchain-certified logo on their labels in strategic high-visibility store locations such as end-of-isle shelving spaces could potentially enhance uptake. Marketers could also showcase how the new technology protects them from food contamination and tampering risks.

To accelerate the awareness of the technology, companies could advertise food products on their websites using the blockchain-based mobile application. Furthermore, special incentive programs based on digital tokens (coupons) designed as customer loyalty rewards schemes could be established to introduce consumers to this digital technology. The mobile application could then offer instant discounts based on digital tokens acquired, providing economic incentives for uptake. Such a loyalty program could expedite insights to companies to advance more sustainable and ethical practices. Finally, one of the most concerning factors for many people is consumer data privacy when using digital technology. Companies will need to develop a policy compliance framework to ensure and safeguard the consumers' private information.

3.14. Limitations, Future Research, and Conclusions

The scope of this study was limited to participants surveyed in Australia. Therefore, there are risks to generalizing the findings to other cultures. Indeed, when studying consumer preferences about food products, it is reasonable to assume there will be strong cultural affects due to unique localized customs that involve food consumption. A natural progression of this research would be to enrich the conclusions of our study by employing a bigger international sample. This would allow researchers to conduct cross-cultural studies and/or compare developed versus emerging economies. Extending this study to include other constructs, such as data privacy and digital tokens, would also be interesting.

Our experimental setting provides natural limitations for this study because a simulated scenario of the blockchain-based mobile application was used. Future studies should consider live experiments by approaching consumers in stores with an operational mobile phone application that customers could use to become more familiar with blockchain digital technology and its advantages. One important step that would manifest from this approach would be the ability to compare the data between behavioral intention and actual use behavior, a higher-order construct.

On the model measurement side, a limitation is the endogenous variable of our model, behavioral intention, is subjectively estimated by analyzing consumers' perceptions concerning their future behavior. Therefore, future studies should explore the interaction effects between effort expectancy and facilitating conditions together since the presence of effort expectancy could hinder facilitating conditions' predictive capability on behavioral intention (Viswanath Venkatesh et al., 2003).

Since consumer behavior is constantly changing and blockchain technology is still maturing, future studies should consider a longitudinal perspective across the life cycle of technology. This would reveal the attitudes of the well-established customer segments of innovators, early adopters, followers, and laggards. Currently, measurement is challenging because we speculate that we are in the innovator stage of blockchain technology 'know-how' for the general consumer.

Furthermore, since social influence is the second most important predictor of behavioral intention in this research, it would be constructive to analyze the weights of different types of social media influencers on behavioral intention. Finally, studying habit formation in a consumer context with a behavioral neuroscience approach would be noteworthy, as *habit* is difficult to measure using a survey instrument. The difficulty in survey-based assessment limits the study's capacity to comprehensively capture and analyze the complexities of habit formation. This restricts a thorough understanding of habit-related factors, impeding a detailed exploration and analysis of consumer behavior through traditional survey methods. The challenge of assessing habit formation through traditional survey methods could be overcome by incorporating a mixed-methods approach. Employing a combination of survey instruments along with behavioral observations or experimental designs, such as longitudinal studies or ecological momentary assessments, may offer a more comprehensive understanding of habit formation. Additionally, integrating qualitative interviews or observational data might provide richer insights into habitual behaviors and bridge the gap between survey limitations and a more nuanced understanding of consumer habits in a real-world context.

The theoretical contribution of our study is the adaptation and confirmation of the UTAUT2 customer-centric model toward adopting and using a blockchain-based mobile application for food provenance, tracking, and safety. In addition, our study also contributes actionable policy framework and managerial insights. Consequently, companies may now move forward with increased confidence regarding adopting this technology in the future by knowing the consumers' behavioral perspective.

The next chapter examines the consumers' readiness to opt for and invest in blockchain-verified food items, utilizing choice experiments featuring latent variables and compositional data. Focusing on egg purchases and blockchain certifications, we probed consumer reactions toward packaging assertions, product traceability, recall responsiveness, and pricing through three multinomial logit models.

CHAPTER 4

Food provenance assurance and willingness to pay for blockchain data security: A case of Australian consumers.

Foreword

The present chapter aims to determine whether consumers are willing to choose and pay a premium for food products with improved transparency via blockchain technology. Since blockchain adoption research has been mainly focused on an organisational level, I applied the lens of consumer behaviour to my work to fill this gap. This study advances the body of knowledge on consumer behaviour with real consumer insights to capture their decision-making choices and consequently predicts consumers' willingness to choose and pay for blockchain-certified food products.

I employed a hybrid choice model estimation approach combining discrete choice modelling with compositional data analysis of food attributes. My results illustrated an overall positive receptiveness of consumers to blockchain-certified products. The choice modelling estimations indicate blockchain traceability manifests a favourable preference in consumers perceiving the value of blockchain technology for transparent food sourcing. On the other hand, there is an opposite effect for the conventional food recall periods denoting that consumers may perceive them negatively and prolonged compared to the blockchain food recall time in case of food incidents. In addition, the consistent negative predisposition for the packaging claim of cage eggs demonstrates consumers' discontent with unethical production practices, manifesting a sustainable/ethical conscious behaviour. Also, price sensitivity is a determining factor in consumer choices, even if blockchain certification offers the added value of product provenance and faster food recalls. Males seem more reluctant to pay higher prices for blockchain-certified food products than females.

My findings have theoretical and practical implications that advance consumer behaviour and marketing research supporting food brands to create strategic blockchain technology awareness and incentivise its adoption. Lastly, I provide marketing implications based on brand resilience and agility to initiate blockchain technology adoption and increase brand equity.

N.B: Please note that for the purposes of publication with multiple authors, I use “we” instead of “I”.

Food Provenance Assurance and Willingness to Pay for Blockchain Data Security: A Case of Australian Consumers.

Abstract

This study investigates consumers' willingness to select and pay for blockchain-certified food products. We conducted choice experiments with latent variables and compositional data to guide our understanding of consumers' choice behavior. The context of our study was the purchase of eggs (caged, free range, organic) and the use of blockchain certification labels to explore consumer reactions to packaging claims, product traceability, food recall response time, and price. We used three multinomial logit models to interrogate our data. The major findings are that traceability, animal welfare, and recall time are positively associated with the likelihood that consumers will choose a blockchain-certified product, with the use-by-date and country of origin being the most important attributes that guide their choice. Our findings also suggest consumers are willing to pay for blockchain-certified food products as long as it is a modest premium. We find that females place a greater value on food transparency and product labeling verification and are willing to pay a larger premium compared to their male counterparts. We translate these findings into tangible and actionable managerial insights for marketing food products using blockchain technology.

Keywords: Food Provenance, Consumer Trust, Blockchain, Food Safety, Compositional Data, Hybrid Choice Modelling

4. Introduction

Food safety and authenticity are critical components of globalized food supply chains where thousands of transactions heighten the risk of food fraud and tampering. Food traceability and authentication help comply with food safety standards and allow a competitive edge for companies offering greater consumer confidence. Numerous food incidents worldwide provide evidence of the limitations of current food traceability systems, exhibiting how quickly a food emergency can propagate and strike public health and impact a company's reputation.

4.1. Food Supply Chain

Food traceability systems in supply chains involve multiple parties having different information systems and technologies. For consumer protection, food businesses must comply with regulatory requirements that meet the standards for audit. Despite the increased digitization of food traceability systems, many firms rely on paper-based processes, which can compromise information accuracy and hinder the link between food ingredients and their digital counterparts. Speed and real-time tracking are critical to safeguarding supply chain stakeholder assets and consumers' well-being.

Supply chains have strengthened their food traceability systems by using Internet of Things (IoT) devices to monitor the condition and movement of products. IoT devices include Radio Frequency Identification (RFID), Near Field Communications (NFC), unique identifications and quality of livestock, chemometrics, isotope analysis, environment loggers, and DNA sequences (Badia-Melis et al., 2015). However, while IoT techniques have improved food traceability systems, they cannot mitigate the risk of data tampering throughout the supply chain.

4.2. Blockchain Technology

Blockchain represents an evolutionary step for database technologies with an innovative mixture of prior technologies: distributed ledger technologies (DLT) containing an append-only list and time-stamped transactions supported by cryptography and consensus mechanisms. These mechanisms intend to safeguard security and validity and permanently store immutable records in a peer-to-peer network (P2P) (Falcone et al., 2021). The immutability feature of blockchain means the data cannot be modified or deleted, unlike traditional databases that allow for entries to be overwritten (Garrard & Fielke, 2020; Hastig & Sodhi, 2020). Blockchain impedes data fraud as all transactions are validated through a consensus mechanism (Pournader et al., 2020). Blockchain provides a higher degree of transparency, enabling more responsive food traceability systems and offering instant auditing of uncorrupted transaction data. By securing the ledger of food records, blockchain technology allows companies to achieve greater consumer confidence. As a result, food companies can prioritize customers' safety while improving their reputation and competitive position in the marketplace.

4.3. Consumer Behaviour and Trust

Consumers' preferences are shifting to more sustainable products since they perceive them as safer/healthier due to using less dangerous inputs. Several studies have reported on this trend (Badia-Melis et al., 2015; Chen et al., 2020; Forbes et al., 2009; Friel et al., 2014; Gao et al., 2020; Losasso et al., 2012; Miller & Cassady, 2012; Reisch et al., 2013; Wang & Yue, 2017). Consumers' environmental knowledge is determinant in purchasing green products regardless of how they perceive their ability to solve environmental problems by consuming them (Choi & Johnson, 2019). A study by the IBM Institute for Business Value (2021) found that the pandemic altered consumer engagement with brands. As a result, consumers are more purpose-driven. They are choosing products based on how well they align with their values. Sustainability is top of mind, with 93% of global consumers stating that COVID-19 swayed their perspective on sustainability (IBM Institute for Business Value, 2021). Similarly, Haller et al. (2022) found that 50% of consumers expressed willingness to pay a premium for products to brands considering sustainability practices. In addition, consumers drawn to novel products in their shopping tend to have favorable attitudes toward green products, increasing their probability of purchasing them (Choi & Johnson, 2019).

However, there has been corporate misconduct for unsubstantiated "green claims," which provokes distrust in the food system and decreases consumers' probability of purchasing certain food products labeled as environmentally friendly as they suspect they are being deceived. Some consumers lack trust in the actors of the food system, demand more transparent food label information, and are willing to pay a premium for trustworthy traceability (Liu et al., 2019). Blockchain poses a new way of providing confidence in food purchases and substantiating the claims of green products. The blockchain-based trust may influence consumers' decision-making in purchasing food products that have been certified with the technology (Li et al., 2023). Since reliable certification and effective communication are essential to reinforce consumer trust (Nuttavuthisit & Thøgersen, 2017), a blockchain labeling standard could become a powerful instrument for brand differentiation and competitiveness. Blockchain creates value for consumers and companies, validating and assuring the product's claims through packaging labels stating food certifications and food traceability information (Li et al., 2023). Therefore, the growing adoption of blockchain technology in the supply chain and the shift in consumer behavior motivate our research questions.

RQ1. What food attributes are the most important drivers of consumers' decision to purchase a blockchain-certified food product?

RQ2. Are consumers willing to pay a premium for food products that offer greater transparency and traceability via blockchain technology?

4.4. Literature Review: Food Safety and Blockchain Traceability

4.4.1. Food Safety

According to the World Health Organization (2022a), approximately 600 million (almost 1 in 10 people globally) get sick each year after consuming contaminated food, and 420,000 die. Unsafe food products containing harmful bacteria, viruses, parasites, or harmful chemicals cause more than 200 diseases (from diarrhea to cancers). The total productivity loss associated with foodborne disease in low-and middle-income countries was estimated at US$ 95.2 billion per year, and the annual cost of treating foodborne diseases is approximately US$15 billion. The economic burden of foodborne diseases is substantial, with US$110 billion annually causing productivity loss in low and middle-income countries (The World Bank, 2018). In Australia, an estimated 4.1 million cases of food poisoning are reported annually (Australian Institute of Food Safety, 2022a). The estimated cost of foodborne illnesses and their sequelae in Australia is $2.44 billion annually. The largest component of this cost is lost productivity due to non-fatal illness, premature mortality, and direct costs (hospitalizations/other healthcare uses) (Food Standards Australia New Zealand, 2022). c

4.4.2. Food Safety Incidents

Food safety includes the management of food processing and storage in a way to reduce the risks of individuals becoming sick from foodborne diseases; food then will not cause harm to the consumer when it is prepared and/or eaten (Australian Institute of Food Safety, 2022b; Manning & Soon, 2016). A food safety incident is a situation within the supply chain with a potential or confirmed risk connected with food consumption (Food Standards Australia New Zealand, 2018). Local food incidents can evolve quickly into international emergencies due to global product distribution. Globally, there have been numerous food incidents. For instance, the Creutzfeldt-Jacob disease (degenerative brain disorder) due to contaminated meat products in the late 1980s; an E. Coli outbreak in 2006 in the USA was triggered by contaminated spinach, where producers and authorities could not promptly detect the contamination source and delayed notifying retailers and consumers (Yiannas, 2018). During 2017–2018 there was a disease outbreak of *Listeria monocytogenes* in South Africa, infecting 1060 patients, of whom 216 died. The outbreak could be traced to ready-to-eat processed facilities; however, the origin of contamination (how the strain was introduced to the factory) (Soon et al., 2020) is still unknown. In 2018, there was a food strawberry tampering with sewing needles in Australian food supply chains. The investigation took several months to find the accountable party affecting the country's food system reputation and causing significant economic losses (Food Standards Australia New Zealand, 2021a). Australia also had a food outbreak (2018-2019) involving a rare strain of *Salmonella* linked with egg consumption, and how the pathogen entered the farms (Food Standards Australia New Zealand, 2019) is still undetermined. In Australia, most food recalls during 2012-2021 were primarily due to undeclared allergens (43%), microbial contamination (26%), foreign matter, and others (31%). This is consistent with Soon et al. (2020) study stating that microbiological and undeclared allergens are the most common causes of food incidents since the root causes entering the supply chain are fragmented. As food recalls for undeclared allergens, microbial contamination, and chemicals are rising annually (Food Standards Australia & New Zealand, 2022), brands must proactively examine traceability mitigation strategies for worst-case recall risks and costs to ensure food transparency and safety along the supply chain.

Furthermore, food traceability is the ability to track food and ingredients through the supply chain, through all stages of production, processing, and distribution (van Rijswijk & Frewer, 2008). A food recall is a process undertaken by a company to withdraw risky food from any stage of the supply chain to safeguard public health (Food Standards Australia & New Zealand, 2022). Guaranteeing how food data is generated and secured plays an essential role in preventing food incidents, foodborne diseases, faster food recalls, and even deaths. Thus, data records generated during all these supply chain stages need a consistent, secure, uncorrupted storage database system.

4.4.3. Blockchain and the Food Supply Chain

Current food supply chain systems have not kept up their capabilities with digital innovation (Yiannas, 2018). Many brands still rely on paper registries, and even though most food traceability systems are digital, they often do not communicate with other parties' systems in the supply chain (Yiannas, 2018). During a foodborne outbreak, tracking data through vast numbers of paper and digital documents wastes precious time, posing risks to public health. Walmart, considered a market leader in the use of technology, recently engaged in a blockchain proof of concept exercise. They simulated a food recall incident by tracing their mangoes' journey through the supply chain from source to store. The blockchain-based system reduced the time to trace from 7 days to 2.2 seconds (Yiannas, 2018). Blockchain technology can also be used to validate sustainability claims, which might have greater acceptance in industries needing prestige enhancement (Saberi et al., 2019). Parmentola et al. (2022) concluded that blockchain technology could also contribute to environmentally sustainable development goals (SDGs) of the United Nations from various perspectives, such as by assisting the implementation of sustainable food supply chains, improving efficiency, rewarding sustainable behavior, and increasing environmental sustainability. Responsible businesses will want to apply traceability methods that guarantee sustainability, product lifecycle transparency, waste reduction, carbon footprint tracking, and fair trade (Friedman & Ormiston, 2022).

4.4.4. Hypotheses Development

Consumers have shown an eagerness to corroborate purchases, ascertain the journey of products, and discern environmental impact along food supply chains (Li et al., 2021). Consumers are also dubious about the authenticity of the greenness attributes of products, and this vagueness, combined with narrow food information for corroboration, may reduce the willingness of consumers to pay extra (Xu & Duan, 2022). Consumer demand for improved food transparency may drive blockchain adoption in the food industry (Bumblauskas et al., 2020). Thus, we posit the following hypothesis:

H1: The presence of blockchain certification positively influences consumers' food choices (eggs).

Australia has an increasing pro-welfare view. Results from a survey of Australian consumers found that 92% of participants were concerned about animal welfare in food production. Since in Australia, animal welfare is market-driven (Cornish et al., 2019; Cornish et al., 2020), blockchain-welfare-certified food products with farm invigilation of animal welfare in the food label could increase the likelihood of selecting products certified with the technology. Using blockchain technology could benefit food brands by guaranteeing genuine ethical production methods and informing consumers about the additional actions done by the brand to adhere to animal welfare (Katsikouli et al., 2021; Kshetri, 2021a). Therefore, we hypothesize that:

H2: Blockchain certification of animal welfare standards positively influences consumers' food choices (eggs).

Food recalls are increasing and becoming more dangerous worldwide, causing concerns in food supply chains, governments, and consumers alike (Bumblauskas et al., 2020). Governmental bodies expect that the advances in food technology, traceability, and analytical testing will influence the number of food recalls (Food Standards Australia & New Zealand, 2022). Blockchain traceability can be used to locate faster the link where the problem was initiated in the food supply chain, define precisely responsible parties, and trigger the food recall (Thangamayan et al., 2023). Hence, we hypothesize that:

H3: The food recall time of a blockchain certified product positively influences consumers' food choices (eggs) in case of a food incident.

Several investigations are related to consumers' willingness to pay a premium for better quality and safer products (Cornish et al., 2020; Shirai, 2010), especially if technology is involved in securing those attributes. Therefore, we expect that once consumers are aware of the benefits of blockchain technology, they will be willing to pay a premium. There is also research about gender as an influential driver of purchase intention (Kraljević & Filipović, 2017; Notaro et al., 2022) and WTP (Alozie & McNamara, 2010; Chiwaula et al., 2018; Gracia et al., 2012; López-Mosquera, 2016; Weigl et al., 2022). We expect that differences between genders will exist when determining WTP. Therefore we posit that:

H4: The carton price (dozen) of the blockchain-certified food product (eggs) negatively impacts consumers' choices, and gender moderates the relationship between consumers' WTP for a blockchain-certified product.

4.5. Methods

4.5.1. Stated Choice Experiment

Experimental design for stated choice experiments entails a process in which attributes and their levels are pre-defined without measurement error and varied to form a choice preference (Rose & Bliemer, 2004). Discrete choice experiments are methods to elicit decision-making without revealed preference data (Weber, 2021) and have been used in many research fields, such as transportation (Clayton et al., 2020; Krueger et al., 2016; Morita & Managi, 2020; Paddeu et al., 2021; Potoglou et al., 2020; Yan et al., 2020), health (Lu et al., 2019; Soekhai et al., 2019), energy (Kubli et al., 2018; Viber-Johansson et al., 2019), economics (Bronnmann & Asche, 2017; Lehmann et al., 2021) or supply chain management (Campbell et al., 2022; Erdem, 2015; Watteyn et al., 2022). Blockchain technology is expected to trigger a huge transformation in the food industry. However, blockchain-certified food products are not widely available to consumers at this technology adoption stage. Therefore, for our study, a stated-preference approach with a latent compositional variable is the best option to approximate how consumers will be willing to choose and pay for blockchain-certified food products.

4.5.2. Integrated Choice and Latent Variable

Latent variable modeling allows us to examine unobserved factors that may not be directly measurable for predicting consumer behavior and outline effective strategies to influence those behavioral factors (Vij & Walker, 2016). For instance, Enam et al. (2018) utilized an Integrated Choice and Latent Variable (ICLV) approach to analyze the effect of psychological factors (modeled as latent constructs) on choice behaviors. Swait and Adamowicz (2001) introduced decision strategy selection into aggregate choice models via latent classes to reflect shifting aggregate preferences. Ashok et al. (2002) had the primary motivation for developing a model to accommodate latent attitudes and perceptions that may shape consumers' choices. Vij and Walker (2016) examined the ICLV model that, under certain settings, can improve predicting outcomes to the choice data, correct for bias arising from omitted variables and measurement error, and reduce the variance of parameter estimates. Kamargianni et al. (2015) used the ICLV model to investigate children's travel mode choice to school incorporating two latent variables, concern, and distrust. Daly et al. (2012) applied an estimation of attitudinal and choice models to a real-world transport study, looking at the role of latent attitudes in a rail travel context. Overall, researchers have acknowledged the latent nature of attitudes. Our study implemented a hybrid stated preference method by relating it with a compositional latent variable to study choice and willingness to pay for blockchain-certified food products.

4.5.3. Experimental Design for Eggs

The study set out to gauge how consumers in Australia will react to blockchain certification. We undertook a number of initial steps to help us determine which product consumers are more likely to make a decision based on the product claims, which product claim attributes consumers are most likely to explore, and what levels would seem realistic while acknowledging that the levels displayed may be outside their experience (Hensher et al., 2015). We first consulted official governmental statistics data on trends in food expenditure in Australia (Australian Bureau of Agricultural and Resource Economics and Sciences, 2018). Based on the collected food product information, we conducted a cross-product survey among academics (N=50), presenting several food products and attributes to identify the most important ones to devise our experimental design. The cross-product survey results revealed that eggs were the most preferred food product. In order to set realistic levels and to inform on the relative demands, we consulted the not-for-profit marketing research group Australian Eggs (Australian Eggs, 2022) to establish the types of egg farming to be used in our choice experiment: free range, organic and caged eggs. To establish a preference for blockchain certification (supply chain traceability), we used a parameter for the presence/absence of the blockchain certification stamp on the product label. The parameter related to this attribute tests hypothesis one (H1). To test hypothesis two (H2), we interacted the blockchain certification with free range/organic food label. Here a positive and significant interaction parameter indicates that consumers are willing to pay a higher price for blockchain certification when it authenticates animal welfare. Food recall was introduced as the time taken to respond to a food contamination or other safety issue. Here the interest was whether faster food traceability contributes to the demand for blockchain-certified food products. Lastly, for our price level, we compared the range of the Australian market prices of various brands as of June 2022.

The features and levels to evaluate consumers' choices are the following (for a summary of features and levels, see Table 16):

Attribute 1. Packaging claim with three levels: caged eggs (hens housed in cages inside large, climate-controlled sheds), free-range (cage-free hens roam & forage outdoors for a specific time), and organic (free-range hens fed without chemicals, hormones, or antibiotics & GMOs).

Attribute 2. Product traceability with two levels: partially traceable eggs (conventional method) and fully traceable eggs (blockchain-certified product). This attribute corresponds to a company's ability to trace food products along the supply chain.

Attribute 3. Food recalls response time with three levels: 12 days, 3 days, and 1 hour. This attribute refers to the action and time a business takes to remove unsafe food from consumption.

Attribute 4. The price per 12-pack carton in Australian dollars has three levels: $10.75, $7.25, and $4.80. We considered the price attribute by comparing the range of the Australian market prices of several brands as of June 2022. At the time of the study, the Consumer Price Index (CPI) rose 1.8% in the June 2022 quarter and 6.1% annually, according to the Australian Bureau of Statistics (2022a).

Table 17. Attributes and Levels of the Choice Experiment Design

Food attributes	**Level 1**	**Level 2**	**Level 3**
Packaging claim	Caged eggs	Free-range / Cage-free	Organic
Product traceability	Eggs partially traceable	Eggs fully traceable	
Food recall response time	12 days	3 days	1 hour
Price per 12-pack ($AUD)	$4.80	$7.25	$10.75

Each participant was presented with realistic images of the egg's options, showing two product alternatives and a third no-choice option, as shown in Figure 12.

	Option 1	Option 2	None
Packaging Claim	Caged eggs (hens housed in cages inside large, climate-controlled sheds).	Free-range / Cage-Free (hens roam & forage outdoors for a specific time)	
Product Traceability	 Eggs Fully Traceable (Blockchain-Certified product)	 Eggs Partially Traceable (conventional method)	
Food recall response time (action taken by a business to remove unsafe food from consumption)	1 hour	12 days	None of these options
Price per 12 pack	$7.25	$4.80	
	○	○	○

Figure 12. Example of Attributes and Levels of the Choice-Set

We chose to use an unlabelled experiment, considering the dominance of preferences for free-range eggs over caged eggs. This allowed the experiment to reveal the value of blockchain even when the product claims were identical. However, to keep the tasks realistic, we used conditional levels for attribute combinations. For example, caged eggs would not have the highest price tag, and blockchain had the two fastest food recall response time levels. A D-efficient design was estimated in the specialized software N-gene. Our design included conditional constraints by setting requirements on attribute level combinations (Rose & Bliemer, 2004; Rose & Bliemer, 2009). Subsequently, we reduced the number of choice tasks from 18 to 9 by eliminating those with attribute dominance. This study received the Ethics approval number 2021/ET000375 to conduct this research.

In the following two sections, we discuss the inclusion of the latent variable based on the level of importance respondents place on different aspects of the product label. In the survey, respondents were asked to allocate 100 points across the ten product label claims they currently verify. First, we discuss our approach to analyzing compositional data. Then, we explain how the latent variable is used in the choice models.

4.5.4. Compositional Data Approach for the Latent Variable

Compositional data (CoDa) are presented as proportions of non-negative parts of the composition and may be described as random vectors as opposed to random variables as "being part of the whole," with each component having positive values and the sum of all components a fixed total (Reimann et al., 2017). Although CoDa is mainly used in geological and biological fields, it can also be applied in economic areas (Chen et al., 2021; Ferrer-Rosell et al., 2016; Morais et al., 2018; Scealy & Welsh, 2017; Thorson & Haltuch, 2019).

CoDa differs in that each dimension is structurally linked by being part of a whole (Pawlowsky-Glahn & Buccianti, 2011). That is, by having a fixed total (in our case, 100 points), raising a score for one dimension will automatically mean that at least one other dimension will need to be reduced. For this reason, treating each respondent's scores as proportions and aggregating over a sample or population is erroneous because two respondents may allocate the same levels of importance to a specific attribute, but their substitution (i.e., allocation of remaining points) may differ substantially. Analytical results may be misleading by not considering these special characteristics of CoDa (Pawlowsky-Glahn et al., 2015).

Filzmoser et al. (2009) suggest that the mathematical basis of a suitable statistical analysis for CoDa is based on defining a specific geometry on the simplex —the sample space of CoDa. When working with CoDa in the Euclidian space, the data must be transformed, such as maintaining the geometric structure, where each dimension still contains relative information (Morais et al., 2018). Aitchison (1982) established a methodological approach based on log ratios for CoDa. He asserted that analyzing compositional data with standard statistical packages was complex as the proportions of compositions require interpretation, and thus, he established a consistent theory based on log ratios. In a compositional framework, rather than trying to normalize the data, it is transformed into log ratio space. As a result, the parts' ratio is conserved and no longer dependent on other parts of the compositions. This ratio preservation is essential since they are sub-compositionally coherent, and the bias from proportions is removed as the relationship between each ratio of the parts is conserved (Pawlowsky-Glahn et al., 2015; Reimann et al., 2017).

4.5.5. Hybrid Choice Model Estimation to Predict Consumers' Preferences for Blockchain-Certified Food Products.

A hybrid choice model estimation approach was selected for its reliability in estimating and relating our choice dataset with a latent variable measured by compositional analysis. We transformed our CoDa with a centered log ratio (CLR) transformation to strengthen our forecast on consumer behavior preferences for blockchain-certified food products. One novel contribution of this study is the hybrid method developed to integrate choice modeling with latent variables estimated using CoDa. Using CoDa instead of rating data, such as Likert scales, has the advantage of forcing respondents to prioritize food attributes, preventing all statements from being labeled as "highly important." This approach helps identify the specific aspects of food labeling and traceability that respondents seek to verify. As a result, examining consumers' choice decisions and their preferences for food attributes using CoDa analysis enables the identification of influential factors that shape customers' purchase intention towards blockchain-certified food options.

In our study, CoDa will be integrated into the estimation of choice models to provide insights into preference heterogeneity regarding blockchain certification, ethical consumption, and price. The latent variable may be integrated within the choice model in three distinct ways. First, the latent variable can be incorporated as an independent variable within the utility functions, following the approach proposed by Yáñez et al. (2010). Yet, this approach is not applicable in our study since we are working with unlabelled choice alternatives. Second, the latent variable can be treated as a covariate in the class membership for a latent class choice model (Smith & Olaru, 2013). This approach allows us to explore different segments of consumers with varying preferences and behaviors related to blockchain certification, ethical consumption, and price. Third, the latent variable can be utilized as a covariate with the conditional mean of a random parameter (Hess et al., 2013). This approach considers that consumer preferences may vary across individuals, and the latent variable helps explain this variation.

We explored the latent class and random parameter methodologies to determine the most appropriate approach for our study. Based on empirical evidence and model fit assessments, we opted to present the random parameter choice models, where CoDa serves as a covariate with the conditional means. This choice allows us to capture the variation in consumer preferences and examine how the CoDa components, *sustainability consciousness,* and *product safety and compliance* explain preference heterogeneity.

4.5.6. Data Collection

The survey instrument consisted of choice tasks, compositional data questions, and questions related to respondents' social-demographic data. To evaluate the questionnaire's content validity and design, the survey instrument was pre-tested with a cohort of undergraduate students in an internal platform at the University of Western Australia. We decided to collect the data in the Prolific online panel by virtue of its speed advantages, the broad reach of the population sample, and demographic representativeness (Peer et al., 2017; Peer et al., 2021). We also conducted a pilot study of ten online panel participants. The study distribution set was a balanced sample of male and female participants consulted previously by the Australian Bureau of Statistics (2021) to ensure representativeness. In the pre-screening inclusion criteria, the location was set only to Australia with a minimum age of 18. The survey was conducted in July 2022, and 453 respondents were recruited.

Respondents were given preliminary material that clarified the definitions of blockchain technology, full traceability, partial traceability, and food safety concepts and provided statistics and visual imagery of Australia's top three most prominent food safety incidents. We explained thoroughly the concept of blockchain digital technology application in the food supply chain in the text as well as a video since people prefer dynamic media (videos and 3D models) rather than static media (text) (Que et al., 2017; B. Wang et al., 2021). An advantage of this multimedia online survey approach is that respondents better understand and facilitate the choice experiment completion, as blockchain is a novel technology.

4.5.7. Current and Anticipated Behaviour of Respondents

The data collection focused on how frequently participants viewed food product labels and their readiness to use a mobile application in grocery shopping. In addition, data was collected on the type of food products for which Australian shoppers already verify label information as well as product information they would want to see when scanning a product's barcode. We considered this information relevant to understand shoppers' priorities when verifying product claims. Respondents stated frequency for reading product labeling when purchasing, shown in Figure 13. Nearly all respondents said they reviewed product labels (97.6%), of which 13.5% claimed to read every label and 29.6% stated they read most labels. Over one-half of respondents (56.9%) stated they read about one-half the time or less frequently.

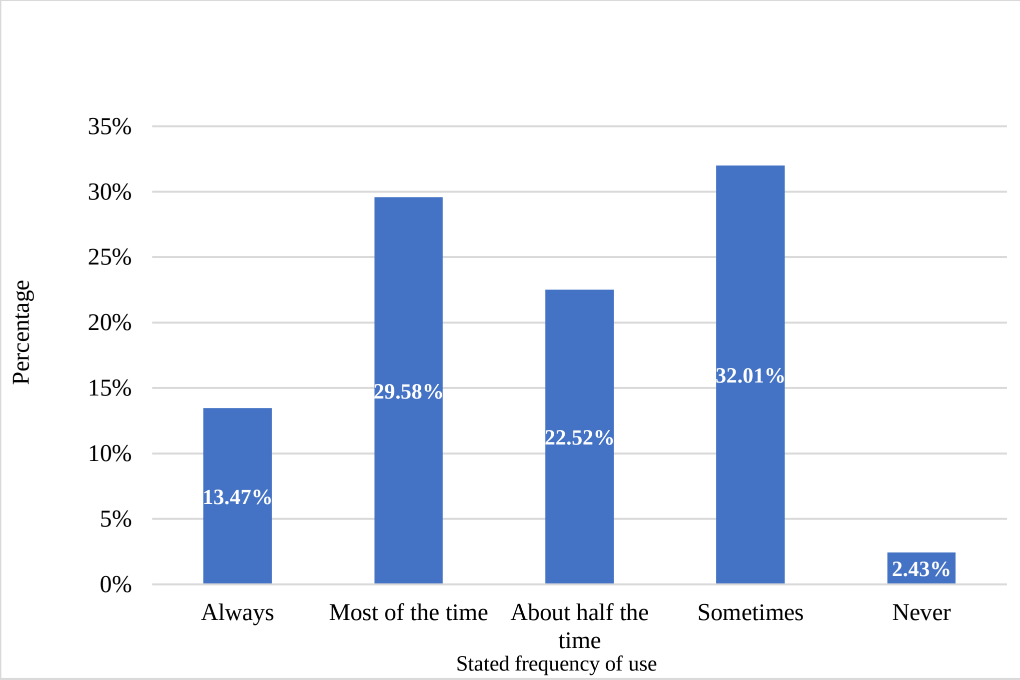


Figure 13. Frequency of participants reading product labels

While there is no dominant product category where the vast majority of respondents verify the product claims, dairy and meat products were found (approximately 14% to 20% of respondents) to be the food that was checked more than others (between 5% and 14%). Figure 14 shows the proportion of respondents who stated to verify the product claim.

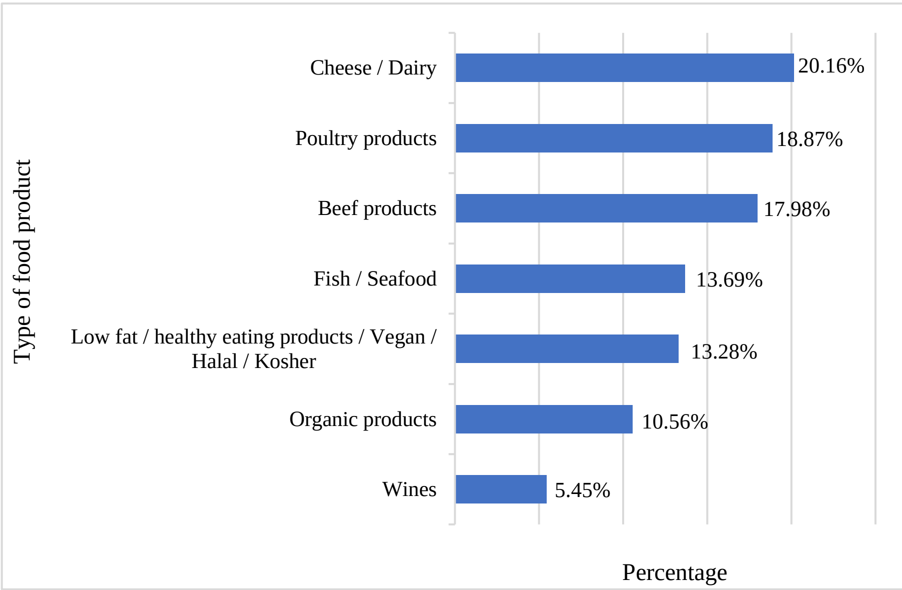


Figure 14. Type of food products Australian participants currently verify labels' information

For our study, we were interested in which product attribute people gave the highest priority when verifying the claim on a label. Therefore, we asked respondents to allocate 100 points across the attributes they would look to verify when using a mobile application to scan a food product's barcode. The motivation for using a relative scale was to determine the weight respondents assign to certain food attributes to enrich our analysis. Compositional data analysis permits an assessment of the relative importance of different attributes providing insights into the prioritization and trade-offs made by consumers. Respondents showed a willingness to share their points across multiple attributes, with 56% allocated points to seven or more categories and 25% of respondents allocated points to each of the ten categories. Figure 15 presents the percentage of total points (i.e., the aggregate of points allocated by all respondents). Use-by date was considered to be the most important (28%), and 99 respondents allocated 50 points or more. Country of origin was allocated the next highest aggregate of points (11% of the total), with 12 respondents allocating 50 or more points.

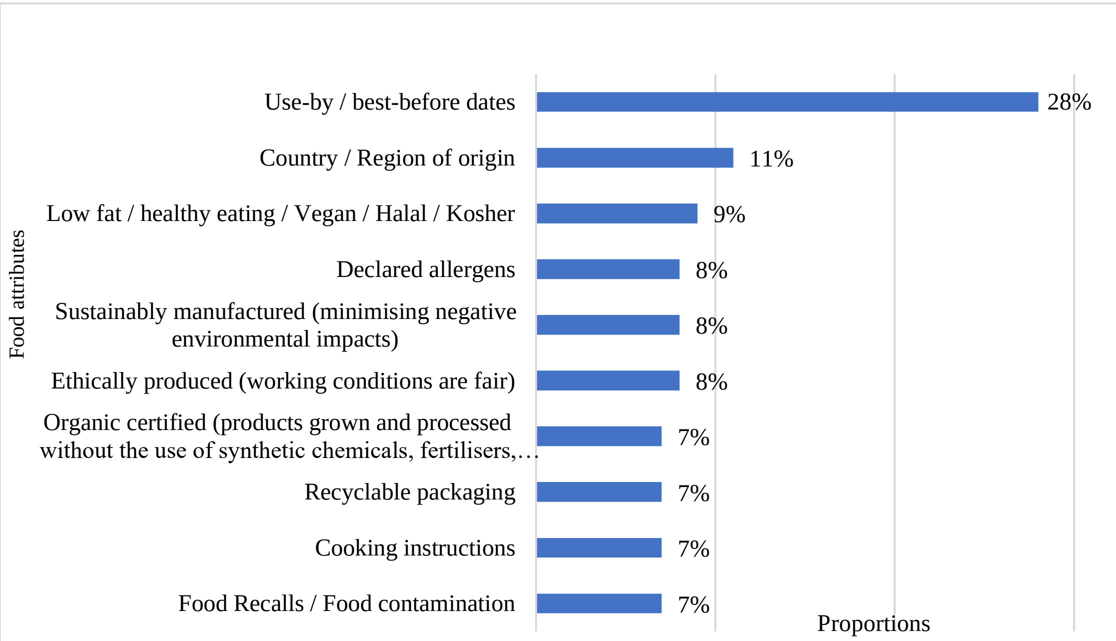


Figure 15. Compositional Data of Food Attributes

4.5.8. Principal Component Analysis of Compositional Data

We conducted a principal component analysis (PCA) to reduce the dimensionality, identify patterns (Hair et al., 2019; Pawlowsky-Glahn & Buccianti, 2011), and better interpret our transformed CoDa. By employing the PCA, we aimed to identify the major components of our CoDa and evaluate the proportion of variation explained by each principal component. We kept the first two dimensions as they behaviourally interpreted PCA1 (21% of variance) as *sustainability consciousness* and PCA2 (13% of variance) as *product safety and compliance.* The dimensions are illustrated in the CLR biplot (see Figure 16).

In Figure 16, the arrows' direction and lengths represent each variable's contribution to the whole variation in the dataset (Aitchison & Greenacre, 2002). The CLR compositional biplot elucidates the compositional dependence structure, meaning the proportion of variance explained by the first two principal components is high enough (Tolosana-Delgado & Mueller, 2021). The two most important food attributes for sustainability consciousness were that the products were sustainably manufactured and ethically produced, as indicated by the horizontal component of the radial lines in Figure 16. In contrast, negative scores in *sustainability consciousness* are associated with individualistic concerns (healthy ingredients and cooking instructions). This is consistent with the dimensional classification of Assiouras et al. (2013) in the food supply chain that investigated Purchasing Social Responsibility (PSR) and Logistics Social Responsibility (LSR) factors combined with industry trends. Assiouras et al. (2013) dimensions encompass animal welfare, biotechnology, health and safety, environment, labor, human rights, community, fair trade, and procurement. While PCA2 *product safety and compliance* is a much weaker component, the biplot revealed that this dimension relates to food recall, and we decided to keep this component to test if it may be a latent explanatory variable in the choice modelling exercise.

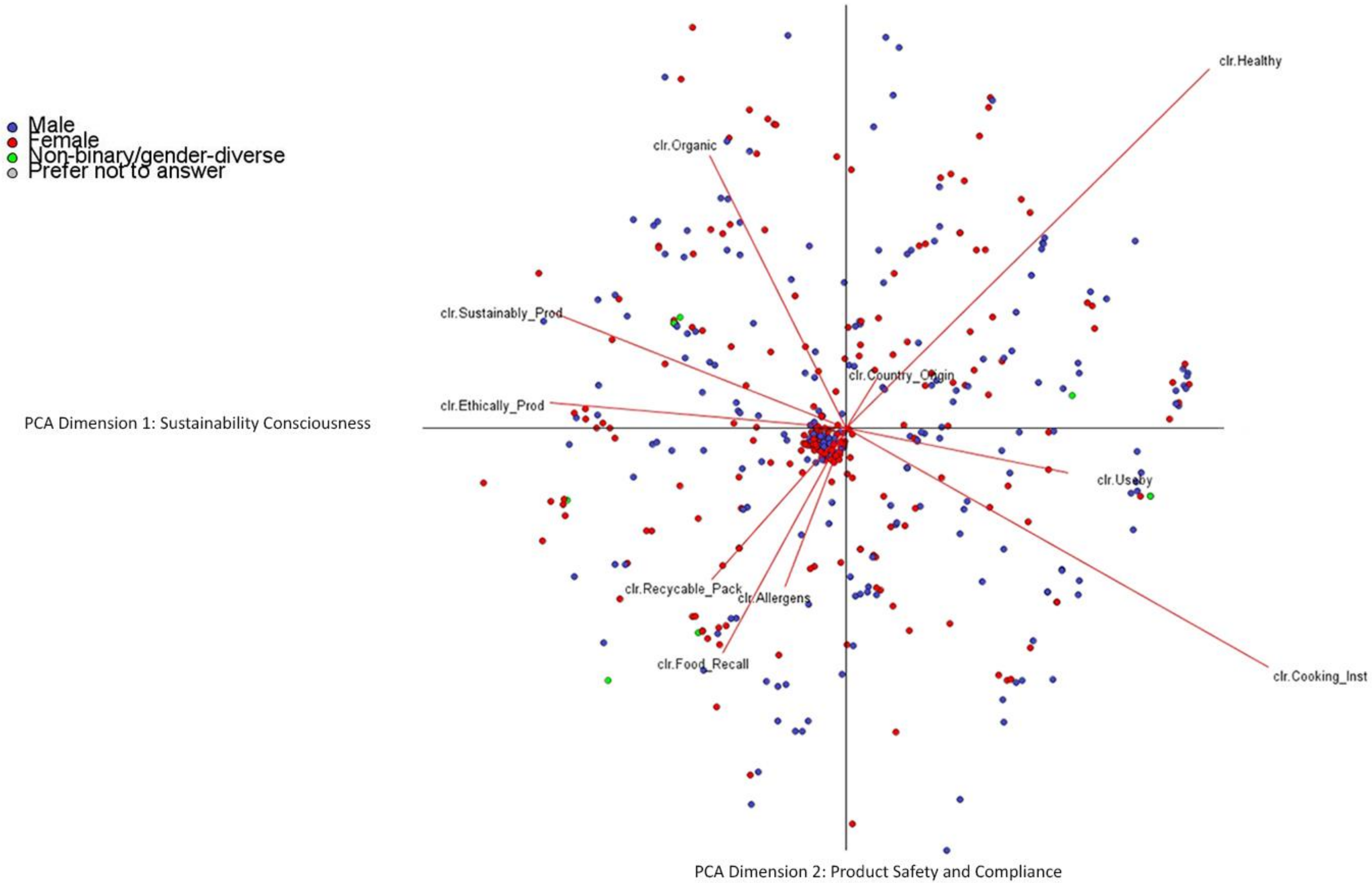


Figure 16. 3D Biplot Output of the CoDa Variables

4.5.9. Sample Profile

The profile of the sample is given in Table 17. We chose to present the demographic profile here as it serves to identify if either *sustainability consciousness* or *product safety and compliance* are related to respondents' demographic profiles. Both components were found to be non-normal, and appropriate non-parametric tests were used. Females place higher importance on *sustainable* product claims (p-value < 0.01) than males. However, there is no difference between genders in how important it is to verify *product safety and compliance* attributes (p-value =0.76). We found no difference concerning age (*sustainability consciousness* p-value = 0.39 and *product safety and compliance* p-value = 0.27). Undergraduates place higher importance on *product safety and compliance* attributes (p-value = 0.01), and there is no difference among the other education levels for *sustainability consciousness* attributes (p-value = 0.16). We found no difference with respect to employment (*sustainability consciousness* p-value = 0.08 and *product safety and compliance* p-value = 0.37).

Table 18. Sample Profile of Compositional Data

Demographic Profile	n		**Sustainability Consciousness**	**Product Safety & Compliance**
Gender				
Male	223	49.2%	-0.441	-0.048
Female	220	48.6%	0.406	0.096
Other/ prefer not to say	10	2.2%	0.889	-1.290
Wilcoxson test (male v female)			*p-value = 0.001 ****	*p-value = 0.763*
Age				
Between 18 - 27	143	31.6%	0.084	-0.305
Between 28 - 37	158	34.9%	-0.128	0.260
Between 38 - 47	81	17.9%	-0.249	-0.124
Between 48 - 57	45	9.9%	0.608	0.236
Older than 58	26	5.7%	0.032	0.076
Kruskall Wallis			*p-value = 0.392*	*p-value = 0.272*
Education				
High School Diploma	97	21.4%	0.563	-0.432
Technical	77	17.0%	0.068	-0.339

Demographic Profile	n		Sustainability Consciousness	Product Safety & Compliance
Undergraduate	190	41.9%	-0.246	0.279
Postgraduate	89	19.6%	-0.119	0.169
Kruskall Wallis			*p-value = 0.162*	*p-value = 0.013***
Employment				
Full and Part-Time	301	66.4%	-0.266	0.093
Unemployed	40	8.8%	0.567	-0.135
Not in the workforce	49	10.8%	0.328	0.067
Student	63	13.9%	0.657	-0.414
Kruskall Wallis			*p-value = 0.082**	*p-value = 0.377*

4.6. Results

4.6.1. Choice Modelling Results

The choice data analysis was performed to determine whether consumers are willing to choose and pay for blockchain-certified food products (eggs) to access transparent food information. We incorporated the covariates of compositional data and gender with the choice modeling analysis. The model assumes individuals choose the alternative that provides the highest utility on an attribute-based choice modeling (McFadden & Train, 2000), and the choice probabilities were calculated using models from the Logit family. We selected the econometric NLOGIT software for choice model estimation (Hensher et al., 2015). We initially scrutinized our data with a based MNL model and estimated our discrete choice model using the Maximum Likelihood Estimation method (MLE). After iterating with various models, we developed and analyzed three models that best fit our data. Although PCA2 product safety and compliance is related to security and our initial hypothesis was that respondents with high scores would value shorter food recall times, models with the conditional mean of the food recall parameter being a function of *product safety and compliance* were not significant. We have not reported these models in the results below.

4.6.2. Model 1 (MNL) with Gender Covariate

Our first model is a basic MNL model. Consumers show a significant positive preference for the packaging claim of free-range/organic egg production method and a significant positive preference regarding the presence of blockchain traceability certification. The conventional food recall time exhibits a significant negative preference, suggesting consumers do not prefer longer food recall periods. A significant negative preference for the carton price of eggs involving the blockchain price suggests consumers will be more averse to higher prices for blockchain-certified food products. Respondents are less likely to select the 'No Choice' option against the other alternatives and vary based on the interaction with gender; males are less likely to select the No Choice option than females.

All t-statistics are large and have absolute values greater than 2.4, indicating the estimated coefficients are statistically significant at the 1% level, providing confidence that the estimates are reliable with strong explanatory power. The model fit shows a log-likelihood at the convergence of -3788.2, AIC/N=1.861, McFadden Pseudo R-squared=0.074, indicating that despite the statistical fit, there remains unexplained choice variation (see Table 18).

4.6.3. Model 2 (Random Parameters Multinomial Logit)

The second model was estimated with Random Parameters Multinomial Logit (RP-MNL) to understand the heterogeneity of preferences (Hensher et al., 2015), gaining insights into the diversity of decision-making processes regarding blockchain-certified food products. The packaging claim of the free-range/organic egg favorably impacts consumer choice behavior, meaning the likelihood of choosing the option increases substantially. Blockchain traceability also has a significant positive impact on consumer choice behavior. The conventional food recall time is negative but not significant on choice behavior, indicating that for this model, the food recall time has no impact on the consumer choice behavior. The RP-MNL analysis in model 2 also displays a significant negative inclination for the carton price of eggs involving the blockchain price, implying consumers will be more reluctant to pay higher prices for blockchain-certified food products.

Similarly to Model 1, respondents are less likely to select the 'No Choice' option against the other alternatives and vary based on the interaction with gender, with males less likely to select the 'No Choice' option than females. The model fit statistics suggest that Model 2 fits the examined data well. Furthermore, the log-likelihood at convergence (-2875.7), the McFadden Pseudo R-squared (0.358), and the AIC/N value 1.416 indicates a reasonable trade-off between model complexity and data fit (see Table 18).

4.6.4. Model 3 (RP-MNL with Covariates of CoDa and Gender)

The third model was also estimated with a Random Parameters Multinomial Logit (RP-MNL) model and incorporated the covariates of CoDa and gender. Consumers' food preferences show a significant positive estimation for a packaging claim with a free-range/organic egg similar to models 1 and 2. Consumers display a significant positive choice preference for blockchain traceability as well. The conventional food recall time is negative but not significant on choice behavior, indicating that for this model, the food recall time has no impact on the consumer choice behavior. The carton price of eggs involving blockchain price shows a significant negative estimation. The presence of blockchain technology certifying sustainability and ethical practices influence positively and significantly the consumer choice behavior. The conventional food recall time is significantly negative, denoting a preference for faster food recalls as in the previous models. There is a significant negative interaction between blockchain price and the male gender, implying that males are more price-sensitive than females. The model fit measures the log-likelihood at the convergence is -2822.7, the McFadden Pseudo R-squared = 0.370, and the AIC/N = 1.392, indicating a better fit of the model to the observed data (see Table 18). Overall, the results of Model 3 denote a strong association with observed sustainable and ethical corporate practices. The consumers' behavior in our study was revealed to be more environmentally conscious and altruistic when avoiding caged eggs and willing to pay higher prices, particularly in females, for blockchain food traceability.

In terms of WTP, the average amount consumers in the study are willing to pay — the mean WTP— is $1.30 with a standard error (S.E.) of $0.22 (see Table 18).

Table 19. Choice Models

Attribute	Model 1 (MNL) with Covariate		Model 2 (RP-MNL)		Model 3 (RP-MNL with Latent CoDa Variable)	
	Estimate	*t*-ratio	Estimate	*t*-ratio	Estimate	*t*-ratio
Random Parameters						
Packaging Claim:						
Free Range or Organic Eggs	1.316***	22.62	2.980***	14.21	2.460***	11.17
SD-RPL			*3.113****	*13.72*	*3.032****	*13.20*
Blockchain Traceability (H1)	0.340***	5.56	0.398***	3.98	0.589***	5.58
SD-RPL			*1.183****	*9.36*	*1.148****	*8.74*
Food Recall Time (H3)	-0.027***	-3.85	-0.022	-1.61	-0.213	-1.57
SD-RPL			*0.197****	*13.13*	*0.189****	*13.04*
Carton Price	-0.291***	-12.42	-0.371***	-9.22	-0.249***	-4.97
SD-RPL			*0.408****	*16.15*	*0.417****	*15.32*
Non-Random Parameters						
No Choice ASC	-3.412***	-16.54	-5.468***	-15.82	-5.023***	-13.08
No Choice ASC * Gender (Male)	-0.346***	3.79	-1.152***	-3.53	-1.810***	-3.73
Covariates with the mean of the random parameters						
Packaging Claim: (Sustainability Consciousness)					0.350***	5.38
Packaging Claim: (Blockchain) (H2)					1.354***	6.39

Blockchain Traceability : (Sustainability Consciousness)					0.078**	2.43
Food Recall Time (Sustainability Consciousness)					-0.012**	-2.78
Carton Price: (Gender - Male) (H4)					-0.219***	-3.28
Log-likelihood at convergence	-3788.2		-2875.7		-2822.7	
McFadden Pseudo R-squared	0.074		0.358		0.370	
AIC/N	1.861		1.416		1.392	
					Mean	**S.E.**
Willingness to pay (Blockchain Certified food products)					$1.30 per carton	$0.22 per carton

Levels of significance: ** indicates at 5%, and *** at 1%.

CoDa: (Compositional Data)

A summary of our tested hypotheses is in Table 19 to identify the proposed effects and findings in the optimized model 3 (RP-MNL with CoDa and gender covariates).

Table 20. Summary of Tested Hypotheses

Hypothesis	**Path**	**Proposed effect**	**β**	***t*-ratio**	**Significance**	**Result**
H1	Blockchain Traceability → Blockchain-Certified Eggs	+	0.589	5.58	< **0.001**	**Supported**
H2	Blockchain-welfare-certified packaging claim (Free range/Organic eggs) → Blockchain-Certified Eggs	+	1.354	6.39	< **0.001**	**Supported**
H3	Blockchain Food Recall Time → Blockchain-Certified Eggs	+	0.027	3.85	< **0.05**	**Supported**
H4	Carton Price Blockchain-Certified Eggs → Gender Moderation WTP Blockchain-Certified Eggs	**-**	-0.219	-3.28	< **0.001**	**Supported**

4.6.5. Discussion of Results and Limitations

The primary objective of this study was to investigate consumer preferences concerning blockchain-certified food products. To achieve this, we introduced a latent compositional variable and gender as covariates to assess their impact on consumers' choices.

Our analysis revealed several key findings. First, the data revealed that respondents value blockchain certification. This was evidenced by the positive and significant coefficient for the presence of blockchain certification, presented to respondents as text and in visual form in the choice tasks. This finding addresses the second research question and highlights the significance of blockchain certification as a determinant of consumer choice. However, it is important to note that while influential, blockchain certification did not emerge as the strongest determinant of choice.

Ethical farming practices and animal welfare emerged as key factors that many consumers deemed "non-negotiable." This was evident from the parameter estimate for labeling of free-range or organic eggs, which exhibited the highest importance in the choice model. In contrast, when respondents were asked to indicate which attributes they were most likely to inspect, information related to use-by-date and country of origin were rated highest in the CoDa. It is important to acknowledge that these variables were not included in the choice tasks, thereby preventing us from examining their direct influence on choice. We consider the use-by-date to be a hygiene-related variable, where consumers ensure the product they are purchasing is safe for consumption. However, the exclusion of country of origin information from the choice tasks may have been an oversight. We deliberated on its inclusion during the experimental design phase but ultimately decided against it due to the choice context whereby eggs are only locally sourced. Studies that investigate foods with imported brands should consider this variable.

Perhaps the most interesting finding in terms of not only understanding behavior but for practical consideration is that the value of blockchain technology was elevated when the certification was issued for ethically sourced goods (free range/organic eggs). This highlights that consumers want to trust packaging claims for attributes they care about but are somewhat distrusting of current claims.

Perhaps one of the most exciting findings with both theoretical and practical implications is the elevated value of blockchain technology when it was applied to certify ethically sourced goods, specifically free-range or organic eggs. This finding emphasizes the consumers' desire for reliable verification of packaging claims regarding attributes that hold significance to them. It is also possible that this result indicates a level of distrust toward current claims made by producers and suppliers, consistent with the literature on the level of doubt held by consumers toward sustainability claims (Xu & Duan, 2022). This insight not only contributes to our understanding of consumer behavior but also highlights the importance of addressing consumer skepticism and ensuring trustworthy and accurate information in packaging claims.

Finally, despite the added benefits of full product provenance, ethical assurance, and faster food recalls that come with blockchain certification, price remains a prominent factor in consumer decision-making. The results confirm that females prioritize the benefits of verifiable and transparent sourcing more than males, as indicated by lower price sensitivity within this demographic. The study's estimation of willingness to pay reveals that consumers, on average, are willing to pay an additional $1.30 for blockchain-certified food products, with a standard error of $0.22. This finding highlights the need for food brands to exercise caution when setting the market price for blockchain-certified food products.

Implementing advanced technologies such as blockchain for food recalls involves initial investment costs for system setup, technology integration, and training. On average, the initial investment for a blockchain-based system might range from several thousand to hundred thousand dollars, depending on the scale and complexity of the supply chain. However, the potential savings from improved recall efficiency, reduced waste, and avoided losses in the event of a food recall are estimated to be substantial, potentially saving millions in economic losses and operational costs. Despite the initial expenses, the long-term benefits in mitigating risks and enhancing food safety can significantly outweigh the initial financial outlay.

4.7. Marketing Implications

According to the analysis and findings of our investigation, we offer practical marketing implications to initiate blockchain awareness and adoption by food brands based on the framework of Rego et al. (2022) for brand resilience and agility.

- *Food brands will need to develop, in a first stage, the engagement of consumers by introducing campaigns focused on generating awareness of blockchain technology benefits:* Our findings show that this can be achieved through positive branding by promoting food transparency with blockchain to create consumer trust. Our findings also suggest that consumers value blockchain positively when certifying supply chain practices that align with their beliefs. Even though blockchain technology per se was unable to change consumers' demand for animal welfare, the blockchain-welfare certification increases the likelihood of choosing them.
- *Develop a strong and positive advertising associations (Rego et al. 2022) emphasizing food transparency with blockchain technology by appealing to sustainable-conscious customers*: a differentiated strategy for brands in the market.
- Integrating an easy approach to consumers to physical and digital communication channels for the access stage will ensure a competitive advantage: increasing brand accessibility to strengthen customer relationships will allow the companies to capture maximum market share.
- *Food brands will need to reinvent themselves by redesigning or creating new business models emphasizing transparency, quality, and safety*: our results showed that consumers valued blockchain food recall time for safety issues supporting Rego et al. (2022) claim

that in case of a food incident, brands should act accountable by actively admitting the incident to reinforce consumer trust. Additionally, emphasizing sustainable/ethical brand practices such as animal welfare, non-toxic ingredients, and allergen declaration. This reinvention should be done with positive branding imagery and insignia, highlighting that those corporate practices are gained through blockchain certification for market uptake.

- *Create strategic gamified marketing interactions with customers through tokenised loyalty rewards programs*: enabling the brand's reinvention with blockchain can include proof of provenance at points of sale to demonstrate blockchain's technological capabilities and create strategic gamified marketing interactions with customers through tokenised loyalty rewards programs.
- *Food brands will need to create paths to reinvention by continually gathering consumers' insights to identify needs, opportunities, cross-selling, and trends*: customer data gathering to keep the continous improvement.

4.8. Future Research

Considering a blockchain-certified food environment, we encountered ample opportunities to review, redesign and standardize unique food labeling in Australia to make more efficient food supply chains. Future research could investigate perceived Corporate Social Responsibility deficiencies in the food supply chain by supply chain stakeholders and how blockchain technology can aid in overcoming those shortfalls.

Lastly, more research is needed with a interdisciplinary approach based on consumer choice behavior and neuromarketing to study WTC and WTP for blockchain-certified high-end/luxury products, as we expect these goods will be embraced faster by customers in the current blockchain adoption stage. Next we provide some future research (including SLR’s) suggestions according to our analysis:

- Research into improved labeling standards could examine deeper into standardizing and improving food labeling in a blockchain-certified food environment. This investigation could focus on designing more efficient and standardized labeling practices to optimize food supply chains, aligning with the transparency and traceability offered by blockchain technology.
- Exploring CSR and blockchain integration within blockchain-enhanced food supply chains. This research could examine how blockchain technology can address perceived deficiencies in CSR within the food supply chain, ensuring responsible practices and ethical standards.
- Neuromarketing approach with high-end products combined with consumer choice behavior could study the willingness to choose (WTC) and willingness to pay (WTP) for blockchain-certified luxury products. Such research could provide valuable insights into consumer behavior and preferences in adopting blockchain technology, particularly within the high-end product market, offering opportunities for companies adopting this technology.

The possible research questions from the suggested topics above are:

1. How can improved labeling practices within a blockchain-certified food environment be standardized and optimized to align with blockchain technology's transparency and traceability features, and what impacts might this have on food supply chain efficiency?
2. What role can blockchain technology play in addressing Corporate Social Responsibility (CSR) deficiencies within the food supply chain, and how might blockchain integration enhance responsible and ethical practices?

3. In the context of luxury products, what psychological and behavioral factors influence consumers' willingness to choose and pay for blockchain-certified high-end items, and how can this inform companies in adopting blockchain within the luxury market?

4.9. Conclusion

We aimed to predict whether Australian consumers are willing to choose and pay for more transparent food products (eggs) from companies implementing blockchain technology. We estimated a hybrid choice model and incorporated CoDa with the covariate of gender. Examining data with choice modeling and CoDA in our analysis provided us with a valuable understanding of consumers' behavior when preferring food products certified with blockchain technology for the foreseeable future. Our findings evidence significant positive attitudes towards blockchain technology traceability, indicating positive receptiveness to products with a transparent provenance and genuineness.

Overall, Australian consumers are becoming more interested in the provenance of food products and the sustainable/ethical practices of producing them. Since several food brands aim to differentiate themselves in the market by validating sustainability practices to customers, blockchain technology can strengthen those claims incentivizing consumer trust and increasing brand equity. Further, we also provided a structured framework to address the marketing implications of our findings through three converging brand dimensions (engagement, differentiation, and access) and three brand resilience and agility phases (resistance, recovery, and reinvention) to initiate blockchain awareness in consumers deriving, primarily in developing positive, sustainable/ethical brand associations with a gender segmentation. Our findings highlight that consumers perceive the value of blockchain traceability, showing concerns about sustainable/ethical food production and faster food recalls in case of food incidents (WTC). However, consumers are unwilling to pay (WTP) a significant premium for blockchain certification.

Our findings contribute to a better understanding of consumer behavior in the context of blockchain adoption and sustainable/ethical corporate practices offering insights for researchers and marketers. Decisively, food brands should not wait for the perfect timing or perfect organization to embrace blockchain technology.

Appendix 1

Survey Instrument

Food Transparency, Authenticity and Safety with Blockchain Technology

Welcome!

Thank you so much for taking the time to contribute to our survey!

Please read this information carefully before deciding whether to take part. To be eligible to participate, you must be over 18.

What is the aim of the study?

We aim to understand the consumers' attitudes towards regularly using a mobile application to instantly scan a food product's barcode, knowing with certainty that the food's attributes and provenance details are trustworthy and verifiable due to the use of secure digital technology (blockchain). This study aims to advance our understanding of how individual perceptions contribute to using new technology.

To accomplish this goal, you are invited to participate in a survey. This survey is conducted by researchers from the University of Western Australia.

What is expected of you as a participant?

First, you will contribute to science by participating in this research by helping us identify the consumers' perspectives on food transparency through secure digital technology (blockchain). Your responses will provide valuable information to determine the importance of using secure digital technology (blockchain) in Australia's food supply chains and raise awareness of this technology for public health. Second, you will respond to some video questions that will provide information to other studies being conducted simultaneously for efficiency reasons. Third, you will be presented with several purchase options for a specific product: eggs. Finally, you will answer a few demographic questions about yourself. The survey should take 15 minutes to complete.

Confidentiality:

All your responses will be anonymous. No individual will be identified in these outputs. Your participation in this study and any information you provide will be treated confidentially. Only the researchers involved in this study and those responsible for research oversight will have access to any information that you provide. The collected data will be kept de-identified in a password-protected computer for seven years. Therefore, there are no foreseen risks associated with participation in this project.

Your participation in this study and any information you provide will be stored at the University of Western Australia. We may also share the data with other researchers so that they can check the accuracy of our conclusions. Still, we will only do so if we are certain that your confidentiality is protected. Information from this project could be published in research articles in academic journals. The research publication will be accessible to everyone with access to the online journal, a common practice in academic research. When we publish any results from this study, we will do so in a way that does not identify you. You can withdraw from the study at any time, and all data will be destroyed after the withdrawal.

Voluntary Participation:

Your participation in this study is voluntary. You are free to decline to participate and to end your participation at any time for any reason.

Risks and Benefits:

There are no known or anticipated risks associated with this study. Although this study will reward you for your participation, we hope that our results will add to the knowledge about how people feel about having access to more transparent food information with the use of digital technology.

Attention and comprehension check policy:

This survey uses attention and comprehension check questions to ensure you are truly paying attention to what is being asked and understand the requirements of the queries. If you fail to complete these checks, you'll be asked to return your submission by closing the survey and clicking 'Stop Without Completing' on Prolific.

Questions:

If you have any questions or discuss any aspect of this study, please feel free to contact PhD candidate Elena Vazquez, the person in charge of this research study. She can be reached at <elena.vazquezmelendez@research.uwa.edu.au

This study has received the Ethics approval number 2021/ET000375 to conduct this research.

Consent

I have read the information sheet entirely and agree with it;

I understand that all information provided is strictly confidential and will not be released by the investigator;

I understand that this study has received ethics approval, and it is administered in line with the ethics criteria outlined in the ethics approval process;

I have been advised what data is being collected, its purpose, and what will be done upon completing the research;

I agree that the research data gathered for the study may be published. Still, my identifying details will not be used in any publication arising out of the research without my consent.

I understand that I may stop my participation and withdraw from this study by contacting the researchers at any moment, and all information that I provided will then be destroyed;

I will provide answers to the best of my knowledge without any deception, truthful and as accurate as possible;

I am 18 years of age or older;

o Yes, I want to participate in this study.

o No, I do not want to participate in this study.

What is your prolific ID?

Please note that this response should auto-fill with the correct ID.

Thank you very much for participating in this study. We value your opinion, and your answers are very important for our research. They will help communicate consumers' perceptions to industry and governmental instances about food provenance information using digital technology.

Please note that **<u>there are no right or wrong answers</u>** as people have different opinions, and all of them depend on your personal preferences.

This survey contains attention and comprehension questions.

In studies like ours, a few people sometimes do not carefully read the questions and "quickly click through the survey." These random answers are problematic because they compromise the results of the studies. Therefore, it is vital that you pay attention and read each question carefully.

CQ1 (Comprehension Question)

This is a comprehension check; you will have two opportunities to answer this question correctly:

"You are a senior editor at a daily newspaper. You have two major tasks:

First, many journalists keep pitching stories to you. You are the one who must sort them into potentially positive or negative news while your fact-checking department verifies their content.

Second, once you get the actual true story from your fact-checking department, it is your responsibility to check that a photo (that someone from your photography department has proposed to go with the story) matches with the true story (yes vs. no) as verified by your fact-checking department."

Based on the instructions you have just read, what do you have to do once a story is pitched to you?

Please re-read the study instructions above if you are not sure. You will have two opportunities to get this question correct.

o Sort them into positive or negative news.

o Judge how well-written they are.

o Nothing.

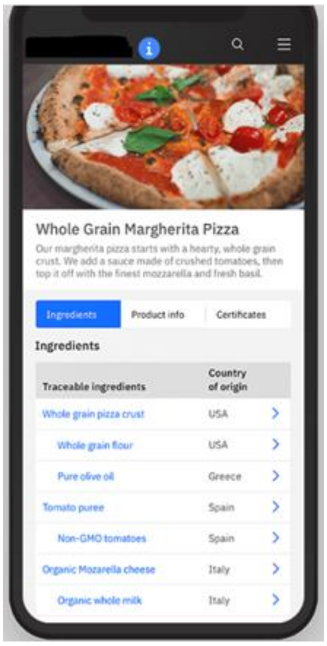
We are interested in your views on the transparency of food's provenance (point of origin) and attribute information. In answering these questions, please take a moment to think about the food you purchase in your daily life and its journey from the farm to the supermarket. As all food production has an impact, making an informed choice is beneficial for consumers and brands.

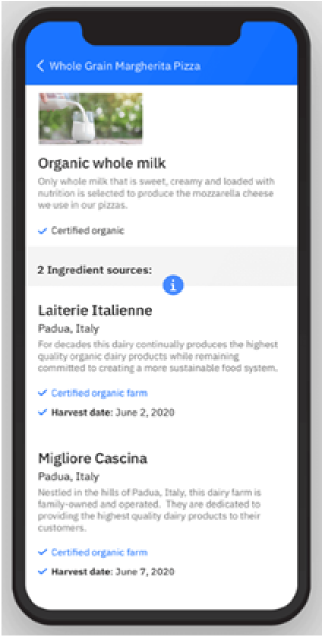
You have the possibility of instantly knowing with certainty that the food's attributes and provenance details are trustworthy and verifiable, thanks to secure digital technology (blockchain).

For example, imagine using your mobile phone regularly in the grocery shop, scanning food products' barcodes to access comprehensive information and images detailing the conditions of how your food was produced. Through this app, you can scan a barcode on the packaging to view the product’s history to better understand the quality. For instance, how the salmon you are about to purchase was raised, the date of harvest, and information concerning the supply route.

See the following pictures from IBM Food Trust showing how the consumers can see the food details (pizza) through a mobile phone application.

Ingredients Details **Ingredients Sources Details** **Food Certifications**





Additionally, please read the following concept of blockchain. The secure digital technology can make it possible to have transparent and verifiable information about the food's provenance and attributes you regularly purchase.

What is blockchain?

Blockchain is a helpful digital technology to trade goods and services securely. It is a system where participants can add data and not change it because the computers have codes that make the information protected (cryptography), converting the data into a secret message.

The added information cannot be erased or tampered with. Thereby, the food you regularly purchase could be verified with strong assurance that the products' labels claims are authentic, reliable, and safe to consume for you and your family. Also, when using blockchain technology, companies in the food supply chain could detect food incidents and make food recalls faster (from days to minutes).

We have added a video from IBM on the next page to help you better understand the blockchain concept.

Also, you will find another concept probably unfamiliar to you: the internet of things. Even though the concept is not part of this research, we want you to get familiarised with it to understand the following video fully.

**Concept of The Internet of things: It describes the network of physical objects—"things"—that are embedded with sensors, software, and other technologies to connect and exchange data with other devices and systems over the internet (Oracle Australia).

Thank you for watching!

Video 1 – Blockchain concept in the food supply chain scenario

You will now be shown a video. Please watch carefully.

https://www.youtube.com/watch?v=HJ1W4vHPDFY

Have you heard about blockchain technology before participating in this survey?

o No.

o Yes.

o Prefer not to answer.

Behavioral Intention

BI1

How frequently would you use a mobile food application in your grocery purchases?

o Always

o Most of the time

o About half the time

o Sometimes

o Never

BI2

If the retailer offered a loyalty program (discounts and promotions) in exchange for your feedback, how likely are you to use a mobile application to scan a food product's barcode?

o Extremely likely

o Somewhat likely

o Neither likely nor unlikely

o Somewhat unlikely

o Extremely unlikely

BI3

What are the chances you would recommend using a mobile phone application to scan a food product's barcode for others?

o Definitely would

o Probably would

o Might or might not

o Probably would not

o Definitely would not

BI4

How likely is a mobile application to become one of your favourite technologies when shopping for food?

o Extremely likely

o Somewhat likely

o Neither likely nor unlikely

o Somewhat unlikely

o Extremely unlikely

Use Behaviour

UB1

Do you currently read product labels of food items you select for purchase?

o Never

o Sometimes

o About half the time

o Most of the time

o Always

UB2

In the following question, you will be given 100 points to rate the most important food label information when using a mobile application to scan a food product's barcode. You can assign those points however you like, from 0 to 100. The higher score you assign, the higher your preference for that food attribute.

o Use-by / best-before dates

o Organic certified (products grown and processed without the use of synthetic chemicals, fertilisers, or GMOs)

- o Declared allergens
- o Sustainably manufactured (minimising negative environmental impacts)
- o Ethically produced (working conditions are fair)
- o Low fat / healthy eating / Vegan / Halal / Kosher
- o Country / Region of origin
- o Food Recalls / Food contamination:
- o Recyclable packaging
- o Cooking instructions

UB3

Please select the products you are currently engaged in verifying labels' information from the following food items (this is a multiple-choice question; you can choose all products that apply to your preferences).

- ▢ Beef products
- ▢ Poultry products
- ▢ Cheese / Dairy
- ▢ Fish
- ▢ Wines
- ▢ Organic products
- ▢ Low fat / healthy eating products / Vegan / Halal / Kosher
- ▢ Other (please specify):

Spatial separation of Dv's and IVs.

You will now be shown a video. Please watch carefully.

Video 2 – What is the fourth industrial revolution?

https://www.youtube.com/embed/mf4E92qPujM

Please answer the following question according to the video you watched.

What is the fourth industrial revolution?

- o It is a space to perform arts.
- o It is a period of intense technological advancement.

- It is an organisation where people discuss literary works.
- It is a playground for kids.

How did the video make you feel?

- Hopeful
- Upset
- Joyful
- Sad
- Excited

CQ2

"You are a senior editor at a daily newspaper. You have two major tasks:

First, many journalists keep pitching stories to you. You are the one who must sort them into potentially positive or negative news while your fact-checking department verifies their content.

Second, once you get the actual true story from your fact-checking department, it is your responsibility to check that a photo (that someone from your photography department has proposed to go with the story) matches with the true story (yes vs. no) as verified by your fact-checking department."

Based on the instructions you have just read, what do you have to do once you get the true story?

Please re-read the study instructions above if you are not sure.

- Rate how accurate it is.
- Check that the photo provided matches the true story.
- Nothing.

Performance Expectancy

PE1

For the following set of questions, when using a mobile phone application to scan the barcode of a food product to display the food's history in real-time:

How positive or negative would it be for you to know where food is coming from and the conditions under which it was produced (e.g., origins, picking, or catch dates, storage, and shipping times)?

- Extremely positive
- Somewhat positive
- Neither positive nor negative
- Somewhat negative

o Extremely negative

PE2

How useful would it be for you to access food information from the farm or sea to the shelf when shopping?

o Extremely useful

o Very useful

o Moderately useful

o Slightly useful

o Not at all useful

PE3

How effective do you think it would improve your selection of fresher food (e.g., buying more local food)?

o Extremely effective

o Very effective

o Moderately effective

o Slightly effective

o Not effective at all

P4

For the following set of questions, when using a mobile phone application to scan the barcode of a food product to display the food's history in real-time:

How beneficial would you consider it for food safety (e.g., faster food recalls investigations, food fraud detection)?

o Extremely beneficial

o Very beneficial

o Moderately beneficial

o Slightly beneficial

o Not beneficial at all

P5

How satisfied or dissatisfied would you be to become aware that the food you are buying has been produced in an environmentally sustainable way (i.e., how workers and animals were treated)?

o Extremely satisfied

- Somewhat satisfied
- Neither satisfied nor dissatisfied
- Somewhat dissatisfied
- Extremely dissatisfied

Effort Expectancy

Remember to read questions carefully because the order of answers can change.

EE1

How knowledgeable do you consider yourself about using mobile phone applications?

- Not knowledgeable at all
- Slightly knowledgeable
- Moderately knowledgeable
- Very knowledgeable
- Extremely knowledgeable

EE2

How easy or difficult would it be for you to learn how to use mobile phone applications?

- Extremely difficult
- Somewhat difficult
- Neither easy nor difficult
- Somewhat easy
- Extremely easy

AQ1

To show that you read our questions closely (regardless of your preference), please answer "Blue" in the question on the next page.

Based on the text you read above, what colour have you been asked to enter?

- Red
- Green
- Blue
- Orange
- Brown

EE3

For the following set of questions, when using a mobile phone application to scan the barcode of a food product to display the food's history in real-time:

How easy or difficult would it be for you to become skilful at installing the app on your device?

- o Extremely difficult
- o Somewhat difficult
- o Neither easy nor difficult
- o Somewhat easy
- o Extremely easy

EE4

How challenging will it be for you to read the food product's details on the app from your mobile phone?

- o Extremely challenging
- o Very challenging
- o Moderately challenging
- o Slightly challenging
- o Not challenging at all

Social Influence

SI1

If people important to you (family, friends) are using a mobile phone application to scan a food product's barcode to access the food's history in real-time:

How likely are you to start using it?

- o Extremely likely
- o Somewhat likely
- o Neither likely nor unlikely
- o Somewhat unlikely
- o Extremely unlikely

SI2

If people whose opinions you value (friends, work colleagues) are using the mobile app:

How likely are you to start utilising it?

- o Extremely likely
- o Somewhat likely

- Neither likely nor unlikely
- Somewhat unlikely
- Extremely unlikely

SI3

If you observed other people in a grocery shop utilising the mobile app:

How likely are you to start using it?

- Extremely likely
- Somewhat likely
- Neither likely nor unlikely
- Somewhat unlikely
- Extremely unlikely

SI4

If influencers on social media are using the mobile app:

How likely are you to start using it?

- Extremely likely
- Somewhat likely
- Neither likely nor unlikely
- Somewhat unlikely
- Extremely unlikely

Facilitating Conditions

FC1

For the following set of questions when using a mobile phone application to scan a food product's barcode to access the food's history in real-time:

How adequate or inadequate do you consider your mobile phone to engage with the app?

- Extremely inadequate
- Somewhat inadequate
- Neither adequate nor inadequate
- Somewhat adequate
- Extremely adequate

FC2

How comfortable would you feel scanning a barcode with your mobile phone frequently?

- o Extremely uncomfortable
- o Somewhat uncomfortable
- o Neither comfortable nor uncomfortable
- o Somewhat comfortable
- o Extremely comfortable

FC3

How challenging would it be for you getting help from others when you had complications using it?

- o Extremely challenging
- o Very challenging
- o Moderately challenging
- o Slightly challenging
- o Not challenging at all

FC4

How important would it be for you to be able to scan all food products you want to purchase using a single mobile phone app rather than having to select multiple mobile phone apps to scan different products?

- o Not at all important
- o Slightly important
- o Moderately important
- o Very important
- o Extremely important

Food Safety Motivations

FSM1

When purchasing your food items, how reassured would you feel about the food's information authenticity provided by the mobile phone app?

- o Extremely reassured
- o Very reassured
- o Moderately reassured
- o Slightly reassured
- o Not at all reassured

FSM2

How important is it for you to be frequently aware of possible food safety incidents (e.g., contaminated food, food hygiene malpractices, food outbreaks)?

- o Extremely important
- o Very important
- o Moderately important
- o Slightly important
- o Not at all important

FSM3

How important is it for you to be informed of food fraud and adulteration (e.g., risky substitute products such as simulated baby milk, horse meat instead of beef, needles in strawberries, mislabeled products)?

- o Extremely important
- o Very important
- o Moderately important
- o Slightly important
- o Not at all important

FSM4

How likely is it that a mobile app for scanning food information will aid in reducing risks to you and your family's health?

- o Extremely likely
- o Somewhat likely
- o Neither likely nor unlikely
- o Somewhat unlikely
- o Extremely unlikely

Consumer Perceived Value

CPV1

How likely are you to select higher quality food that uses secure digital technology (blockchain) through the mobile food application?

- o Extremely unlikely
- o Somewhat unlikely
- o Neither likely nor unlikely

- Somewhat likely
- Extremely likely

CPV2

How likely do you think the mobile food application could quickly help you identify food products that contain risky allergenic ingredients for you and your family (e.g., peanuts, dairy, fish, shellfish, and wheat)?

- Extremely unlikely
- Somewhat unlikely
- Neither likely nor unlikely
- Somewhat likely
- Extremely likely

CPV3

How likely do you think using a mobile app to scan food authenticity information will empower you as a consumer (e.g., what to buy, where to shop and which brands to choose)?

- Extremely unlikely
- Somewhat unlikely
- Neither likely nor unlikely
- Somewhat likely
- Extremely likely

CPV4

How probable do you think using a mobile food application will make you more sustainable-conscious?

- Extremely improbable
- Somewhat improbable
- Neither probable nor improbable
- Somewhat probable
- Extremely probable

CPV5

If you choose more environmental food products using the mobile application, how influential do you think you will be to incentivise brands to change their behaviour to more sustainable practices?

- Extremely uninfluential

o Somewhat uninfluential

o Neither influential nor uninfluential

o Somewhat influential

o Extremely influential

Habit

HT1

How dependent are you on mobile phone applications in your everyday routine?

o Extremely dependent

o Very dependent

o Moderately dependent

o Slightly dependent

o Not dependent at all

HT2

How accustomed would you be to using a mobile app to be aware of your purchase's transparent food story?

o Extremely accustomed

o Very accustomed

o Moderately accustomed

o Slightly accustomed

o Not accustomed at all

HT3

How familiar will it be for you to use a mobile application to scan a food product just like you use other apps (e.g., the Uber, and Spotify apps)?

o Extremely familiar

o Very familiar

o Moderately familiar

o Slightly familiar

o Not at all familiar

HT4

How frequently do you think you would access detailed food information you regularly buy in a month using the mobile application?

- Several times a week
- Once or twice a week
- Once a week
- Twice a month
- Once a month

Consumer Trust

CT1

For the following set of questions, when using a mobile phone application to scan a food product's barcode to access the food's history in real-time:

How accurate do you think the information would be?

- Extremely inaccurate
- Somewhat inaccurate
- Neither inaccurate nor accurate
- Somewhat accurate
- Extremely accurate

CT2

How confident would you feel about the goods purchased?

- Extremely unconfident
- Somewhat unconfident
- Neither confident nor unconfident
- Somewhat confident
- Extremely confident

CT3

By having more transparency on a company's product claims, how likely is it to increase your trust in the brand?

- Extremely unlikely
- Somewhat unlikely
- Neither likely nor unlikely
- Somewhat likely
- Extremely likely

CT4

By having more clarity on a company's product claims, how likely is it to improve your loyalty to the brand?

- o Extremely unlikely
- o Somewhat unlikely
- o Neither likely nor unlikely
- o Somewhat likely
- o Extremely likely

AQ2

It is important that you pay attention to this survey. Please click 'Strongly agree' for this question.

- o Strongly disagree
- o Somewhat disagree
- o Neither agree nor disagree
- o Somewhat agree
- o Strongly agree

Open Question

OQ1

Do you have any other feedback regarding food transparency you want to let us know?

We want to ask you for some background information to finalise the study. Then, we will use your answers to these questions to compare different groups of people.

Demo1

With which gender do you identify?

- o Male
- o Female
- o Non-binary/gender-diverse
- o My gender identity isn't listed. I identify as:
- o Prefer not to answer

Demo2

Which of the following age groups describes you?

o 18 -27

o 28 - 37

o 38 - 47

o 48 - 57

o 58 +

Demo3

In what region is your current residence located?

o Western Australia (WA)

o Northern Territory (NT)

o South Australia (SA)

o Queensland (QLD)

o New South Wales (NSW)

o Victoria (VIC)

o Tasmania (TAS)

Demo4

What is the highest education level you have attained?

o No formal qualifications

o Secondary education

o High school diploma

o Technical / Community college

o Undergraduate degree

o Graduate degree

o Master/Professional degree

o Doctorate/PhD

Demo5

Which of the following categories best describes your employment status?

o Full time

o Part-time

o Unemployed, looking for work

o Unemployed, not looking for work

- Not in paid work (e.g. home maker', retired' or disabled)
- Student
- Other

Demo6

What is your annual household income?

- Less than $25,000
- $25,000 - $50,000
- $50,000 - $100,000
- $100,000 - $200,000
- More than $200,000
- Prefer not to answer

Demo7

Are you a parent or caretaker of children?

- Yes
- No

Thank you for taking part in this study. Please click the button below to be redirected back to Prolific and register your submission.

CHAPTER 5

General Discussion

My research identified a gap in blockchain adoption regarding consumer behaviour research. The main objectives of this thesis research are three: to establish the current state-of-the-art of blockchain adoption by academic and industry fields in supply chain management, to estimate willingness to accept (WTA) blockchain-certified food products via a simulated mobile application and analyse willingness to choose (WTC) and pay (WTP) for blockchain-certified food products. My first aim was achieved by conducting a systematic literature review. My second aim was attained by implementing and adapting a well-renowned theoretical framework, the Consumer Acceptance and Use of Technology (UTAUT2), to the context of blockchain in the food supply chain. My third aim predicts through the lens of consumer behaviour research and choice modelling the WTC and WTP for blockchain-certified food products.

This thesis encompasses a interdisciplinary research approach. On the one hand, it advances supply chain management research by analysing the drivers and benefits gained by early adopters of blockchain technology. On the other hand, it also expands the marketing research by studying consumer behavioural factors in the context of blockchain technology adoption. This research advances our understanding of the present state of blockchain's adoption in the industry beyond that of cryptocurrencies, primarily in food supply chains. Finally, in this chapter, I review my research's theoretical and actionable implications innovative contributions and conclude the thesis by addressing the limitations and future research on the topic.

5.1. Theoretical Implications

In the first stage of my investigation, I undertook a systematic literature review of the current state-of-the-art on blockchain and supply chain provenance from the academic and practitioner domains. Typically, systematic reviews are limited to peer-reviewed literature. However, given that blockchain-certified food technology is not yet established in the market, I considered it essential to expand the literature to include the latest reports and opinions from the technology sector. The result is that I present a comprehensive overview of the blockchain landscape in supply chain management, comparing academic and industry articles.

The SLR study also compares and contrasts the academic and industry literature using two different methods, text-to-data algorithms and traditional investigator interpretation and classification of the literature. The findings show the synergy across academic and industry domains considering blockchain benefits and recognise such confluence on the need to reinforce data traceability in the supply chain. Insights from both research domains illustrate blockchain adoption's efficiency gains to increase consumers' perceived value and trust in brands' claims.

Furthermore, the SLR identified the underlying drivers of blockchain technology implementation and business values achieved by early adopters within the supply chain domain. One of the most significant findings from this review is the characteristics of the products and services that have driven blockchain technology's early adoption. Applying qualitative analysis to the archival data, I categorised the industries, the adoption business rationale, the business values achieved by the trials and the type of products involved. Interestingly I noticed patterns in the type of products with blockchain adoption by these firms and classified them into three primary groups: Group A encompasses perishable goods, mainly for human consumption with a high degree of health risk mitigation. Group B involves non-perishable goods with a long chain of custody, mostly of high value for collection/investment purposes and a high degree of financial risk reduction. Lastly, Group C comprises manufactured goods, mostly of high value for digital twins' creation, responsible sourcing and an intrinsic need for provenance validation. The findings of the SLR study shed light on the transformative potential of blockchain technology in reshaping various aspects of supply chain management, including product provenance, security, authenticity, accountability, safety and consumer confidence.

In addition, I address the blockchain oracle issue in food supply chains. Recall that the oracle problem, within the context of blockchain, refers to the challenges of securing accurate and reliable data from external physical sources (Kshetri, 2021a) and incorporating the digital data into a blockchain system. Within food supply chains, it is complicated to counteract food fingerprinting. To tackle this problem, I explore the applicability of fingerprinting techniques (hardware oracles) to install a direct connection between physical products and the tamperproof blockchain digital ledger. I present diverse analytical/chemical methods, such as vibrational spectroscopies, mainly for product authenticity and adulteration by rapidly identifying foodborne bacterial/spoilage contamination and food poisoning (Ellis et al., 2012). Nuclear magnetic resonance (NMR) for detecting adulteration of a wide range of food, mass spectrometry providing rapid packaging screening for food bacteria contamination detection. Biochemical tracing testing agricultural products back to where they were grown since they absorb the environment.

Blockchain also offers the possibility of implementing smart contracts (internal software oracle) and integrating the analytical/chemical for food fingerprinting (hardware oracle) to reinforce the resilience of the food supply chain. Altogether, the SLR findings presented in this thesis shed light on the potential of blockchain technology and offer insights into its implementation and limitations regarding supply chain management laying out future research directions.

Once I examined blockchain digital technology as a potential game-changer for food companies, I conducted another study in the second stage of my investigation to discern the attitudinal factors that drive consumers' adoption of new technologies. For this purpose, I applied and extended the Consumer Acceptance and Use of Information Technology (UTAUT2) of Venkatesh et al. (2012). The UTAUT2 theoretical framework best fits my consumer behaviour research aim as it integrates and unifies eight prior well-researched theoretical models, such as the theory of reasoned action (TRA), the technology acceptance model (TAM), the innovation diffusion theory (IDT), the motivational model (MM), the theory of planned behaviour (TPB), the combined technology acceptance model (C-TAM-TPB), the model of PC utilisation (MPCU), and the social cognitive theory (SCT) (Ajzen, 1985; Bandura, 1977; Davis, 1989; Davis et al., 1989, 1992; Fishbein & Ajzen, 1975; Rogers, 2003). Ultimately, the UTAUT model explained as much as 70% of the variance in usage intention decisions (Viswanath Venkatesh et al., 2003a). For my methods, I employed a structural equation model and path analysis by using survey data gathered from real consumers across Australia to examine the latent factors that can drive consumers' adoption of blockchain-based food products with a mobile application. My findings denote that *habit* is the major predictor of behavioural intention, followed by *social influence*.

On the other hand, a non-significant effect is confirmed for performance expectancy, effort expectancy, and consumer perceived value and trust (the extended factor of the UTAUT2 theory in this study). This second study is of theoretical importance to further the academic literature on technology acceptance and supply chain management from a costumers' stance. Thus, the theoretical contribution of study two is fitting the UTAUT2 customer-centric model toward accepting blockchain-certified food products (WTA) using a mobile application for food provenance. At present, I am unaware of any other studies investigating user acceptance of a mobile application that scans food products certified with blockchain technology, and believe this work is a novel contribution. In addition, I outline a policy scheme for adopting blockchain technology centred on strengthening traceability, trust and collaboration among food supply chain stakeholders, governmental instances, and customers.

The third study of my investigation focuses on analysing the most influential food features for Australian consumers and their willingness to choose (WTC) and to pay (WTP) for blockchain-certified food products (eggs). I aimed to assess whether choice preferences exist in consumers for blockchain-certified food products once they perceive the value of blockchain advantages in terms of authenticity, safety, and sustainability consciousness. For the methods for this third and final study, I integrated a hybrid choice model estimation (discrete choice modelling) and compositional data (CoDa) by designing an online choice experiment composed of food feature preferences. With this behavioural study, I wanted to analyse whether the latent compositional covariates affected the intensity of consumer choice. During the statistical analysis, I observed a notable tendency of consumers towards a sustainability-consciousness dimension. This observation is consistent with several investigations in the academic and industry literature reporting on the ongoing transformation in several industries powered by strong consumer demand for corporate sustainable and ethical practices (Amini et al., 2018; Campbell et al., 2022; Friedman & Ormiston, 2022; Kim & Kim, 2017). The last study of this thesis has produced significant positive findings on consumers' perceptions of accessing transparent food origins information with blockchain certification and are WTP a small premium —provided that it does not surpass greater price limits— to brands engaging in sustainable/ethical matters along the food supply chain. The choice modelling findings paved the way for practitioners to develop marketing campaigns. Blockchain technology can be used to differentiate a food brand by emphasizing sustainability and ethical practices in marketing campaigns. This thesis's second and third research phases raise the likelihood that consumers in Australia will support blockchain adoption by the food industry by sharing its potential with practitioners. In summary, all studies in this thesis enrich the existing literature by employing distinctive methodological approaches.

5.2. Managerial Implications

The studies in this thesis provide potential implications for management and organisations. This research supports practitioners planning to attempt blockchain adoption in their food supply chains, depicting substantial knowledge in two ways. First, the results from my first study (SLR) illustrate the importance of having a balanced literature review (academic vs. industry domains), especially when studying nascent technologies yet to be established in the market. The SLR displays the adoption drivers, business values achieved, and categorisation by type of industries and products involved in blockchain implementation from early pioneers in their supply chains. These outcomes enable practitioners to gain insights into the motives and gains from other companies to elucidate the viability of blockchain adoption as an initial exploration point. However, it is important to bear in mind that even though blockchain is an innovative technology in supply chain management, organisations should not follow the hype and assess its adoption's decision-making by considering the stakeholders' technical, organisational and consumer scenarios. This objective can only be reached when all supply chain stakeholders collaboratively manage blockchain interoperability. Subsequently, based on the blockchain experiments performed by early adopters, I propose that its adoption should start small before progressing to a large-scale strategy conducting blockchain proofs of concept. Further, management buy-in and support is crucial in establishing and communicating an organisational vision for blockchain implementation.

The second stage of this thesis analyses the behavioural factors influencing consumers' willingness to accept blockchain-certified food products using a mobile application to access the journey of a product. I expect the insights from this study to help the decision-making of supply chain stakeholders on blockchain's adoption by providing the most significant factors of consumer behaviour: *habit* and *social influence*. In this manner, food businesses can gather better information for blockchain implementation by considering these factors, perhaps designing more user-friendly and visually attractive applications to support the effect of habit on behavioural intention. Gamification can offer the opportunity as it has a direct and solid relationship with the intention to use mobile services when appropriately designed (Baptista & Oliveira, 2017), which can boost customer acceptance. Likewise, marketing managers can refine social media campaigns in light that social influence is the second most important factor driving market uptake. The agency of public figures, opinion leaders, or influencers can promote the vision of the modern-technologically sustainable-conscious consumer with blockchain acceptance. Thus, food brands may advance with increased confidence in blockchain's adoption in the foreseeable future by better understanding the consumers' behavioural perspective.

Based on choice modelling, the final study predicts consumers’ positive receptiveness and WTC and WTP for blockchain-certified food products. The results also show a constant negative inclination for the packaging claim of cage eggs, displaying consumers' disapproval of unethical production practices. Regarding WTP, food brands should be cautious when determining the market price threshold for blockchain-certified food products.

Since the key to influencing subconscious minds in consumers is identity-driven and brands' positive associations in their memories (Platt & Zane, 2019; Reed et al., 2012), brands should implement powerful branding with blockchain-positive associations to influence consumers' decisions when selecting blockchain-certified products. I also recommend that marketing strategies emphasise the positive utilitarian value of the blockchain-based mobile application, perhaps by showcasing how the technology safeguards consumers from food contamination and tampering risks creating kiosks with easy access to food products and positioning them with exhibited blockchain-certified labels in strategic high-visibility store areas. To expedite awareness and acceptance of blockchain technology, brands could also publicise continuously using the mobile application on their websites. Further, I provide marketing implications to facilitate brand resilience and agility.

In summary, my propositions for blockchain awareness and initiation by the food industry are the following:

- Based on the SLR analysis, food brands can verify the similarities and opportunities of early pioneers of blockchain adoption in the supply chain to gain insights for starting the technology experimentations.
- Companies must map and digitise their supply chain and evaluate blockchain adoption and related set-up costs.
- The food industry needs to collaborate with governmental bodies and consumers to identify supply chain needs and initiate blockchain adoption. I provide a policy framework with actionable guidelines (see the framework in 3.11. Policy Implications).
- With *habit* as the most significant driver of consumers' behavioural intention, food brands must design more user-friendly and visually attractive applications. Perhaps gamification will provide such an opportunity. Marketing managers can craft social media campaigns with the insight that *social influence* is the second most important factor driving market uptake. They could employ celebrities, opinion leaders, or influencers to push the image of the modern-technologically and sustainable-conscious consumer.
- Since the findings from the choice modelling show that consumers perceive value from end-to-end traceability, it is essential to craft marketing messages that establish deep positive associations with blockchain technology's capability to support food transparency and safety.
- Develop positive blockchain associations in consumers around supply chain transparent practices with imagery and insignia on high-quality, non-toxic ingredients and allergen

declaration, emphasising sustainable/ethical manufacturing methods. Since our choice models exhibit a marked favourable preference for the packaging claim of free-range/organic eggs with blockchain-welfare certification. The advertising campaigns should highlight the brand's unique and differentiated blockchain traceability of its supply chain vs. the competitors.

- The favourable preference for blockchain food recall time implies that consumers may perceive it as beneficial for safety matters. In case of experiencing negative brand associations (e.g., food incidents), activating immediate recovery strategies and initiating gradual positive messages in consumers' minds is vital. Communicating the circumstances opportunely through accountable admission of the incident to reinforce consumer trust.
- Integrating easy access to physical and digital channels with blockchain content to consumers as a competitive advantage. Increasing brand approachability to boost customer relationships will allow the company to capture maximum market share. For instance, the mobile application could offer instant discounts based on digital tokens acquired, providing economic incentives for uptake. A loyalty program could expedite insights to companies to advance more sustainable and ethical practices.
- Redesign or create business models centring on transparency and quality through blockchain certification, enabling the brand's reinvention with blockchain proof of provenance at points of sale and digital exhibition of the technological capabilities with the mobile application.
- In the case where food brands charge the consumer a premium for blockchain certification, they need to be cautious when establishing the price increment since consumers may be less willing to pay higher prices. In my analysis, consumers are WTP

per carton (dozen) of eggs a premium of $1.30 with a margin of error of approximately $0.22.

- Ensuring constant consumer reach reduces disruptions, establishing paths to reinvention by continually collecting consumer insights to identify needs, cross-selling opportunities, and trends.

Overall, this thesis provides scientific evidence that should increase food practitioners' confidence to strategically allocate resources to blockchain adoption, considering the insights of consumers' WTA, WTC and WTP for blockchain-certified food products.

5.3. Limitations and Future Research

Even though the findings of this thesis contribute to theoretical and practical implications, certain relevant inquiries may have been overlooked or omitted. As the topic of blockchain for supply chain provenance advances, I anticipate an expanding corpus of literature to elicit more evidence-based findings. The SLR exhibited a narrow body of knowledge published in peer-reviewed journals on blockchain and supply chain provenance.

More studies are needed on fingerprinting food supply chains by assuring the link between the physical flow of products and the digital blockchain ledger. Similarly, there are ample opportunities for investigating the compliance-governance challenges of blockchain by embedding smart contracts applications in the food supply chain since the academic literature on this topic is limited. Another subject of merit for scholarly exploration is related to sustainability/ethical consciousness topics and how blockchain technology can hinder malpractices in the supply chain.

While acknowledging the limitations of this research, I posit that it contributes to a significant inquiry into a subject worthy of a comprehensive investigation, especially for the shortage in the literature on analysing consumer behavioural factors of acceptance and willingness to choose and pay for blockchain-certified food products.

- However, there needs to be more investigation on whether preference for blockchain-certified food product selection would occur in other products since the study was limited to study eggs. For example, high value food products with a long shelf life and highly collectable nature, such as rare whiskey and wines, cross the boundaries of the product categories we've identified in Chapter 2 and studied in Chapters 3 & 4.
- Despite the demonstrated evidence-based findings in Chapters 3 and 4, a significant limitation of this investigation is that the extent of enquiry was circumscribed to participants surveyed in Australia. Therefore, there are risks to the generalisability of these results to other cultures. A logical progression of this research would entail extending the findings by employing a larger international sample. Then researchers could conduct cross-cultural analysis and/or compare developed versus emerging economies. In addition, extending this study to incorporate other constructs, such as data privacy and digital tokens, is worth investigating to expand this research.
- My experimental setting is also limited to consumers' using a simulated mobile application scenario for accessing blockchain-certified food products. The simulation constraint derives from the current state of the infancy of blockchain applications, which are not readily available today. On the measurement side, another limitation of this investigation is that the endogenous variable in the model, behavioural intention, is subjectively estimated by scrutinising consumers' perceptions regarding their future behaviour. Again, at this maturation stage of blockchain technology, it was not possible to perform live experiments as the technology is in the innovation stage for the general consumer. Future studies could overcome these limitations as blockchain technology develops in the food supply chains. Additionally, the upcoming analysis should

contemplate a longitudinal investigation throughout the life cycle of blockchain technology.

- Since *social influence* is the second most important predictor of behavioural intention in this investigation, it would be beneficial to examine the weights of different types of social media on behavioural intention. Finally, the most important predictor in Chapter 3 is *habit* formation in a consumer context; analysing it with a neuromarketing approach would be interesting since habit is difficult to measure using a survey instrument. In addition, this thesis also contributes an actionable food policy framework that can serve as guidance for governmental bodies that can inspire their food policies in a blockchain environment.

Consequently, companies may move forward with increased confidence regarding adopting blockchain technology by knowing the consumers' behavioural perspective and having actionable managerial marketing implications.

However, brands should consider that introducing cutting-edge technologies like blockchain for managing food supply chain requires an initial investment covering system setup, technology integration, and training expenses. This investment will vary based on the supply chain's scale and complexity. Despite these upfront costs, the projected substantial savings from enhanced recall efficiency, waste reduction, and prevention of losses during food recalls could amount to millions in economic and operational benefits.

5.4. Conclusion

Overall, this thesis has provided evidence, rationale and managerial implications for the uptake of blockchain in supply chains to offer consumers greater transparency, faster traceability, improved quality label information, and superior proof of provenance of food products. This thesis also has unveiled and measured the attitudes of real shoppers to assess their willingness to accept, choose and pay for blockchain-certified food products with a mobile application serving as an instrument to verify the product's history. Blockchain foundations have been established, and notable real-world applications among enterprises have been successfully executed in the supply chain. We have learned and proved that customers care about blockchain technology and provenance.

Blockchain technology’s origin as a digitally native technology designed to secure digitally native assets like cryptocurrencies is now clearly being extended to physical assets. However, the digital-physical divide poses many new challenges for the technology to deliver value. Therefore blockchain technology must adapt to obtain the proper task-technology fit. We have learned that blockchain technlogy cannot create value on it’s own in the physical world, but must be integrated with other technologies to do so. We have learned that blockchain requires oracles reporting on the state of physical assets in a supply chain. We have learned that these oracles can be either software (smart contracts) or hardware (IoT devices). We have learned that blockchain technology will disintermediate some actors in the supply chain while creating opportunities for new intermediaries who can add value in the new context. Supply chain actors that support oracle platforms will be the future beneficiaries. We have learned that molecular fingerprinting can move us beyond proof of provenance through packaging to proof of provenance of the actual product. Supply chain actors that support molecular fingerprinting capabilities will be the future beneficiaries.

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