Lahden ammattikorkeakoulu
Lahti University of Applied Sciences

THE ADOPTION OF BLOCKCHAIN IN FOOD RETAIL SUPPLY CHAIN

Case: IBM Food Trust Blockchain and the Food Retail Supply Chain in Malta

LAHTI UNIVERSITY OF APPLIED SCIENCES
Bachelor of Business Administration
Degree Programme in International Business
Autumn 2018
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Abstract

Authors	Type of publication	Published
Nguyen, Ha Do, Linh	Bachelor's thesis	Autumn 2018
	Number of pages 150 pages, 6 pages of appendices	

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Abstract

The year 2008 witnessed the birth of Bitcoin, a cryptocurrency that has partly kindled the blazing flame of Industry 4.0. As the archetypal representative of this age, blockchain has proven itself to be not only the power behind Bitcoin but also the disruptive technology in numerous fields, including supply chain management. Observing the optimistic changes that blockchain promisingly brings about, the authors decide to pen this thesis to assess the adoption of blockchain in food retail supply chain with the case study as IBM Food Trust Blockchain and the Maltese grocery retailing.

This thesis predominantly employs an abductive approach, supported by a small amount of deduction and processes both qualitative and quantitative data. The theory and empiricism stretch throughout the whole contents. In the theoretical part, readers are provided with the fundamentals of blockchain, food retail supply chain, blockchain-enabled food supply chain, IBM Food Trust, PEST analysis, and the theories of technology acceptance.

In the empirical part, the desk research of the macro-environment and food retail supply chain in Malta is carried out. Further, there are two comprehensive analyses, one for Maltese retailers and one for the country's end-consumers. While the data of the former are harvested completely online, the data of the latter are amassed through an online survey and face-to-face interviews.

The findings in the thesis lead to the conclusion that it is tolerably feasible to adopt blockchain in the food retail supply chain in Malta mainly due to the supportive macro-environment, the willingness to use IBM Food Trust of end-consumers and the influence of stakeholders, including end-consumers, on Maltese food retailers. Notwithstanding the positive surface, the actual implementation requires deeper and wider contemplation. Consequently, the authors also furnish the thesis with theoretical and practical implications, as well as suggestions for future research.

Keywords

Food retail supply chain, SCM, Blockchain, Malta, IBM Food Trust, Transparency, Traceability

ACKNOWLEDGEMENTS

Ups and downs, highs and lows, the journey of this thesis has finally come to an end. Had it not been for the priceless support of our nearest and dearest, it would have just scratched the surface leaving too many loose ends. We shall, therefore, take this opportunity to thank everyone who have stood by us during this venture.

First and foremost, we are extremely grateful to all of the teachers from Lahti University of Applied Sciences, especially our supervisor Miika Kuusisto and language supervisor Aria Kanerva, for the valuable feedback, constructive recommendations and dedicated instructions.

Our heartfelt appreciation also goes to B Company in Malta that has broadened our horizons with the precious internship experience and connected us with the surprisingly joyful, interesting and valued friends. Our busy summer in Malta, simultaneously working on thesis and doing internship, would not have been such an unforgettable memory without any of them.

We would as well owe a great debt of gratitude to John and Maria in Malta who have kindly lent us a helping hand with the process of data collection.

We are always ready to acknowledge our debt to our beloved estimable roommates and friends in Finland. The special thanks are reserved for AT and AT.

And last, but certainly not least, from the bottom of our hearts we wish to express our deep indebtedness to our parents. Thank you for your heart-warming encouragement, your enormous sacrifices and your boundless love. ♥

Sincerely,

Ha Nguyen and Linh Do.

CONTENTS

LIST OF ABBREVIATIONS

AI	Artificial Intelligence
API	Application Programming Interface
AVE	Average variance extracted
BEV	Blockchain-enabled E-voting
BI	Behavioral Intention
CEO	Chief Executive Officer
CPU	Central Processing Unit
CR	Composite reliability
CTO	Chief Technology Officer
EE	Effort Expectancy
EHR	Electronic Health Record
EIT	European Institute of Innovation and Technology
EU	European Union
EU27	All European Union Member States except the United Kingdom
FC	Facilitating Conditions
GPS	The Global Positioning System
GTIN	Global Trade Item Number
GVA	Gross Value Added
IBM	International Business Machines Corporation
IDT	Innovation Diffusion Theory
IOS	The International Organization for Standardization
IoT	The Internet of Things
IT	Information Technology
KWh	Kilowatt hour
LTE	Long Term Evolution
MITA	Malta Information Technology Agency
MPCU	Model of Personal Computer Utilization
MSV	Maximum shared variance
NE	Negative Experience
PC	Personal computer
PE	Performance Expectancy
PEU	Perceived Ease of Use
PEST	Political, Economic, Social and Technological
PKI	Public Key Infrastructure
PoW	Proof of Work
PoS	Proof of Stake
POS	Point of Sales
PU	Perceived Usefulness

R&D	Research and Development
R&I	Research and Innovation
RFID	Radio Frequency Identification
RQ	Research Question
SaaS	Software as a Service
SCM	Supply Chain Management
SI	Social Influence
SQ	Sub Question
TAM	Technology Acceptance Model
TRA	The Theory of Reasonable Action
TWh	Terawatt hour
UPC	The Universal Product Code
UTAUT	The Unified Theory of Acceptance and Use of Technology
SPSS	Statistical Product and Services Solutions
SWIFT	The Society for Worldwide Interbank Financial Telecommunication
WHO	World Health Organization

1 INTRODUCTION

The introduction chapter lays the very first brick to construct the whole thesis by addressing eight key issues, namely research background, objectives, research questions, limitations, theoretical framework, research methodology, data collection, and thesis structure. They are all designed to help readers acquire the panorama, as well as the rationale of the research to a certain extent.

1.1 Research background

Today in a globalized world, more and more business operations are spreading out internationally, and the volume of global trade gets boosted. Companies across all industries seek to gain competitiveness and improve supply chain efficiency through outsourcing, international sourcing and lean manufacturing practices. As a result, the number of entities involved in the supply network increases, amplifying the supply chain complexity. (Jahncke & Lee 2016, 2.) Not only does the supply chain grow in width (the number of tiers in the chain) but also in length (geographical locations). The more complex a supply chain is, the more effort is required to enhance visibility and transparency. The advent of the internet in the last century has partly solved this problem by making the cross-border flow of information smoother than ever. However, the way organizations manage contracts, transaction records, or other administrative tools that would hone visibility and transparency, is still lagging behind in the digital era (Iansiti & Lakhani 2017, 1).

While transparency remains as a headache for supply chain managers, blockchain technology shows up just in time, promising to get the problem solved. The technology underlying Bitcoin is believed to pose enormous influence on the economy, foundationally transform how businesses operate, which is similar to how the Internet has disrupted many industries in the past few decades. Indeed, many experts predict that blockchain is becoming the next generation of Internet (Iansiti et al. 2017, 5; Tapscott 2016).

Even though Bitcoin has still been an extremely controversial topic, rational opinions are placed more on the technology behind it. This cryptocurrency represents only the tip of the iceberg, as the operational mechanism for Bitcoin, i.e. blockchain, can accelerate a disruptive innovation in any fields, if applied. Gupta (2017, 3) defines blockchain as a shared, distributed leger recording lists of transactions.

There are several applications of blockchain in business operation and other areas which have been widely recognized, such as cryptocurrencies, smart contracts, and e-voting.

Therefore, it is certainly impossible for supply chain management to lie beyond the reach of blockchain. Laaper, Fitzgerald, Quasney, Yeh & Basir (2017, 6) argue that blockchain can increase the traceability and transparency of material supply chain, reduce losses from counterfeit or grey market trading as well as lower the cost of administration. In food retail industry, there are several leading corporations that have adopted blockchain in their business due to the importance of having solid records to trace each product to their origin. For example, Walmart keeps track of pork imported from China by employing blockchain. Thanks to the technology, they are aware of the source, processing, storage and selling date of the meat product. Blockchain is also used by Unilever, Nestle, Tyson and Dole for similar purposes. (Marr 2018a.) However, the capacity of blockchain for supply chain and food retailing has still left plenty of room for further investigation and development.

For empirical research, the authors select the Maltese food retail industry to examine the application of blockchain on its supply chain for three main reasons.

Firstly, being a small yet densely-populated island in the Mediterranean Sea, Malta has limited natural resources and land for agricultural production. The country's food production capacity merely accounts for less than a quarter of its food needs (Biasetti 2010, 2). Therefore, most of the food products are imported from overseas. This apparently indicates that food retailers in Malta need great visibility and transparency in its supply chain in order to ensure the smooth flow of food supplies on the island.

Secondly, according to the authors' initial observation on the Maltese food retail industry, the competition within the industry is extremely intense with a diverse range of food retailers, from street vendors to small local markets and larger supermarket chains. Efficient supply chain management would enable better customer service, and the adoption of blockchain technology has the potential to bring this competitive advantage to the companies.

Lastly, Malta is among the few countries where Bitcoin and blockchain are strongly advocated by the government. The country has the vision to become the "Blockchain Island" and even proposed a national strategy to promote blockchain (Cauchi 2017; Schembri 2018, as cited in Sanchez 2018). The government looks forward to implementing the technology in not only Fintech area but also other sectors such as public transportation, healthcare systems, land registry and so on (Sanchez 2018). The authors, therefore, believe that a study on blockchain's application on the Maltese food retail supply chain would ultimately contribute to the nation's prospect of becoming the pioneer in constructing a nationwide blockchain ecosystem.

1.2 Thesis objectives, research questions and limitations

Thesis objectives

The main objective of the research is to assess the feasibility of blockchain technology adoption in the Maltese food retail supply chain. Based on the assessment and analyses, the authors will also provide some suggestions for future research regarding this topic.

Research questions

After clarifying the objectives, the main research question (RQ) and sub-questions (SQ) are formed as below:

RQ: How feasible is it to adopt blockchain technology in the food retail supply chain in Malta?

- SQ1: What are the potential effects of blockchain on food retail supply chain?
- SQ2: How does the macro-environment affect the adoption of blockchain in food retail supply chain in Malta?
- SQ3: Do Maltese retailers intend to use blockchain application?
- SQ4: Do end-consumers of food intend to use blockchain application? What factors affect their intention to use?

Scope and limits

Firstly, the geographical scope of the research is narrowed down to the country of Malta. This is a fair geographical limit for the study due to the fact that Malta is a small nation with a population of fewer than half a million people, and there is no significant difference among its cities and villages culture-wise, economic-wise and social-wise. This means the findings can be generalized within this scope without substantially affecting the validity.

Secondly, the authors will focus only on the aspects concerning supply chains in the food retail industry, even though blockchain technology is also applicable in other business functions such as marketing or accounting, as well as in other industries.

Thirdly, in order to be as specific as possible in the empirical research, the blockchain technology will not be examined as a huge vague concept but it will be investigated through the representation of the IBM Food Trust platform, which is so far one of the most applicable practical implementations based on the fundamentals of blockchain.

Finally, the empirical research will only take into account the perspectives of the two major actors in the food retail supply chain, i.e. retailer and end-consumer. The viewpoints of the agriculture sector as well as the food processing sector will be reviewed in subchapter 4.2 based on the existing literature, yet they will not be examined empirically. This is because the supply network of food distributed on the Maltese islands is not limited to the domestic production but is widespread globally, not to mention that most of the food products are imported. Therefore, empirical research on these two supply chain actors would not add significant values to the final research results, thus are not necessary.

1.3 Theoretical framework

How feasible is it to adopt blockchain technology in the food retail supply chain in Malta?

Sub-question	Theory content	Content location
What are the potential effects of blockchain on food retail supply chain?	• Blockchain technology • Food retail supply chain • Blockchain-enabled food supply chain	Chapter 2, 3, 4
How does the macro-environment affect the adoption of blockchain in food retail supply chain in Malta?	• Macro-environment analysis (PEST)	Chapter 5
Do Maltese retailers intend to use blockchain application? Do end-consumers of food intend to use blockchain application? What factors affect their intention to use?	• Unified theory of acceptance and use of technology	Chapter 6

Figure 1 Theoretical Framework

Since the research attempts to explore the feasibility of a disruptive technology acceptance in a specific market, especially placed in the case that it has still been such an abstract notion to the vast majority, the theoretical framework, first and foremost, consists of the *fundamentals of blockchain technology* that are carefully discussed in Chapter 2. It acts as one of the two main pillars supporting the whole research.

The other theoretical pillar is the key theories associated with *food retail supply chain* in Chapter 3. The sketch of the complete supply chain, following by the concept of food retail used in the thesis will be drawn. It is also important to evaluate the contemporary pains of the food supply chain, along with the technology adoptions in grocery retailing.

Chapter 4 serves as the interchange of the two previous chapters, continuing with the theories of *blockchain-enabled food supply chain*. Accompanied by the theories in Chapter 2 and 3, it aims to answer the first research sub-question SQ1: What are the potential effects of blockchain on food retail supply chain?

The authors will also employ *PEST model* with modifications in Chapter 5 to examine the macro-environment in Malta, responding to the second sub-question SQ2: How does the macro-environment affect the adoption of blockchain in food retail supply chain in Malta?

In Chapter 6, the Unified Theory of Acceptance and Use of Technology (UTAUT) model will be employed as the base theoretical model for the retailer analysis and end-consumer analysis. SQ3: Do Maltese retailers intend to use blockchain application? and SQ4: Do end-consumers of food intend to use blockchain application? What factors affect their intention to use? will be answered after these two analyses. An illustration of the theoretical framework is shown in Figure 1.

1.4 Research methodology and data collection

Research methodology and data collection are indispensable for researchers in order to systematically unravel the research questions (Kothari 2004, 8). If research methodology is regarded as an action repertoire based on the structural logic of the research and research questions, data collection assumes the responsibility of gathering data to answer the research questions (Jonker, Pennink & Bartjan 2009, 22; Bryman & Bell 2015, 14). According to the “research onion’’ by Saunders, Lewis and Thornhill (2007, 132), there are six elements formulating the methodology: techniques and procedures, time horizons, choices, strategies, approaches and philosophies. In the scope and purpose of this thesis, the authors decide to simplify the model into 3 layers: research approach (approaches), research method (choices), and data collection (techniques and procedures), which are illustrated in Figure 2.

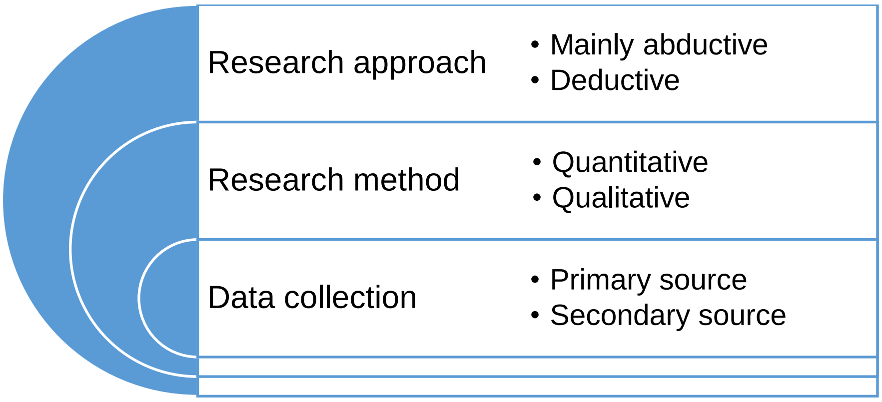

Figure 2 Research methodology of the thesis

Research approach: mainly abductive, deductive

Traditionally, there are two opposing research approaches originating from the reasoning behind the empiricist and rationalist: inductive and deductive respectively. Whilst empiricism acquires knowledge through sensory experience, rationalism is knowledge gained by reasoning. (Walliman 2011, 17-19.) More specifically, induction happens when the theory is developed after the data have been collected (repeated observations lead to conclusions). In sharp contrast, deduction is indicated by the discussion of theory prior to the collection of data (General statement leads to conclusion). (Saunders et al. 2007, 38.) To put it another way, no theories are applied in the beginning of an inductive study, allowing the researcher to unlimitedly modify the direction of the research (theory comes last), whereas theories would be reviewed first in a deductive study (theory comes first).

However, there still exists the third mode - abductive approach, which is invented by Charles S. Peirce (Niiniluoto 1999, 436). Abduction is conceptualized as the form of reasoning through which humans perceive an observation as related to other observations and shifts back and forth between the researcher's own data, experience, and broader concepts (Tavory & Timmermans 2014, 37; Coffey & Atkinson 1996, as cited in Mason 2002, 180-181). Table 1 delineates the differences between three approaches: inductive, deductive and abductive.

The abductive approach will be predominantly applied in this research as it is regarded as appropriate to evaluate new or unknown situations and develop new understandings, which aptly fits the objectives of this thesis (Richardson & Kramer 2006, 500).

Table 1 Differences between three approaches: inductive, deductive and abductive (Tavory et al. 2014, 36-37)

	Inductive	**Deductive**	**Abductive**
Process	Rule → Case → Result	Case → Result → Rule	Result → Rule → Case
Proposition	The proposition is assumed before the fact.	The proposition is observed.	The proposition is guessed at, presumed after the fact.
Conclusions	Generalization	Corroboration or falsification	Suggestions (for future directions / paradigm / tool / theory)

The authors first review relevant theories about blockchain, food supply chain, etc. Based on the initial observations, a presumption is formed as below:

It can be feasible to adopt blockchain in food retail supply chain in Malta.

After that the case is studied in depth. The empirical findings are used to verify the presumption to a certain extent, but not at an absolute level. Finally, the authors will arrive at conclusions, which are followed up by suggestions for future research directions. In addition, deductive approach is to be employed particularly in the end-consumer analysis.

Research method: mixed method – quantitative and qualitative methods

Basically, quantitative and qualitative methods are widely mentioned as two paradigms of research methods (Jonker et al. 2009, 38). The former is broadly described as involving the series of numerical data and as linking the chain of theory and research as deductive, whereas the latter works with words rather than numbers and conveys an inductive viewpoint of the relationship between theory and research. However, in many methodological issues the status of the distinction between the two methods is found to be ambiguous. (Bryman et al. 2015, 37, 159 & 391.) In addition, mixed methods appear as the general terms for the combination of both quantitative and qualitative methods in a research design, which potentially give a more thorough and multifaceted grasp of the research content (Saunders et al. 2007, 145-146.)

A mixed methodology of both quantitative and qualitative methods is used in the thesis on the grounds of its explorative nature. Firstly, the authors employ qualitative methods to evaluate the viewpoint of food retailers in Malta in answer to the third sub-question SQ3:

Do Maltese retailers intend to use blockchain application? Statistical techniques supported by IBM SPSS Statistics 23 and Excel Data Analysis will be employed with further details presented in Chapter 6. Secondly, quantitative methods are applied to the analysis of Maltese end-consumers' perspective on the adoption of blockchain in food supply chain, offering a panoramic vision to the fourth sub-question SQ4: Do end-consumers of food intend to use blockchain application? What factors affect their intention to use?

Data collection: primary and secondary sources

Having finished defining the research problem, the research approach and the research method, there begins the task of data collection, the key point of any research project (Kothari 2004, 9). There are two types of data: primary and secondary. What is "observed, experienced or recorded close to the event" is called primary data. Four basic types of primary data include: measurement, observation, interrogation and participation. Secondary data refers to data that are "interpreted and recorded" and that can be illustrated by the written sources from, for example, newspapers, documentaries and the Internet. (Walliman 2011, 69-71.)

In the context of this thesis, both secondary and primary sources will be used to collect data. Primary empirical data are synthesized using three techniques. First, the authors create and send out a questionnaire with open-ended questions to food retailers and distributors in Malta. Second, an internet survey is distributed to the Maltese residents to examine their views as the end-consumers of the food supply chain. Third, face-to-face interviews are carried out on street with random pedestrians. As for secondary data, the authors retrieve the information from published books, white papers, reliable reports and certified internet sites.

1.5 Thesis structure

This thesis is mainly composed of two key foundations, namely theoretical base and empirical research. The detailed structure is presented in Figure 3.

Chapter 1 outlines the skeleton of the research: thesis background, thesis objectives, research questions, limitations, theoretical framework, and research methodology and data collection.

Chapter 2, Chapter 3 and Chapter 4 assume the responsibility of theoretical basement to answer the first research sub-question SQ1: What are the potential effects of blockchain on food retail supply chain?

An introduction to blockchain appears in Chapter 2 to provide the readers with the significant facets of blockchain: its definition, generic elements, key concepts, operating mechanism, taxonomy, costs, benefits and limitations and several typical applications of blockchain. Chapter 3 deals with the issues of the food retail supply chain, discussing the concept and formats of retail and food retailing, supply chain management, food supply chain, current matters in the food supply chain and finally, technology adoption in the field. Serving as a cross-border between the two previous chapters, Chapter 4 looks at the blockchain paradigm in the food supply chain, then addresses the impacts of blockchain on the food supply chain and moves on with the area's status quo of the adoption of blockchain.

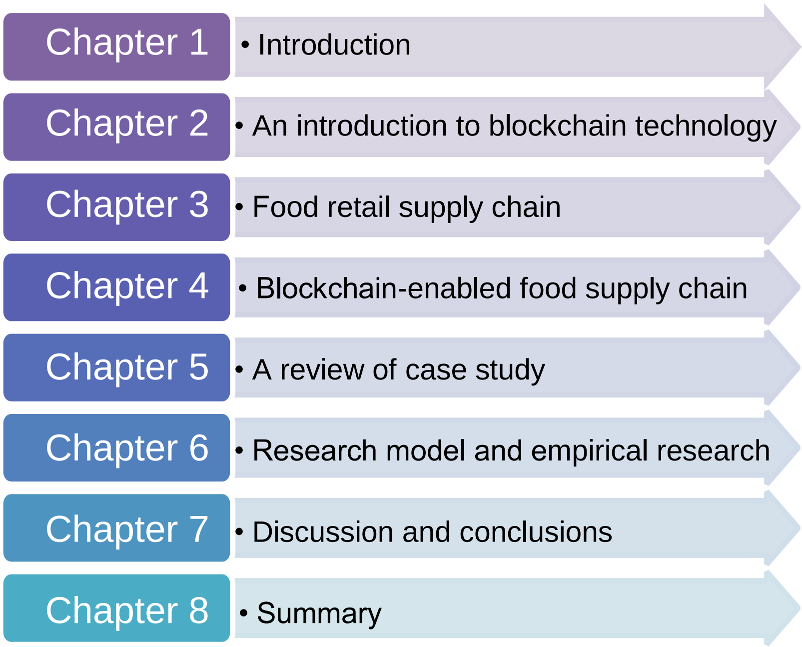

Figure 3 Thesis structure

Chapter 5, which includes the answer to the second sub-question SQ2: How does the macro-environment affect the adoption of blockchain in food retail supply chain in Malta? is a meticulous review of the thesis's case study. It first introduces IBM Food Trust, the blockchain-based platform that the authors choose to specify the case study. Second, an analysis of the macro-environment in Malta and the Maltese food supply chain is presented.

Chapter 6 is built of research model and empirical research. After examining the theories of Technology Acceptance to opt for the most suitable analyzing model, the authors will separately conduct two analyses of distribution sectors and end-consumers. It aims to provide the responses to the third and fourth sub-questions SQ3: Do Maltese retailers intend to use blockchain application? and SQ4: Do end-consumers of food intend to use blockchain application? What factors affect their intention to use?

Chapter 7 not only signifies an ending to thesis but also recommend for future research. Starting with the answers to the research question, the authors then shift to theoretical and practical implications. Subsequently, the reliability and validity is covered. Last but not least, several constructive suggestions are put forward for future studies.

Chapter 8 is the summary of the whole thesis.

2 INTRODUCTION TO BLOCKCHAIN TECHNOLOGY

This chapter aims to give a comprehensive viewpoint on blockchain technology as a base for understanding its adoption in food supply chain. After subchapter 2.1 lays the foundation for the knowledge about blockchain, subchapter 2.2 gives a more thorough insight into the important characteristics of the technology. The taxonomy of blockchain will be viewed in terms of tier and type in subchapter 2.3 while subchapter 2.4 takes care of the matter of operation costs. Subchapter 2.6 will weigh up the pros and cons of blockchain. Finally, subchapter 2.7 is the practical picture of blockchain.

2.1 Overview on blockchain

> *The blockchain cannot be described just as a revolution. It is a marching phenomenon, slowly advancing like a tsunami, and gradually enveloping everything along its way by the force of its progression. (Mougayar 2016, 12.)*

Undoubtedly, this tsunami-like influx has been seen attacking almost every corner of life and blowing the wind of changes. “If the blockchain has not shocked you yet, I guarantee it will shake you soon” (Mougayar 2016, 12). A number of questions arise as to what blockchain stands for, when it was born, why it exists and how it can shake every single person. The part Overview on Blockchain helps to answer some of the questions by giving the definitions and the brief history of this technology.

2.1.1 Definitions of blockchain

In recent years the definition of blockchain has not varied dramatically. Blockchains are a transparent and decentralized way of recording transactions (Boucher, Nascimento & Kritikos 2017, 4). This definition lies at the broadest level and can be further cleared by Lewis (2016, 5). He points out that what blockchain records is not simply transactions but a network of databases, which is spread across multiple entities kept in sync. If being decentralized means there is no single owner or controller of the data, being transparent is referred to appending-only: the data can be added and written to, but there is no way to alter historical data without the approval of the network’s participants. (Lewis 2016, 5.)

However, blockchain was originally divided into two different words as block and chain or chain of blocks before evolving into one single word as it is today. These terms first appeared in the paper *Bitcoin: A Peer-to-peer Electronic Cash System* by Satoshi Nakamoto, a pseudonym who is believed to be the father of Bitcoin and blockchain. (Bashir 2017, 9.) Since Nakamoto focuses on introducing Bitcoin, a purely peer-to-peer version of electronic cash and explaining the characteristics of this cryptocurrency, there is no exact definition of blockchain found in the paper of Nakamoto. Nevertheless, numerous striking blockchain-related features are mentioned. He indirectly defines chain by stating that an electronic coin is a chain of digital signatures. In addition, a block refers to a block of items to support the work of a timestamp server, which hashes transactions into an ongoing chain of hash-based proof-of-work. The longest proof-of-work chain is accepted as proof of what happened when nodes were gone. (Nakamoto 2008, 1-2.) Based on these depictions of Bitcoin's foundation, blockchain can be defined as peer-to-peer electronic transactions and interactions using cryptographic proof without a trusted third party or a central institution (Mougayar 2016, 18).

Mougayar (2016, 18) also takes a further step by giving three different field-specific definitions of blockchain, namely technique, business and legal matter. Technically, blockchain is equivalent to a back-end database with the responsibility of maintaining a distributed ledger that can be inspected openly. In the context of business, blockchain represents an exchange network for transferring transactions, values and assets between peers (participants) without intermediaries' involvement. Legally, blockchain is a transaction validation mechanism, replacing the role of trusted entities. (Mougayar 2016, 18.)

In general, no matter how the blockchain is viewed, the key features that form the definition of blockchain are a distributed ledger, being decentralized without intermediaries, recording of transactions (blocks) and tracking assets. Despite being initially built as a foundation for Bitcoin, blockchain, the authors highly believe, has gradually separated to become a disruptive innovation thanks to these breakthrough characteristics.

2.1.2 Brief history of blockchain

The blockchain traces its history back to 2008 with the release of the paper entitled *Bitcoin: A Peer-to-peer Electronic Cash System* by Satoshi Nakamoto. Rumor has it that the author's name is actually a pseudonym used by an individual or group whose real identity still remains unknown to public. (Crosby, Nachiappan, Pattanayak, Verma & Kalyanaraman 2015, 5.) Due to the close relation between Bitcoin and blockchain, hardly can the authors discuss the history of blockchain without having a look at the timeframe of Bitcoin. Table 2 shortly describes the important phases of Bitcoin from 2008 to 2009.

Table 2 Important dates of Bitcoin from 2008 to 2009 (Crosby et al. 2015, 5)

August 18, 2008	Domain bitcoin.org registered
October 11, 2008	Bitcoin design paper published
November 9, 2008	Bitcoin project registered at SourceForge.net
January 3, 2009	Genesis block established
January 9, 2009	Bitcoin version 0.1 announced on the cryptography mailing list
January 12, 2009	First Bitcoin transaction, in block 170 from Satoshi to Hal Finney

Markedly, it is just one decade since the dawn of the recorded history of Bitcoin and blockchain. Over the past ten years there have been five major blockchain-related innovations that have imposed a great impact on the way people live and work. The first innovation, as shown in the Table 2, was Bitcoin, a digital currency experiment. The second innovation was blockchain, which was basically the underlying technology that operated Bitcoin. Even today many a person consider Bitcoin and blockchain to be one single concept, the realization that blockchain could be utilized for more than cryptocurrency dawned on several individuals, companies and organizations in around 2014. The third innovation was named “smart contract”, embodied in a second-generation blockchain system called Ethereum, allowing financial instruments, like loans or bonds, to be represented. The fourth innovation is “proof of stake”, which is expected to go live in late 2018. It has the potential for substituting “proof-of-work” by replacing data centers with complex financial instruments. The fifth major innovation on the horizon is blockchain scaling. It is hoped that a scaled blockchain runs at a satisfactory speed to power the internet of things and to be a rival to the major payment middlemen (VISA and SWIFT) of the banking world. (Gupta 2017; Marr 2018b.) In the context of food supply chain, the thesis mainly concentrates on the second innovation.

All of these innovations form the fifth disruptive computing paradigm. The four preceding paradigms, which arose on the order of one per decade, are the mainframe, PC (personal computer), the Internet, and mobile and social networking. (Swan 2015, xi.)

Being one of the disruptive innovations, blockchain is believed to radically transform the world as its predecessors. The technology is just at the dawn of history and promises to bring an even more complete revolution in the near future.

2.2 Fundamentals of blockchain technology

In spite of being alive for only ten years, blockchain has already entailed such a wide variety of complex features that it is extremely hard to cover every single concept of blockchain. Thus, this part aims to include blockchain's key principles that are necessary for the implication of the technology in food supply chain. These principles are divided into four categories: generic elements, key concepts, operating mechanism and security and privacy.

2.2.1 Generic elements

This section presents four basic critical elements that lay the foundation for the implementation of almost every blockchain system. They are called transaction, block, node, and peer-to-peer network.

Transaction

According to Bashir (2017, 19), a transaction indicates a transfer of value from one address (identifier) to another. The transferred value is not only finance-related but also any information and data created and owned by users. There are two contracting parties involved in a transaction with a view to exchanging a digitally recordable asset such as data, money, and contracts between themselves (Seffinga, Lyons & Bachmann 2017, 9).

Block

A block is constructed by multiple transactions and several other factors, for example block hash and timestamp (Bashir 2017, 20). A block hash (hash pointer) is a digital fingerprint or unique identifier with a fixed-length output. The blocks are linked together by the previous block hash. (Gupta 2017, 14.)

In terms of timestamp, it proves the existence of the data at the time in order to get into the hash by including the previous timestamp and forming a chain with each additional timestamp reinforcing the ones before it (Nakamoto 2008, 2).

Node

There are various functions that a node can perform depending on different positions. It assumes the responsibility for proposing and validating transactions as well as performing mining in order to facilitate consensus and secure the blockchain. Other roles that a node might be assigned to are simple payment verification and validators. (Bashir 2017, 21.) A network might have multiple types of nodes, such as a full node and a lightweight node. While the former is able to store a full local copy of the replicated ledger and apply all consensus mechanism rules to proposed transactions, the later can only store a subset of data from the ledger. (Nelson 2017, 13.)

Peer-to-peer network

This network topology is one of the critical bones that form the skeleton of blockchain. The name implies that peers in the network can directly communicate with each other and exchange messages (Bashir 2017, 21). A peer contemporaneously acts as a client (requestor) and a server (provider) to share and access resources directly from the others (Steinmetz & Wehrle 2005, 36; The Government of the HKSAR 2008, 3).

2.2.2 Key concepts

Developing from these generic elements, the key concepts explained in this section are central principles which empower the operation of blockchain technology. Due to the scope of this thesis, only four key concepts are chosen for discussion, including distributed ledger, consensus, cryptography and smart contracts. Once the knowledge has been acquired, the burden of understanding blockchain's application for food supply chain might be reduced.

Distributed ledger

Blockchain is regarded as a type of distributed ledger, which can record transactions between parties securely and permanently (The World Bank 2018a; Kückelhaus, Chung, Gockel, Acar & Forster 2018, 3). Hancook and Vaizey (2016, 5) also state that the "block chain" is what underlies distributed ledger technology when invented to create the peer-to-peer digital cash Bitcoin in 2008. Therefore, it is essential to comprehend the terminology of distributed ledger to help unravel the mystery of blockchain. Despite the intense relationship and being often used interchangeably, blockchain and distributed ledger are distinct – though subtly different technologies (Rutland 2017, 2). If blockchain is composed of a shared and replicated ledger with information stored in blocks, distributed ledger is a record of consensus with cryptographic audit trail which are maintained and validated by nodes. A significant point is that a distributed ledger can be either decentralized or centralized. Thus, "a blockchain is a way to implement a distributed ledger, but not all distributed ledger necessarily employs blockchains". (Rutland 2017, 2-3.)

Thanks to the power of a distributed ledger, every single participant in the blockchain possesses a simultaneous access to a view of the information (Eckert, Loop & Berlin 2018, 2). Tapscott and Tapscott (2016, 49) shed the light on this feature of distributed ledger by clarifying the principle of distributed power. The power is distributed across a peer-to-peer network without a single point of control, which means that no single party can bring the system to a halt. Even when an individual or group is blacked out or cut off by a central authority, the system still survives. (Tapscott et al. 2016, 49.)

When it comes to distributed ledger, centralized and decentralized system are usually used to draw comparisons. Figure 4 gives a visual illustration of these three ledgers.

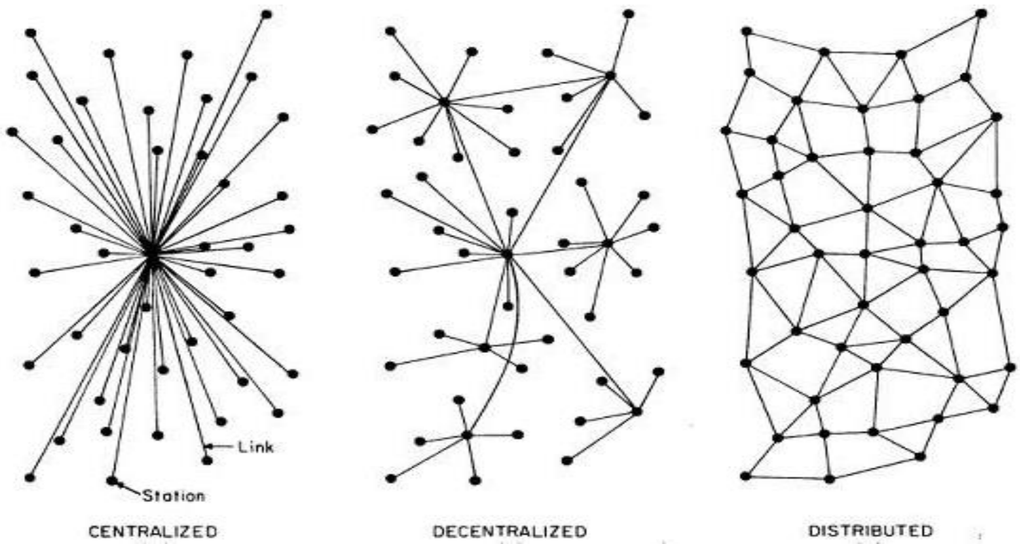

Figure 4 From a centralized to a decentralized and distributed ledger (Kückelhaus et al. 2018, 3)

Central ledgers have existed for centuries. A trusted middleman with the total control over the whole system is employed to mediate every transaction. The functioning of the ledger and the data is not fully visible to every user in a centralized ledger. In contrast, decentralized and distributed ledgers, which run blockchain, erase the appearance of the middleman and give the participants the data-accessing right. However, there comes a subtle difference between decentralized and distributed systems and moreover, “a decentralized system is a subset of a distributed system”. Regarding decentralization, there is no decision-making single, but every node makes a decision for its own behavior and the resulting system behavior indicates the aggregate response. On the other hand, being distributed means that the processing is shared across a number of nodes, but the decisions may still be centralized and use complete system knowledge. (Eagar 2017.)

Consensus

Blockchain's distributed ledger puts an important question about the matter of trust or verification of the transactions as no central authority is hired to control the activities of the participants. It is the consensus algorithms, or "decentralized consensus" that is used to solve the problem. To put it another way, blockchains are built on consensus-forming protocols determining the next block of data added in the chain (Finlow-Bates 2017, 1). Basically, consensus is a distributed computing concept as a means of agreement to a single version of truth by all peers in the blockchain (Bashir 2017, 28).The right to update the network's status or, literally, to vote for the truth is divided securely by the consensus algorithm, which transfers the authority and trust to all members and enables the nodes to continuously and sequentially record transactions (Tapscott et al. 2016, 47; Mougayar 2016, 43).

To achieve consensus, blockchain uses "proof-of-work" (PoW) mechanism, as illustrated in Figure 5. The terminology was first mentioned by Satoshi (2008, 3) together with the introduction of Bitcoin. The PoW involves scanning for a value beginning with a number of zero bits when hashed. It is implemented by incrementing a nonce in a block until the block's hash reaches the required zero bits. Once the CPU has expended all the efforts on satisfying the PoW, it is impossible to change the block without redoing the work. Moreover, PoW is essentially one-CPU-one-vote, which determines representation in majority decision making. The longest chain with the most strenuous proof-of-work effort will indicate the majority decision. (Satoshi 2008, 3.)

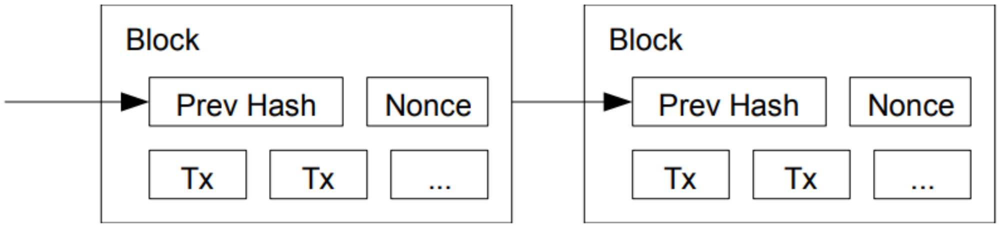

Figure 5 The proof-of-work consensus in blockchain (Satoshi 2008, 3)

PoW is the consensus mechanism used by Bitcoin at the dawn of blockchain. As time has gone by, a new mechanism called "Proof-of-stake" (PoS) was born with the development of Ethereum, a blockchain-based digital cash after Bitcoin. Miners using PoS are required to invest in and hang on some store of value. Hardly do they need to spend energy on votes. (Tapscott et al. 2016, 48.)

Apart from PoW and PoS, two main consensus mechanisms, several algorithms have been created, for example Proof of Elapsed Time, Proof of Activity, and Proof of Capacity.

Proof of Elapsed Time helps provide randomness and safety in the leader election process. Proof of Activity is a combination of PoW and PoS, requiring an unknown number of miners sign off on the block using a cryptokey. Proof of Capacity compels miners to allot a considerable volume of the hard drive to mining. (Bashir 2017, 29; Tapscott et al. 2016, 48.)

Cryptography

After the question of consensus in distributed ledger arises another matter of concern called security, and cryptography is the answer. It is the science of making information secure in the presence of adversaries. Data is encrypted using ciphers with a view to making data meaningless when intercepted by an adversary. It is compulsory to possess a secret key to decrypt the coded data (Bashir 2017, 51.) There are two types of cryptography: symmetric and asymmetric. In the former, the key used to encrypt the data is similar to the one for decrypting the data, which is a reason why this technology is also named as a shard key cryptography (Bashir 2017, 57). The latter is known as asymmetric cryptography, or public key cryptography. In contrast to symmetric type, the keys to encrypt and decrypt the data are different. It uses a pair of keys, namely public key and private key that are mathematically related to each other. The public key is likely to be open to public without eliminating the security of the process while the private key is required to remain strictly confidential provided that the data is to retain its cryptographic protection. (Bashir 2017, 66; Yaga, Mell, Roby & Scarfone 2018, 13-14.)

There are various security services provided by cryptography, such as confidentiality, integrity, authentication and non-repudiation. Confidentiality assumes the responsibility to assure that only authorized entities have the access to the information. Integrity means that the information is modifiable only by authorized entities. Authentication takes charge of verifying an identity or the validity of a message. Non-repudiation guarantees that a previous commitment or action is undeniable for an entity by providing unforgettable evidence. (Bashir 2017, 53-54.)

Smart contracts

The last key concept of blockchain is smart contracts. As a matter of fact, this is not a nascent concept but has held an increased attraction with the advent of blockchain. A smart contract is defined as a collection of code and data deployed to a blockchain (Yaga et al. 2018, 35). More specifically, “a smart contract is a secure and unstoppable computer program representing an agreement that is automatically executable and enforceable” (Bashir 2017, 199). Thus, the transaction fees in a smart contract based system are promised to be considerably lower than that of the traditional middleman-trusted system (Alharby & Moorsel 2017, 127).

An address with 20 bytes is assigned to each contract and unchangeable once the contract is deployed into the blockchain. After users send a transaction to the address to run the contract, the transaction is executed by every consensus node (miner) to reach an agreement on its output. The status of the contract is able to be updated accordingly. Based on the transactions received, the contract reads or writes to its own private storage or even create a new contract. (Alharby et al. 2017, 218.)

Smart contracts can be divided into two different types: deterministic and non-deterministic smart contracts. A deterministic smart contract does not require any information from an external party outside the blockchain system. In contrast, a non-deterministic smart contract depends on information (called oracles or data feeds) from an external party. (Morabito 2017, 101-124, as cited in Alharby et al. 2017, 218.)

2.2.3 Operating mechanism

This section aims to give a brief depiction of the blockchain operation based on the key features mentioned in the previous parts. Initially, participating entities need to install and activate some software connecting their server and computer to other participants in order to be a part of a blockchain network. The participants play a role as individual validators, called network nodes. (Lewis 2016, 13.)

When a node gets connected to the network for the first time, a full copy of the blockchain database is downloaded onto its own computer or sever. After the download is completed, the network of nodes takes responsibility for managing the database, known as the blockchain. The nodes represent entry points for new data together with the validation and propagation of new data. The next step concerns the consensus of the network by using protocols. A blockchain system will include protocol, such as pre-agreed rules for technical and business validity of data and a rule of consensus achievement. After that, identical transactions fall into the same category to found blocks, which are added chronologically in a way that resembles a chain. The newly-created blocks are then stored by the nodes on the local blockchain database on their computer/server. (Lewis 2016, 13-14.)

Kückelhaus et al. (2018, 5) give a more practical example by illustrating a blockchain financial transaction in Figure 6.

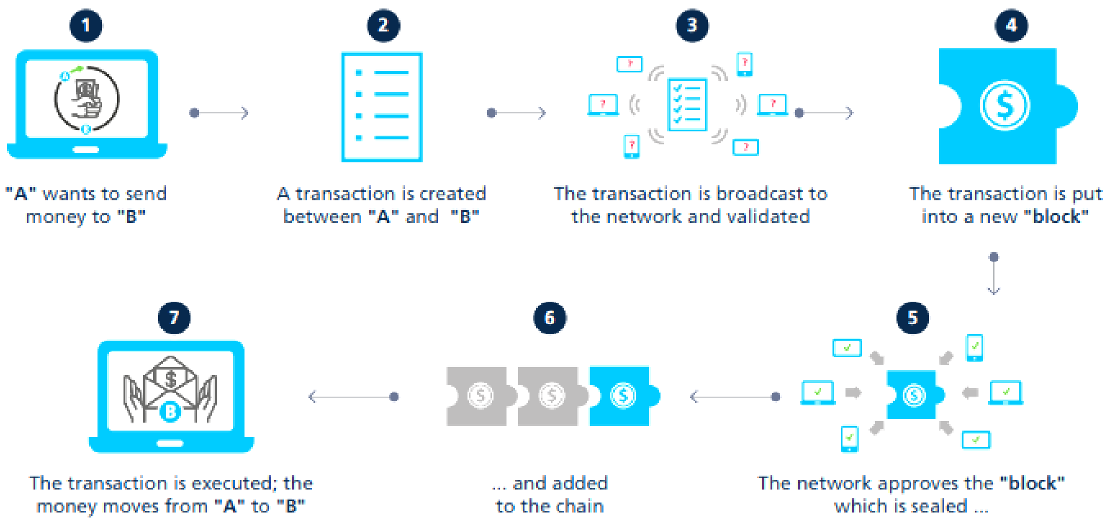

Figure 6 Illustration of a blockchain transaction (Kückelhaus et al. 2018, 5)

Other types of assets transfer, such as data and information, are traceable by using a similar process to commit new data to a blockchain and to update data in a blockchain (Kückelhaus et al. 2018, 5).

2.2.4 Security and privacy

Over the past few years, the issues of security and privacy have been addressed serious questions due to the outburst of the Internet age and the manipulation of giant middlemen such as Google and Facebook. Blockchain, with its outstanding features such as decentralization and the elimination of intermediaries, promises to bring a new perspective on the matter. People also articulate grave concern about the security and privacy of this technology.

Security

According to Hancook et al. (2016, 47), security can be simply defined as “Things that should happen, do; and things that shouldn’t happen, don’t.” As a matter of principle, safety measures are embedded in the network without failure. Not only confidentiality but also authenticity and nonrepudiation are provided in every single activity. Besides, cryptography is mandatory for any participants. (Tapscott et al. 2016, 54.)

The first era of the Internet has still left numerous security problems such as identity theft, hacking, malware, and spam. By using public key infrastructure (PKI), a kind of asymmetric cryptography, to establish a secure platform, blockchain promises to solve these remaining problems and increase safety standards. Cryptokeys to data are kept by users and transact directly with one another, leading to the responsibility of keeping one’s private keys private. Thus, with a more secure design and transparency, blockchain helps make transactions of value and protect the activities of data. (Tapscott 2016, 54-56.)

Privacy

Privacy is a difficult notion to completely explain with a variety of different definitions. To put it the simplest way, privacy is called “the right to be let alone”. More specifically, privacy refers to “the right to maintain a certain level of control over the inner spheres of personal information and access to the body, capacities and powers”. (Moore 2008, 412-420.) Considering the principle of privacy in the Internet world, Tapscott et al. (2016, 56) emphasize that people “should control their own data” and “ought to have the right to the right to decide what, when, how, and how much about their identities to share with anybody else.”

Over the past twenty Internet years, central databases have amassed almost every sort of confidential information of individuals and institutions even, sometimes, without their knowledge. On the contrary, there is no prerequisite for personal identity in blockchain. Additionally, the identification and verification layers operate separately from the transaction layer, indicating that no reference to anyone’s identity in the transaction is needed. Moreover, it is possible for blockchain users to choose to maintain a degree of personal anonymity without the attachment of any other details to their identity or the storage in a central database.

Blockchain markedly designs higher levels of transparency and promotes opportunities for companies to tell the truth to their customers, shareholders and business partners. (Tapscott et al. 2016, 57-59.)

2.3 Taxonomy of blockchain technology

This subchapter digs deep into the classification of blockchain technology. Basically, in terms of categorization, only different types of technology are taken into consideration. However, the subchapter would provide a new perspective by not only examining the types but also the tiers of blockchain technology.

2.3.1 Tiers of blockchain

The tiers specifically mean the classification based on the technology’s chronological revolution and application (Bashir 2017, 24). The original concept was described by Swan (2015, ix) with three different layers, namely Blockchain 1.0, 2.0 and 3.0. Two years later, Bashir (2017, 24) added the fourth generation of blockchain called Tier X or Generation X, which hopefully would become a reality with the advancement of the blockchain.

Blockchain 1.0

Blockchain 1.0 is directly currency and the deployment of cryptocurrencies in applications related to cash (Swan 2015, ix). It is not a challenge to reason when tracing the blockchain back to its history in 2008 with the introduction of Bitcoin, a digital cash, by Satoshi. Obviously, currency and payments form the first and foremost application. Bitcoin and all alternative digital cashes such as Ethereum and ripple fall in to this category. (Swan 2015, 5; Bashir 2017, 25.)

Blockchain 2.0

Due to the capacity of cryptocurrencies for decentralization and distributed system, Blockchain 1.0 has already been extended into Blockchain 2.0 in order to utilize the most robust functionality of the digital coins. If Blockchain 1.0 is used for the decentralization of money and payments, Blockchain 2.0 implements the decentralization of markets and contemplates the transfer of various other kinds of assets (Swan 2015, 9). Blockchain 2.0 refers to contracts, applications in financial services, which includes multiple assets, for instance derivatives, bonds, swaps and options, and even applications beyond currency, finance and markets (Bashir 2017, 25). There are several popular Blockchain 2.0 illustrations, including Escrow transactions, crowdfunding, smart properties and smart contracts, to name but a few (Swan 2015, 10-16).

Blockchain 3.0

Whereas Blockchain 1.0 and 2.0 are directly related to monetary markets and finance, the development of Blockchain 3.0 strongly proves that it can go further than the initial purposes and the preconceptions about the technology. Blockchain 3.0 is defined as blockchain applications in the areas of government, health, science, literacy, justice, culture and art (Swan 2015, ix). For example, OneName and BitID use blockchain-based digital identity services. Monegraph is a digital-art protection project based on the blockchain ledger Bitcoin 3.0. Moreover, blockchain-based governance systems are able to offer a range of traditionally governmental services with users – citizens opting in and out at will. (Swan 2015, 34-46.)

Generation X (Blockchain X)

This term is actually a vision of blockchain singularity with a public blockchain service like Google search engine conceptualized by Bashir. He describes the next blockchain generation as “a public open distributed ledger with general-purpose rational agents”. The system operates on blockchains to make decisions and interacts with other intelligent autonomous peers on behalf of humans and manipulated by codes rather than laws or paper contracts. (Bashir 2017, 25.)

2.3.2 Types of blockchain

Currently blockchain is divided roughly into three different types: public blockchain, private blockchain and consortium (or federated) blockchain (Buterin 2015). These types would be examined in this section.

Public blockchain

Public blockchains, as the name drops a hint, are open to public so that anyone can join the system as a node in the decision-making process. All records are set in a visible status. (Bashir 2017, 26; Zheng, Xie, Dai, Chen & Wang 2017, 559.) Read access and ability to create transactions are granted to all users to let users transfer value without the expressed consent of blockchain operators (BitFury Group 2016, 2). Public blockchains are also known as permissionless ledgers where all users maintain a copy of the ledger on their local nodes and a distributed consensus mechanism is employed to agree on the eventual stage of the ledger (Bashir 2017, 26). Bitcoin blockchain and Ethereum blockchain can be quoted as two prime examples of public blockchains (Nelson 2017, 4).

Private blockchain

Contrary to public blockchain, private blockchain “limits read access to the predefined list of entities”, for example blockchain operators and auditors. It is necessary that end users depend on interfaces provided by operators to read and submit transactions. (BitFury Group 2016, 2.) By restricting the network-accessing rights, participants are all known and trusted, leading to the omission of many mechanisms, replaced with legal contracts (Lewis 2015, 6). Hyperledger fabric indicates a popular private blockchain (Nelson 2017, 4).

Consortium/federated blockchain

While private blockchains are considered to be a centralized network due to being fully controlled by one single organization, consortium (or federated) blockchains are constructed by several organizations and therefore, are partially decentralized. The consensus in the system would be determined by only a small portion of nodes. (Zheng et al. 2017, 559.) There are several major consortia in existence today: the Enterprise Ethereum Alliance, Ripple, and R3 (CB Insights 2017, 22).

Comparisons among public, private and consortium blockchain

Despite some overlapping attributes such as decentralized peer-to-peer networks, replicas in sync and the immutability of the ledger, the differences do exist among three types of blockchain (Jayachandran 2017).

Consensus determination possibly indicates the first difference. Each node in public blockchain gains permission for participating in consensus process while only a selected set of nodes assume the responsibility for block validation. In private systems, it is just one organization that fully controls and determine the final consensus. (Zheng et al. 2017.) The mechanism used for consensus in public chain requires solely difficult proof-of-work whilst there are a variety of possible consensus mechanisms for permissioned blockchain (private and consortium) (Natarajan, Krause & Gradstein 2017, 12).

The second comparison that cannot be overviewed is the openness and accordingly, level of trust. Since anyone is able to join the public systems, the ledger is open, transparent and shared between all members, who are pseudonymous or anonymous. Thus, it is not compulsory for network members to trust each other. Conversely, the participants in permissioned blockchain are pre-selected with different degrees of openness and transparency of the ledger. Due to the fact that the collaboration between members can alter the ledger, a higher degree of trust is required among members in permissioned networks. (Natarajan et al. 2017, 12; EQM Indexes Llc. & Emerita Capital Indices Inc. 2018, 6.)

Efficiency and speed form the third comparative elements. Tampering transactions in a public blockchain is nearly impossible due to a mass of participating records but an easy task in a private or consortium system. The large number of nodes in public blockchains also restrict the speed as well as the volume of transaction processing in the network, which is opposite to the high transaction throughput and low latency in permissioned systems. (Zheng et al. 2017, 559; EQM Indexes Llc. et al. 2016, 6.)

The last point is related to the assets of the blockchain types. As for public blockchains, the asset is typically native cryptocurrencies. However, the implementations are possible if a token is used to represent any asset. Meanwhile, it is likely for private and consortium blockchains to accept any kinds of assets. The fact that there is no ownership of assets in a public blockchain is a matter of legal concern compared to a greater legal clarity over ownership in a permissioned ledger. (Natarajan et al. 2017, 12.)

2.4 Cost considerations

Hardly can cost-related details of blockchain be provided comprehensively, meticulously and precisely in that the nascent technology is still on the threshold of development and implementation. The limited sources notwithstanding, this subchapter would attempt to give a gentle depiction of possible blockchain pricing as the financial issue plays an important role in the adoption of any technologies. The authors choose to examine initial costs and maintenance costs, among multiple types of involved expenses, due to their relevance and practicability.

2.4.1 Initial costs

Initial costs are the starting capital to build a blockchain system. Officially, not a single precise number has been calculated, but most of the perspectives argue on the side of tremendous blockchain-constructing fees. Baruri (2016, 7) states that the high initial capital costs of blockchain, which indicates a major concern for banks, are likely to be a deterrent to its implementation. Regarding the challenges of blockchain's performance, Vysya and Kumar (2017, 10) even emphasize that the prohibitive initial capital costs required by the adoption of blockchain does not necessarily ensures the scalability of blockchain applications.

In addition, it is advisable that companies weigh the potential yet uncertain benefits of blockchain adoption due to the potentially high costs, both financially and organizationally, associated with the construction of blockchain technology. These costs may also consist of issues of integration with legacy systems and the limited pool of human capital needed for a fruitful blockchain project. (Niforos 2017a, 5.) Statistically, only approximately 0.1% of 20 million software developers have a certain knowledge of a blockchain code; whereas, the number with sufficient skills and experience does not even reach six thousand. In Western Europe, companies have to spend from USD 100 to USD 150 paying for blockchain specialists. The figure is still USD 50 lower than that in North America, which ranges between USD 150 and USD 200. (Suprunov 2018.)

2.4.2 Maintenance costs

Having finished the initial implementation of blockchain, organizations need to take maintenance costs into consideration. This type of costs would be generally divided into power consumption and subscription fees.

Power consumption

Almost every high-tech application demands an energy cost, not to mention such a disruptive innovation with ever-increasing verification complexity like blockchain technology. The best estimates approximate the annual electricity usage of blockchain at 32 – 34 TWh, or 250 KWh per block verification, which is equivalent to one-week electricity consumption by the average American household (Energy Information Administration 2017, as cited in Serpell 2018, 3).

At this rate, some strongly suppose that blockchain's energy consumption is able to power a country like Switzerland in one year as a blockchain illustration, Bitcoin, is currently estimated to use 61.4 TWh of annual electricity – 1.5% of the electricity consumed in the United States (Lee 2018). The tremendous use of electricity markedly refers to an enormous expense that may financially be a burden and, in some cases, even a matter of sustainability.

Subscription fees

There are several companies that have been offering blockchain development, such as LeewayHertz, Techracers, PixelCrayons and Blockobi, whose prices for blockchain service may vary accordingly (Gomathi 2018). IBM, which is also regarded as a leading corporation in blockchain solutions, formulates four membership plans with different monthly subscription fees to serve any organizational customers (IBM 2018a.) The pricing of IBM Blockchain service will be discussed in more details in Chapter 4.

2.5 Benefits and limitations

This subchapter looks at the blockchain from two opposite angles by discussing the pros and cons of the technology.

2.5.1 Benefits

There are such a lot of advantages of blockchain discussed and proposed by thought leaders and specialists that it is extremely hard to cover all the positive effects (Bashir 2017, 30). The section only includes the significant and relevant benefits that helps blockchain stand head and shoulders above the rest. These benefits are decentralization and disintermediation, transparency and auditability, immutability and security.

Decentralization and disintermediation

Decentralization is not only a core concept but also a prominent benefit of blockchain. Direct transfers of digital assets are allowed between two parties without the need for an intermediary or a central authority. (Bashir 2017, 31.) This can translate into reduced costs, shorter time and better scalability to market. The dismissal of intermediaries also offers the potential of increasing speed and lowering inefficiencies by partly reducing or completely removing frictions in transactions. (Natarajan et al. 2017, 15.)

Transparency and auditability

Blockchain promises a greater degree of transparency on the grounds that all network members possess a full copy of the blockchain. Only when consensus is established and propagated across the entire network in real-time can changes be made. Strengthened by the lack or limited involvement of a central authority, this feature demonstrates the capacity for reducing fraud and eliminate reconciliation costs. (Natarajan et al. 2017, 15.)

Immutability

Once data has been recorded in the blockchain system, it is extremely complicated to alter the information (Bashir 2017, 31). In spite of the fact that the immutability, in most cases, is desirable, it possibly gives rise to problems related to recourse mechanisms in case of system's failure. However, immutability is not equivalent to the sheer impossibility of annulling a disputed transaction by a countervailing transaction. Recently, a patent for cryptographic solution allowing an administrator to unlock blockchain units and edit them has been filed by two researchers from Massachusetts Institute of Technology. Nevertheless, it is highly controversial, for immutability is considered to be one of the key attributes of the first blockchain generation. (Natarajan et al. 2017, 15-16.)

Security

Compared to a traditional centralized database with one easily recognizable single attack point, decentralized blockchain potentially creates the opportunity for a more resilient system and provides more efficient protection against different types of cyber-attacks. Moreover, that all blockchain transactions are cryptographically secured and provide integrity equals enhanced cybersecurity. (Natarajan et al. 2017, 16; Bashir 2017, 31.)

2.5.2 Limitations

Apart from the notable benefits, blockchain undeniably needs to surmount multiple obstacles as the nascent technology is still in its evolving stage. The most commonly cited challenges related to blockchain are listed in this section, including scalability, governance, privacy and environmental costs.

Scalability

Over the past few years, the issue has been a focus of intense debate, rigorous research and media attention (Bashir 2017, 444). The concerns are expressed in terms of both transaction volume and speed of verifications due to the limited transaction speed of existing permissionless blockchains. By illustration, only 4 to 7 Bitcoin transactions per second are processed owing to the limitation of the block size at one megabyte. Provided that the size is to be expanded, another problem arises as bigger block would take a longer time to propagate through the network. Although permissioned blockchain have greater capacity to process higher transaction volumes, there is a lack of global scale and a reduced degree of decentralization and transparency in these platforms, which removes many of the benefits that an open public blockchain has. (Natarajan et al. 2017, 17.)

Governance

The fact that no central infrastructure and central identity exist puts a question to the effective governance of the overall system, especially in the context of public blockchains where it is usually unclear to whom governance arrangements apply. Considering permissioned blockchains such as private and consortium types, the administrator is able to be subject to specific governance arrangements. The problem is that the administrator, depending on the nature of particular blockchains, may have inadequate means to enforce these arrangements among network peers. (Natarajan et al. 2017, 18.)

Privacy

Despite encryption and anonymity, all transactions are open and visible to all network members in public blockchains such as Bitcoin and Ethereum. Based on the transaction patterns or the other markers, the identity of the participants can be inferred in some certain cases. (Natarajan et al. 2017, 20.) This may, in some contexts, inhibit the usage of blockchain in numerous industries in which privacy is of paramount importance. (Bashir 2017, 450).

Environment costs

Proof-of-work, which is embedded in consensus mechanism of blockchain technology, consumes a large electricity footprint for computing processing power used up for "mining" (Natarajan et al. 2017, 20). Thus, the energy consumption indicates a matter of concern about the implementation of blockchain technology.

2.6 Blockchain technology in practice

The existence of blockchain, albeit for just a decade, has opened the door to a plethora of ideas for possible applications. Were it not for the outstanding features of blockchain, such as decentralization, the technology would not separate from Bitcoin to rapidly evolve into a disruptive innovation with the impacts on not only finance but also many non-financial industries. Blockchains are especially fitted to the situations that require ownership histories. For instance, they would suggest a solution to music and video piracy without precluding digital media from being legitimately bought, sold, inherited and given away. They also pave the way for all kinds of public services like health and welfare payments, as well as present self-executing contracts for companies operating themselves without human intervention. They could be used for e-voting with blockchain-enabled e-voting (BEV) by allowing voters to hold the copy of the voting records (Boucher et al. 2017, 4-12.) Another striking blockchain-based application is e-Science, which pertains the trust in scientific research as it offers a method to audit and confirm the reliability of the results of scientific studies (Carlisle 2014, as cited in Romano & Schmid 2017, 7).

The subchapter would outline three innovative and considerable ideas for blockchain adoption in different fields: financial services, healthcare and supply chain management.

2.6.1 Financial services

Bitcoin and cryptocurrencies are by far the most popular applications of blockchain technology. Hence, financial services are seen to be in the vanguard of blockchain technology (Boucher et al. 2017, 6). These services can be, for example, cross-border payments and transaction validation.

Cross-border payments are one of the comparative advantages of cryptocurrencies, which offer significantly lower costs and instant transfers without intermediaries and cut down fund validating time. Using a distributed ledger, digital tokens, which can be issued by a trusted authority for the need of participating parties, potentially represent the transacted asset. This assists in processing payments, eliminating paperwork such as title transfers, and reducing disrupted transactions. (Cann & Catmur 2017, 3.)

Turning to transaction validation, a blockchain-based system implements a rigorous professional validation only once and then the verified identity document is used for all subsequent transactions. The identity can develop overtime together with the accrual of attestations, property, and other types of licenses and authoritative power. (Niforos 2017b, 4.)

2.6.2 Healthcare

A variety of proposals for employing blockchain in healthcare sector have been formulated, many of which are related to electronic health records (EHRs). One of such proposals is utilizing blockchain to authenticate patients and health providers, enabling the sharing of EHRs. (Jaikaran 2018, 5.) Moreover, an interoperable blockchain possibly has the ability to strengthen data integrity and, contemporaneously, to protect patient's digital identities, thanks to the inherent properties of cryptographic public/private key access, proof of work and distributed data (Krawiec, Housman, White, Filipova, Quarre, Barr, Nesbitt, Fedosova, Killmeyer, Israel & Tsai 2016, 6).

2.6.3 Supply chain management

It is demonstrated that blockchain-based applications should improve the supply chains by providing infrastructure for registering, certifying and tracking at a low cost. Basically, all goods are individually identified via tokens as a digital asset and transferred between different entities within blockchain network. Each transaction is subject to verification and time-stamping in an encrypted but transparent process. The system could deploy smart contracts to automatically execute payments and other procedures. (Boucher et al. 2017, 16.) Further details with a more meticulous analysis would be discussed in the following chapters of this thesis.

2.7 Summary

The purpose of this chapter is to form the basis for the exploration of the first sub-research question **SQ1**: What are the potential effects of blockchain on food retail supply chain?

Initially, the main points mentioned in Chapter 2 are:

- Blockchain, the technology behind Bitcoin born in 2008, is a distributed ledger, being decentralized without intermediaries, recording of transactions (blocks) and tracking assets.
- Important elements of blockchain are transaction, block, node, and peer-to-peer network, which build the key concepts of blockchain: distributed ledger, decentralized consensus, cryptography and smart contracts.

- There are four tiers of blockchain (Blockchain 1.0, 2.0, 3.0 and generation X) and three types of blockchain (public blockchain, private blockchain and consortium blockchain).
- The expenses for the adoption of blockchain may involve initial costs and maintenance costs and can be a financial burden.
- The benefits of blockchain can be decentralization, transparency, immutability and security while the limitations may be related to scalability, governance, privacy and environmental costs.
- Blockchain has been adopted in financial services, healthcare and supply chain management.

In order to investigate the influences of a new technology on a specific area, it is vital to comprehend its nature first, and then its implementations in other industries. Chapter 2 demonstrates that blockchain is inevitably a disruptive technology with numerous innovative features that can radically change the operation of the world. Even though blockchain is often assumed to be Bitcoin, an argumentative cryptocurrency, its potential application can be beyond the human’s imagination and disrupt not only financial industry but also other sectors, such as health care and supply chain management. Thanks to the outstanding exclusive advantages, blockchain is expected to upgrade the activities of many fields, especially those involving multiple intermediaries and paperwork. Therefore, if applied, it is highly likely that blockchain can bring about enormous impacts on the food supply chain. Further discussion about what the effects specifically are would be described in Chapter 4.

3 FOOD RETAIL SUPPLY CHAIN

This chapter focuses particularly on outlining the main characteristics of food retail supply chain. Therefore, elemental terminologies and concepts related to the topic will be discussed. Subchapter 3.1 peels out the themes of retail and food retailing. Next, subchapter 3.2 widens the view by sketching the picture of supply chain management and subchapter 3.3 focuses on food supply chain. Finally, a review of current issues in the food supply chain will be included in subchapter 3.4.

3.1 Retail and food retailing

In subchapter 3.1, the authors will study retail and food retailing in the context of the food retailing concept and food retail formats. Adjacent to the first subchapter, subchapter 3.2 intently concentrates on the food supply chain. Afterwards, current issues in the food supply chain are taken into account. Last but not least, the authors will give a depiction of technology adoptions in the food supply chain.

3.1.1 Food retailing concept

There are various types of business that fall under the umbrella of retailing, for instance, businesses that serve physical products such as apparel store, drug store, grocery store, etc. or providers of service such as barber’s shop, transportation, doctor, etc. (Tiwari 2009, 2; Dhotre 2010, 49). Despite the differences in products provided and location requirements, these businesses share something in common: They all sell the goods or services to the end consumers.

Originated from the French word “retaillier”, retail literally means to “cut off, shred, paring”. Later, the meaning of “sales in small quantities” was developed and recorded in many European language systems. (Ahmad 2009, 33.) In professional business context, Ahmad (2009, 31) defines retailing as the sale of goods and services from a fixed location in small quantities for direct consumption by the purchaser. Dhotre (2010, 47) also emphasizes the aspect of direct consumption in his definition, but disregards the quantity point by stating that “retailing includes all the activities involved in selling the goods and services directly to final consumers for their personal, non-business use “. Meanwhile, Tiwari (2009, 6) takes a slightly different approach to define retailing by associating it to the final stage of distributing a product to end consumers.

He also differentiates this term from the wholesaling concept, in which products are not sold to end consumers but to business customers at the intermediate stage in the distribution process.

As these definitions of retailing encompass the sales of not only goods but also services, some confusion may arise when applying to the food sector. According to Eastham, Sharples & Ball (2003, 4), there are two basic options for consumers to buy and consume food. One is to purchase fresh food or semi-prepared meals from food retailers such as supermarkets and grocery stores and consume it at home. The other is to eat out in restaurants, cafeterias or deli's, i.e. places that provide full or partial service catering. The major dissimilarity between these two is that, the former is not within the scope of hospitality operation, while the latter is. Food industry book writers clearly differentiate the two options by assigning the term "food retailing" to the former and "food catering" or "foodservice" to the later (Bourlakis & Weightman 2004, 116; Dani 2015, 4-5, 56-57). However, since in both ways, some sort of products, either physical goods or services are sold to the end consumers, both can technically be considered retailing. The former is physical goods retailing and the latter is service retailing.

Under the scope of this research, the catering sector of the food industry will be excluded. The authors use the term "food retailing" in this paper to implicate the sales of food products which are distributed to end consumers through non-service retailers.

3.1.2 Food retail formats

Based on method of operation, food retailing can be classified into two types: store based retailing and non-store-based retailing. Store based retailers are those that operate in physical infrastructure where the products are displayed, and customers can come directly to the store to purchase them. On the other hand, non-store-based retailers do not require physical space to perform selling activities. (Dhotre 2010, 112-113.) In fact, there are retailers that utilize both store based and non-store-based formats to enhance convenience for customers.

Some popular store-based food retail formats are introduced as followings:

Hypermarket is the largest type of retail establishment in terms of commercial area size and the variety of products offered. This is a combination of supermarket and department store, selling everything from fresh food, packaged food to non-food items such as clothing, appliances, etc. (Dani 2015, 56.) Apart from the wide and unique range of product collections, hypermarket also attracts customers by offering low prices and frequent discount promotions. Besides, hypermarket is categorized as self-service store, in which customers can look around, pick up the right product and make purchasing decision by themselves without interference from store staff. (Ray 2010, 363.)

Supermarket is also a large retail store where most of the store space is dedicated to food products (Dani 2015, 57). Despite being limited in the amount of product categories, supermarket offers a wide variety of food product lines which are sourced from a huge number of suppliers. Supermarkets also sell items of their own brand, which are manufactured in accordance with retailer's specifications (Eastham et al. 2003, 10). Supermarkets also offer products at low price level and customers are self-serviced (Ray 2010, 363).

Discounter is a type of retailer that offers limited product lines from own brand or budget brands (Dani 2015, 57). Usually discounters sell products at lower prices than other retailers as they work at lower margins and higher selling volume (Dhotre 2009, 110-111). Like supermarket and hypermarket, discounter is also categorized as self-service store (Tiwari 201, 79).

Independent stores are stores that do not belong to any chain but are established and owned by a single proprietor. This type of retailer usually has small selling space and offers only one or few product lines, which can be packaged food, meet or vegetables. (Dani 2015, 57.)

Convenience store is a special retail format that puts emphasis on customer convenience, as the name says. Convenience stores are located in places where customers can access quickly and conveniently such as busy roads, train stations or petrol stations. In addition, they operate in extended opening hours compared to other retailers, some even open around the clock. (Dani 2015, 57.) Convenience stores' product range includes everyday high-convenience items such as snack food, microwave food, soft drink, confectionary, toiletries, magazines, etc. Generally, prices in convenience stores are slightly higher than the above-mentioned retail formats, even though they are also a self-service type of retailer.

Regarding non-store based retailing, formats such as door-to-door selling, catalogue retailing or television home shopping, which are relatively old and not widely applicable in the food sector, will not be discussed in this paper. Popular non-store based retail formats that are emerging in the last few decades are introduced as followings:

Vending machines are automated machines that sell packaged food and drink with limited availability. This is a fully self-service retail format with no human interface involved in selling activities.

Online grocery retailing is the retail format where selling activities take place over the internet. The products are displayed on retailers' web pages, which allows customers to search, select and purchase online. This type of retailing is gaining immense popularity recently as many retailers who originally operate solely in traditional formats have started selling products on online channels for the sake of customer convenience, thus improving market competitiveness. (Dhotre 2010, 156.)

3.2 Supply chain management

The concept of Supply Chain Management (SCM) was first introduced in the 1980s, when organizations realized that distribution costs could be reduced by integrating different logistics processes into a total managerial system. Throughout the decades, the influential role of SMC has become increasingly greater as market dynamics constantly change how companies seek to optimize efficiency in their operations. (Camerinelli 2009, 5-6.)

3.2.1 Supply chain

In the narrowest sense, Camerinelli (2009, 7) defines supply chain as "the process by which products or services are brought to the market". Similarly taking the operational perspective to describe supply chain but in greater details, Greasley (2008, 85) states that supply chain is "a series of activities that moves materials from suppliers through operations to customers". This series of activities, including processing, transportation, warehousing and retail, engages a complex amount of parties that are generally divided into the upstream and downstream sides of the chain. Figure 7 illustrates a simplified supply chain.

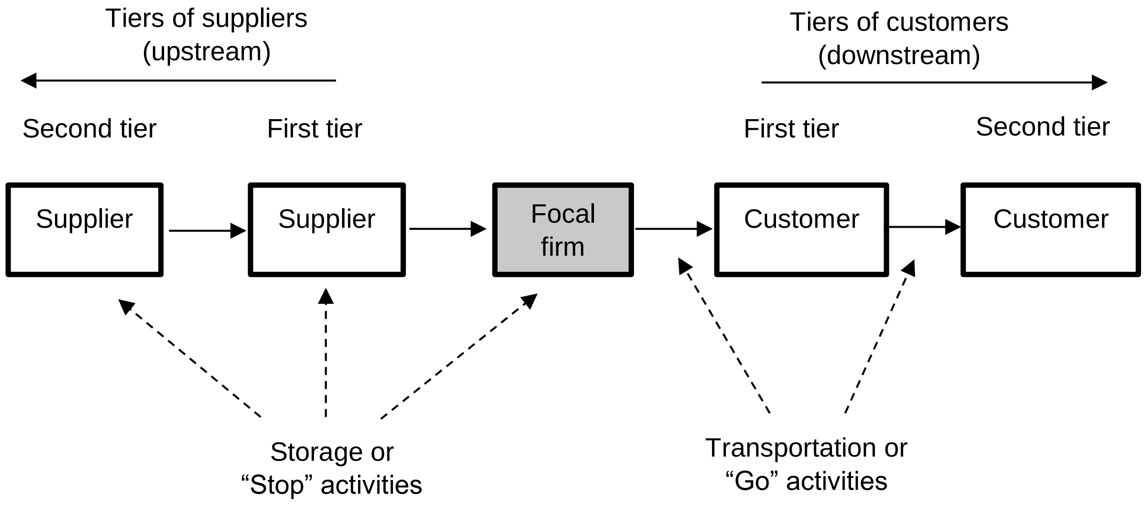

Figure 7 A simplified supply chain (Grant, Trautrims & Wong 2017, 10)

The upstream, i.e. the supply side, consists of tiers of suppliers. The parties that directly supply the organization in the middle of the chain (the focal firm) are called “first-tier” suppliers; and the suppliers of the first-tier suppliers are known as second-tier suppliers etc. Similarly, in the downstream, or the demand side, there can also be multiple tiers of customers. (Greasley 2008, 85; Grant et al. 2017, 10.) The number of tiers on each side varies depending on the focal firm and their supply strategy for each product that they offer. For example, if a manufacturer acts as the focal firm, the upstream can include raw material suppliers while the downstream can involve wholesalers, retailers, etc. who distribute the manufacturer’s products.

In addition to showing the main actors in a supply chain, Figure 7 also points out the chain’s principal activities, which, according to Grant et al. (2017, 10), are storage (“stop” activities) and transportation (“go” activities). The materials stop at each node, being stored and processed while waiting to be moved to the next “stop” point through “go” activities. In real business context, supply chains appear to be more complicated. Apart from the core organizations that directly deal with and generate revenue from the products, the supply chain also involves such logistics service providers as warehousing and transportation companies which take significant part in the “stop” and “go” activities.

3.2.2 Supply chain management

Due to the growing complexity of today’s supply chains, it is challenging to come up with a universal definition for SCM which takes into account different focus points. Aswathappa & Bhat (2010, 532) put emphasis on how the flow of materials from suppliers all the way to customers is viewed as an integrated system to be managed. Weele (2010, 251-254) and Christopher (2009, as cited in Camerinelli 2009, 7), on the other hand, direct the attention to the fact that SCM encompasses not only the internal management of logistics processes but also the external relationship management that links the focal organization to the downstream and upstream of the supply chain. The Council of Supply Chain Management Professionals (2018) has more or less covered both points by describing SCM as following:

> *Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies.*

Another interesting aspect of SCM is touched on in Farooqui's (2010, 13) definition:

> *Supply Chain Management (SCM) is the term used to describe the management of the flow of materials, information, and funds across the entire supply chain, from suppliers to component producers to final assemblers to distribution (warehouses and retailers), and ultimately to the consumer.*

This definition highlights three major flows that run along the supply chain, which are material (physical product) flow, information flow and financial flow. Many definitions focus only on the flow of physical product as this is the most visible one. The last two are, however, of as great importance. Information flow is a bidirectional flow from suppliers through the focal firm to the customers and backwards. It enhances visibility within the supply chain and the degree of information sharing reflects the level of collaboration among the channel partners, which is an essential aspect of SCM. Finally, financial flow is the flow of money along the supply network, which travels in a reverse direction to the material flow.

To sum up, SCM is a management system that integrates different logistics processes to support the flow of physical product, information and money within and across the organizations in a supply chain.

3.3 Food supply chain

The food supply chain incorporates a complex network of organizations and individuals who take part in the farming, processing, distributing and consumption of food (Iakovou et al, 2012, as cited in Bochtis, Iakovou, Vlachos & Aidonis 2016, 33; Cagliano, Caniato & Worley 2016, 2). This series of "farm to fork" processes and operations helps to turn food from its raw material state into the edible food that human-beings consume every day. The main actors of a food supply chain are exhibited in Figure 8.

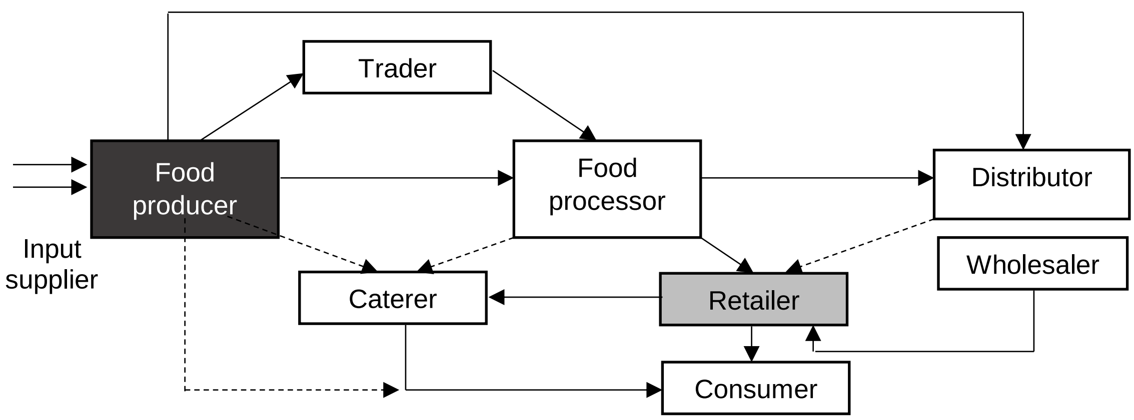

Figure 8 The actors in a food supply chain (Dani 2015, 2)

Cagliano et al. (2016, 9) classify the actors in the food supply chain before it reaches end-consumer into three sectors: agriculture, processing and distribution. The agricultural sector marks the start of the supply chain with food producers who supply food in its raw form, for example, fruits, vegetables, meat, fish, etc. through farming activities. The farming businesses vary from small family farms to large corporations. After harvesting, they sell their products to food processors, distributors and in some cases, to the catering sector or directly to final consumers. In fact, the agricultural sector also engages input suppliers who supply materials that are needed for farming activities such as farming machinery, seeds, fertilizers, etc. to the food producers (Dani 2015, 3).

The food processing sector is responsible for transforming raw food supplied by the producers into food products at different processed-levels according to customer's requirements (Dani 2015, 3). It involves a diverse variety of entities and activities that process food in different ways such as cutting, drying or juicing vegetables and fruit; roasting coffee; slaughtering and mincing meet; etc. (Dani 2015, 3-4; Cagliano et al. 2016, 9). Packaging is the final activity in the processing systems, which is done before the products are delivered to the next stops in the supply chain.

Finally, the distribution sector acts as a link that connects producers, processors and the consumer markets. Distributors and retailers are the two major actors in this sector. Distributors source fresh food from farmers or processed food from processors, then distribute it to the end consumers through multiple channels. These channels might include wholesalers, retailers, catering sector or other distributors. The role of distributors is especially critical in a global supply chain as they will be the ones who deal with various local regulations as well as other cross-national boundaries of international food trading. (Dani 2015, 4.) Retailing, as introduced in the previous chapter, is the last stage in the distribution process which sells the products directly to the ultimate consumers. Retailers can adopt various types of retail formats ranging from physical shop to online store. Large retail companies usually have their own distribution networks and distribution centers where they receive the products directly from their contracted food manufacturers instead of going through any middleman. The products are then distributed to their individual stores along the network. (Dani 2015, 54.)

Food supply chain characteristics

The food supply chains possess a set of distinctive characteristics that set them apart from the other types of supply chain. Some of the important ones are listed below:

- The short life-cycle nature of most food products leads to the need for quick processing and short storage times;

- Perishable goods require specific transport and storage conditions;
- Production operations have frequent set-up cycles due to the dependence on the seasonality of products;
- Strict quality control and compliance with different national and international food safety legislation, regulations and directives are required as the consumption of food has direct effects on human's health;
- There is a high product differentiation within the chain.

3.4 Current issues in food supply chains

The present pains of the food supply chain are going to be identified in this subchapter, all of which are involved in transparency, traceability and food safety.

3.4.1 Supply chain transparency

The industrialization that took place in certain countries since the previous centuries has left less room for agricultural production to grow. In those areas, the domestic supply of food is no longer sufficient to fulfill consumer demands. Moreover, as retailers realize the opportunity to improve cost-effectiveness by purchasing goods from low-cost nations, international sourcing practices become increasingly common. These factors, as a result, have intensified the cross-border movement of food products, thus making the supply chain more complex as it requires contribution from multiple entities in a global scale. The importance of supply chain transparency consequently becomes more critical.

According to Financial Times' lexicon (2018), supply chain transparency is the extent to which every actor in the supply chain, especially the end-users, can easily access the information regarding the companies in the network, as well as suppliers and sourcing locations of the products. From another point of view, Schiefer & Deiters (2012, 12) claim that in order to achieve transparency in a food supply network, the provision of information must encompass economic, environmental, social and ethical aspects.

Supply chain transparency can be viewed horizontally or vertically. The horizontal dimension of transparency relates to the compliance of legislation and information provision of each respective company in the supply chain to its own relevant stakeholders. Horizontal transparency concerns the corporate strategies and operational processes within companies. Corporate reporting is a common tool for horizontal transparency. (Wognum, Bremmers, Trienekens, Vorst & Bloemhof 2011, 66.) Meanwhile, vertical transparency requires the exchange of information among all the entities in the supply chain, with a view to facilitating the ability to trace a product backward and forward throughout the production and distribution processes. This is also known as traceability, which will be discussed further in the next sub-chapter (Kalfagianni 2006, 19; Wognum et al. 2011, 66.)

Transparency in a food supply chain is beneficial not only to the end-consumers who require the quality and safety of products to be guaranteed, but also to the firms that operate in the supply chain and governmental authorities. For companies, transparency helps promote market efficiency, improve information exchange with suppliers and customers and facilitate supply chain risk management (Trienekens, Wognum, Beulens & Vorst 2012, as cited in Ionescu Florea & Corbos 2016, 38; Global Reporting Initiative 2017). For the governments, the acquisition of transparent information on trade relationships between countries, food safety issues, etc. would ease the drafting, amendment and adoption of related legislation.

Food fraud is an important issue in the food industry that reflects how the complexity of food supply chain significantly calls for transparency. An example is the UK horsemeat scandal in 2013, which had created a huge disturbance across the food industry. Horse meat was found in frozen beef burgers that were supplied to the major supermarkets in the UK, without being properly declared on the labels. When investigating the case, it turned out that the supply chain of this product was tremendously complicated with the product movement map spreading all over Europe. (Dani 2015, 147-148.) Numerous involving parties were placed under suspicion yet tried hard to deny responsibilities of mislabeling the products (BBC News 2013). The scandal not only required costly investigation and product recalling, but also did enormous harm to the retailers' credibility, which resulted in a fall in their market shares (Fletcher 2013). If a more transparent information exchange had been implemented, the consequences could have been less serious.

3.4.2 Food traceability and food safety

The European Commission (2007) defines traceability as “the ability to track any food, feed, food-producing animal or substance that will be used for consumption, through all stages of production, processing and distribution”. In a more comprehensive definition, Bosona & Gebresenbet (2013, 35) mention that the information sharing process in traceability encompasses both backward traceability (tracing) and forward traceability (tracking). In backward traceability, the information is traced from the consumer back to producer, while in forward traceability it is tracked in the opposite direction. The scope of traceability is explained further in ISO 16741:2015, that the aspects to be tracked and traced include the origin of food materials and non-food parts, processing history and the physical movement of products after delivered.

There are multiple factors that encourage organizations to implement food traceability systems, for example: food safety and quality, legislation, social, economic and technological concerns. Among this variety of driving forces, food safety and quality stand out as the most vital ones and have indirect impacts on the other drivers. (Bosona et al. 2013, 36; Karlsen, Dreyer, Olsen & Elvevoll 2013, 412; Bochtis et al. 2016, 196.) This is due to the growing number of food related crises that threaten human's life, causing hospitalizations and deaths on a frequent basis (Bochtis et al. 2016, 196). The large E. coli outbreak that occurred in Europe in 2011 caused at least fifty deaths and sickened thousands of people (Food Safety News 2015). Another recent E. coli outbreak in the US in March 2018 has affected hundreds of people, among which ninety-six were hospitalized and five were killed (LaMotte 2018). In both cases, it took months to trace back the root cause of the outbreak. Because of the time-consuming tracing process, which included inaccurate predictions and conclusions, the farmers and industries recorded a loss of USD 1.3 billion, and emergency aid cost another USD 236 million (WHO 2015, as cited in Food Safety News 2015). With superior traceability, the investigation as well as product recalling processes would consume less time, thus save considerable costs and more importantly, save human lives.

As food safety appears as the common concern for the entire society, traceability benefits both public and private sectors in this aspect (Bochtis et al. 2016, 196). Besides, the implementation of traceability systems would help private entities to improve competitiveness by differentiating and marketing food products with credence attributes. The most important credence attributes that consumers usually pay attention to are content and process attributes. While content attributes involve the physical characteristics of the products, such as ingredients or the amount of nutrients, process attributes refer to the characteristics of the production process, for example: country of origin, environmental-friendly or fair-trade issues. (Golan, Krissoff, Kuchler, Calvin, Nelson and Price 2004, 7.) Apparently, these attributes cannot be determined or detected without traceability as the tool of evidence provision. Hence, private actors in a food supply chain would be able to showcase more hard-to-perceive values to their customers by enhancing traceability.

3.4.3 Challenges for transparency and traceability in the current supply chains

Despite the obvious socially perceived benefits of supply chain transparency and traceability, there still exists a few challenges that hinder the utilization of traceability systems and restrain supply chains from achieving transparency at its utmost state.

Firstly, the vertical scope of traceability requires all supply chain actors to join hands and cooperate. However, in lengthy and complex supply chains, this is not really within the bounds of possibility since organizing a shared supply chain approach for all the entities entailing in such supply network is an extremely challenging task. Full traceability is usually only found in less complex supply chains that are short geographically and involve a small number of actors. (Wognum 2011, 74.)

Secondly, the costs of developing and implementing traceability systems are high, and huge investments are required at the initial stage (Bosona et al. 2013, 39; Wognum 2011, 74). At the same time, the upstream of the food supply chains is mostly made up of small and medium-sized companies, whose financial resources and production scale do not facilitate the ability to adopt such costly systems. Even with strong financial standings, most farmers and growers would prefer investing in production and processing technologies, rather than in management systems. (Wognum 2011, 74.)

The final problem which is worth paying attention to is the centralization of data processing in the contemporary supply chain management. Supply chains nowadays use neutral, non-profit or governmental parties to create a centralized information storage which acts as an enabler for trusted information exchange among the supply chain entities. However, there is no guaranty that the third party can be trusted at the absolute degree as in most cases, it is impossible for this firm to totally get rid of the inherent bias as well as to manage the system at its optimal technical capability. Moreover, being the single point of weakness, this central party would be likely to become the target for corrupt practices, social engineering and hacking. In case the centralized data storage is not managed by a third party but by any of the actors in the supply chain who has the most power, there is also a high chance of selective disclosure and extortion. Nonetheless, even though centralization incurs many associated risks, this is considered the most credible way for supply chains to attain transparency in recent times. (Provenance 2015.)

3.5 Technology adoptions in food supply chain

In the past few decades, the role of technology in food supply chains has speedily become more critical to every organization due to the need for improving traceability, transparency and operational efficiency in a competitive global context. Consumer trends are changing at a fast pace. At the same time, companies need to cope with the acute shortage of resources. Moreover, as the food industry is characterized by the perishability nature of most product categories, it is important that specific logistics requirements must be strictly followed. These factors have consequently fostered the emergence of various technology innovations, especially information technology, which are considered the key enablers in today supply chains. (Bochtis et al. 2016, 222-223.) In this subchapter, the most important technologies along with their states of adoption in food supply chain will be discussed.

3.5.1 Barcode and radio frequency identification

Adopted since the 1970s, barcoding is an identification technology that is widely utilized in multiple industries, especially manufacturing and retailing. It is a line-of-sight technology that requires a scanner to see and read the code. The barcode consists of black parallel lines and blank spaces that vary in width, which provides enough space to store the Universal Product Code (UPC). This code is made up of a series of 0-9 digits, allowing the computer to identify and match the item with the corresponding information. (Attaran 2007, 250.) The information to be captured in barcode can be manufacturer identification number, product number, packed date, price, etc. (Bosona et al. 2013, 41). Being useful in inventory recording, controlling and checkouts, barcoding and UPC have helped to improve product tracking process for retailers, decrease labor costs and speed up product replenishment. As time goes by, more investment is put on the research and development of barcoding technology, resulting in the advent of the new two-dimensional code which lets users to store more data, thus giving rise to a better operational efficiency. Despite the numerous benefits, the technology still meets with different criticisms. For instance, such environmental conditions as extreme temperature, hazardous contamination and dirt sometimes cause inaccuracy in scanning and thus make the barcodes useless. (Attaran 2007, 250.) Besides, errors and inefficiency might also result from the significant amount of human involvement in the processes of positioning and scanning the labels (Regattieri et al. 2007, as cited in Bosona et al. 2013, 42).

With a view to overcoming the disadvantages of barcoding, the RFID technology has been widely introduced and is known as the next generation of barcode. This technology does not require line-of-sight to read the code and collect data from it but instead, it uses radio waves which help to automatically identify the objects. (Bochtis et al. 2016, 226.) An RFID system has three major components: the electronic tag (RFID tag), the reader and the computer. The tag contains a microchip that is attached to an antenna, through which the data is stored and transmitted to the reader. The reader which consists of radio frequency transmitters and receivers is responsible for communicating with the tag and passing the received data to the computer for processing. The process of transferring data from the reader to computer is in fact similar to how it works in the barcoding systems. (Attaran 2007, 250-251.)

RFID not only offers faster speed and greater efficiency in inventory management and forecasting but also plays a pivotal role in enhancing supply chain traceability (Dani 2015, 156). In the food industry, RFID particularly shows superior benefits that barcoding is short of. For example, for the sake of consumer's safety as well as to ensure the data entered on the traceability database is accurate, the tag to be used on food should be relatively small in size and have no compatibility problem with food. In this aspect, RFID tag can fulfill perfectly. Furthermore, the RFID system can store an extensive range of unique food product information, and can update them without using a new tag, which is definitely more efficient than when barcode is used. In addition, RFID signal can be read from a long distance depending on the frequency bands, which is flexible to different using purposes. (Bosona et al. 2013, 42.) For retailers, RFID helps cut off the costs of receiving, inventory and shrinkage losses by 11 to 18 percent; the number of logistics delays is decreased by 5 percent, while the occurrence of out-of-stock goods is also reduced by 9 to 14 percent. However, regardless of these functional and operational benefits of RFID, so far barcoding and UPC are still the dominant tracking tools for packaged goods due to its low cost of implementation. Indeed, high implementation cost is probably the biggest drawback of RFID, as it can cost USD 13 million to USD 23 million for a big manufacturer to run the full-fledge systems. (Attaran 2007, 250-251.)

Initially when RFID was in the beginning phase of its life cycle, the deployment of this technology in the supply chain environment was mainly pushed by external factors as its capabilities remained in doubt for several years with negative industry perceptions and many technical problems detected. At that time, small companies in the supply chain did not adopt RFID for the benefits it had to offer, but mostly because they were pressured by the large retailers such as Walmart and Metro. Nevertheless, in the recent years, the deployment of RFID technology has entered the rationality phase, in which internal motives and cost-benefit assessment are the main reasons for companies to make decisions. (Bochtis et al. 2016, 224-225.)

According to a survey by Pramatari & Dimakopulou (2014, as cited in Bochtis 2016, 225), there has been a growing trend to adopt RFID in supply chains among European firms over the period of 2011 to 2014. The survey indicated that RFID projects in traceability, asset tracking, inventory audit and logistics were among the top concerns. Taking traceability for instance, while in 2011, only about one-third of the respondents showed their interest in utilizing RFID to improve supply chain traceability, the proportion had increased dramatically in 2014, where nearly 80 percent of the respondents answered that they were interested. Moreover, approximately 30 percent of the respondents in 2014 declared that they had already launched the projects while in 2001 this figure was less than 5 percent, indicating an enormous growth in adopting RFID. The same growth patterns were also identified in RFID projects for other supply chain functions.

3.5.2 Internet of things

Another disruptive technology that affects not only the food supply chains but also the other industries across the globe is the Internet of Things (IoT). This is one of the leading drivers in Industry 4.0, or the fourth Industrial Revolution which concerns cyber-physical systems and the digitalization of the physical world. Rentokil Initial (2017, 5) defines IoT as following:

> *The Internet of Things (sometimes Internet of Everything) is a network of physical objects or 'things' embedded with electronics, software, sensors, and connectivity to enable the network to achieve greater value and service by exchanging and/or collecting data. This may be entirely within a given business or may extend to 'things' installed on the premises of partners and customers (including consumers).*

In fact, IoT is not considered to be a sole technology that operates on its own, but rather an integration of different enabling technologies, namely RFID, wireless sensor networks, cloud computing, data analytics and internet protocols (Nukala, Panduru, Shields, Riordan, Doody & Walsh 2016, 1). In the food industry, IoT is believed to pose an end-to-end influence on the food supply chain from the production phase to the consumer phase. In food production, IoT has been utilized in different agricultural operations with the use of sensors, wireless technology and mobile devices. It helps boost productivity with smart farming as well as facilitate the management of livestock. For food processors, the intervention of IoT can be found in production line automation, where the temperature of food, contamination risk or the alignment of labelling are controlled (Rentokil Initial 2017, 8). In transportation and distribution stage, operations have been adopting such technologies as RFID, sensor technology, GPS or climate-controlled vehicles to track products, monitor vehicle fleets, ensure the safety and freshness of food when handling and transporting and so on (Nukala et al. 2016, 3; Rentokil Initial 2017, 8-9). Finally, regarding the retail phase where the main goals are to maintain high food quality and to achieve optimum sales revenue, IoT gets involved in improving the following areas: supply chain management, customer experience, innovative revenue streams, energy efficiency and personnel usage (Nukala et al. 2016, 3).

A recent survey concerning the organizational impact of IoT on food safety issues by Rentokil Initial (2017, 7) revealed that IoT had had at least some influence on roughly 60 percent of the organizations under examination. Besides, nearly a quarter of the respondents expect that their operations will be affected by IoT technologies within the next twelve months. In fact, since there were a large number of respondents who admitted to not having a deep knowledge on IoT, their organizations might have already deployed some applications of IoT without them realizing it. Therefore, the survey conductors believed that the majority of companies had actually been deeply engaged in the world of IoT.

3.6 Summary

Similar to Chapter 2, this chapter aims to act as the basis for the exploration of the first sub-research question SQ1: What are the potential effects of blockchain on food retail supply chain?

In this chapter, the concepts of retail and food retailing were explained in the beginning where the authors noted that the term “food retailing” used in this study refers to the sales of food products distributed to the end consumers via non-service retailers, excluding the hospitality sector. There are various formats of food retailing, including but not limited to hypermarket, supermarket, discounter, independent grocery store, convenience store, vending machines and online grocery retailing.

The next sections elaborated the idea of supply chain management as well as food supply chain. Viewing from a focal firm’s perspective, a supply chain consists of a series of activities such as processing, transportation, warehousing and retailing. These activities are controlled by multiple parties, which are basically grouped into tiers of suppliers and tiers of consumers, along with the focal firm. The management of supply chain involves the three principle flows, namely information flow, physical product flow and financial flow. The food supply chain, in particular, involves four main actors, i.e. the production sector, the processing sector, the distribution sector and the consumer.

The current important issues along with the status of technology adoption in the food supply chain were discussed in the final parts of this chapter. It was pointed out that supply chain transparency and traceability are difficult to achieve, especially in complex supply chains. Another challenge for the current supply chains to optimize supply chain transparency is the costs of developing, implementing and integrating IT systems.

Additionally, the centralization of data, which is considered the most reliable way to maintain transparency at the moment, is associated with the risk of data fraudulent practices. Till the present, some technology advancements have been introduced and adopted in the food retail industry to tackle the issues concerning supply chain transparency. While RFID has been reported to be on an impressive growth, the IoT technologies have just started their disruptive influences recently.

4 BLOCKCHAIN-ENABLED FOOD SUPPLY CHAIN

Having reviewed the essentials of blockchain technology and food retail supply chain individually, the authors continue the study by discussing their interchange. Firstly, the blockchain paradigm in subchapter 4.1 expounds a practical view on the implementation of the technology in food retail supply chain, specifically how blockchain potentially applies in the industry. Secondly, the study examines the impacts that blockchain, once adopted in food retail supply chain, can be exerted on the field, both positively and negatively in subchapter 4.2. Lastly, subchapter 4.3 analyzes the status quo of the blockchain adoption in food retail supply chain.

4.1 Blockchain paradigm in food retail supply chain

Being a newly-born concept, the implementation of blockchain in food retail supply chain has still been a proposal with related studies undertaken. Therefore, the authors aim to grasp the basics of a blockchain system that is potentially adopted in food retail supply chain in this subchapter. These are among the most significant characteristics widely accepted in the research-wise world.

4.1.1 Overview on potential features

Some general features of a blockchain used for food retailing will be mentioned in this part. Initially, a food retail blockchain system belongs to the tier of Blockchain 3.0 with non-financial application (Swan 2015, ix) as mentioned in Chapter 2.

Regarding the types, as food retailing falls into the category of supply chain, its related blockchain is likely to follow the structure of the larger industry (Kehoe, Gindner, Dalal, Andrzejewski & O'Connell 2017, 10). In fact, when conducting studies on the adoption of blockchain in supply chain, researchers have a tendency to overlook the potential blockchain types and therefore leave room for discussion. Peck (2017, 38-60) visualizes the selection of blockchain by a logical flow shown in Figure 9.

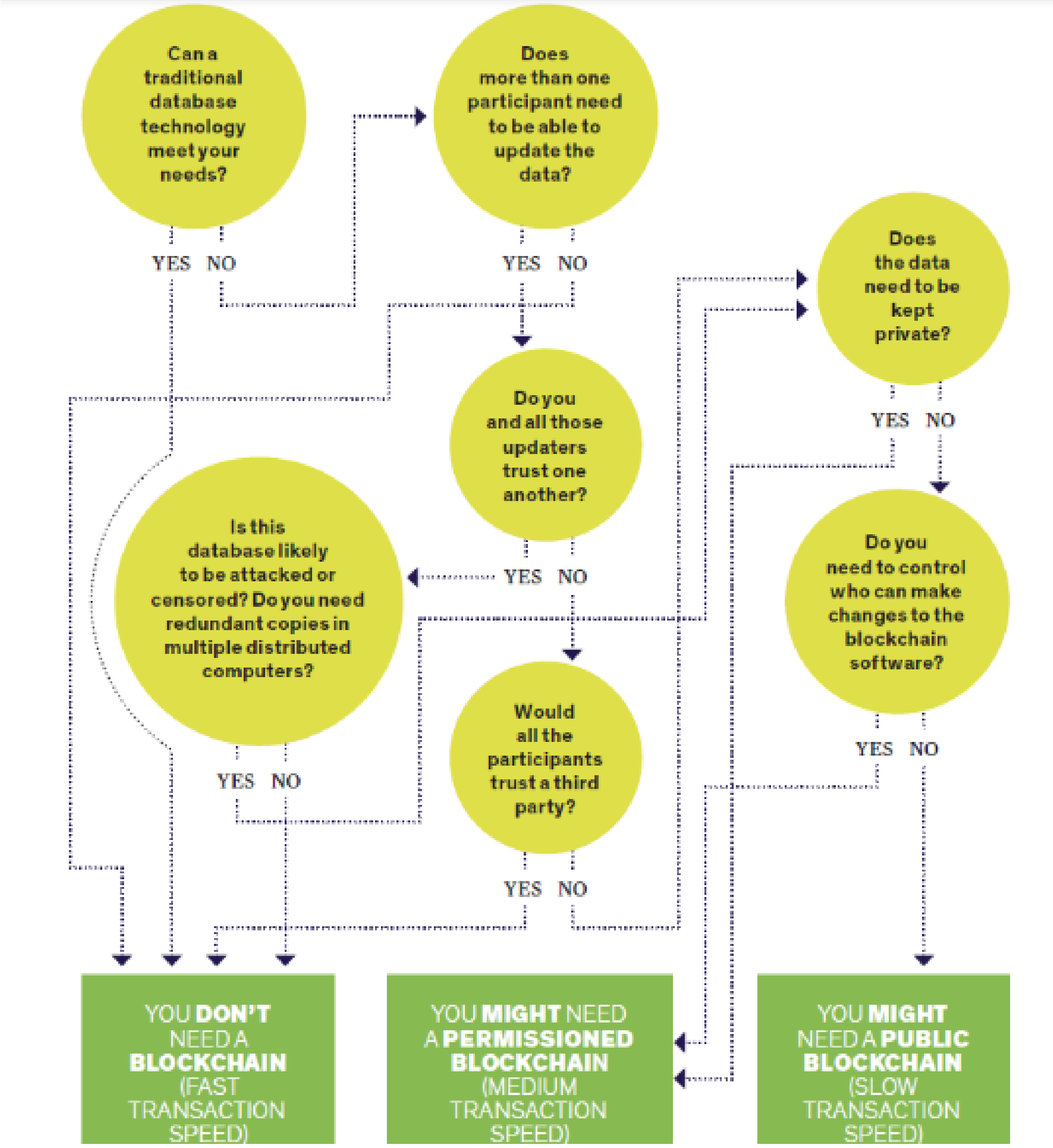

Figure 9 Blockchain selection (Peck 2017, 38-60)

Based on the selection flow, Chen (2017, 25) decides that the blockchain implemented in supply chain can be permissioned blockchain. Firstly, hardly can traditional database meet the demands of modern supply chain. Secondly, obviously more than one company or organization need data to be updated. Thirdly, trust issue does exist in the supply chain and there is no trusted third party agreed among all participants. Fourthly, it is necessary that the data should be kept private. All of the reasons lead to the choice of permissioned blockchain with generic elements of all blockchain types and some other distinct typical features mentioned in the second chapter. (Chen 2017, 25.)

4.1.2 Specific blockchain paradigm

This part illustrates the possible framework of a blockchain system adopted in food retail supply chain, specifically its modelling and operation.

If the actors in food supply chain in Chapter 3 have been reviewed as food producer, food processor, trader, distributor, wholesaler and retailer (Figure 10), which are classified into agriculture, processing and distribution, the authors decide to simplify the figure into a linear structure in this chapter. Moreover, physical flow, digital flow (digitized information) and blockchain network are added to complete the visualization of blockchain-enabled food supply chain.

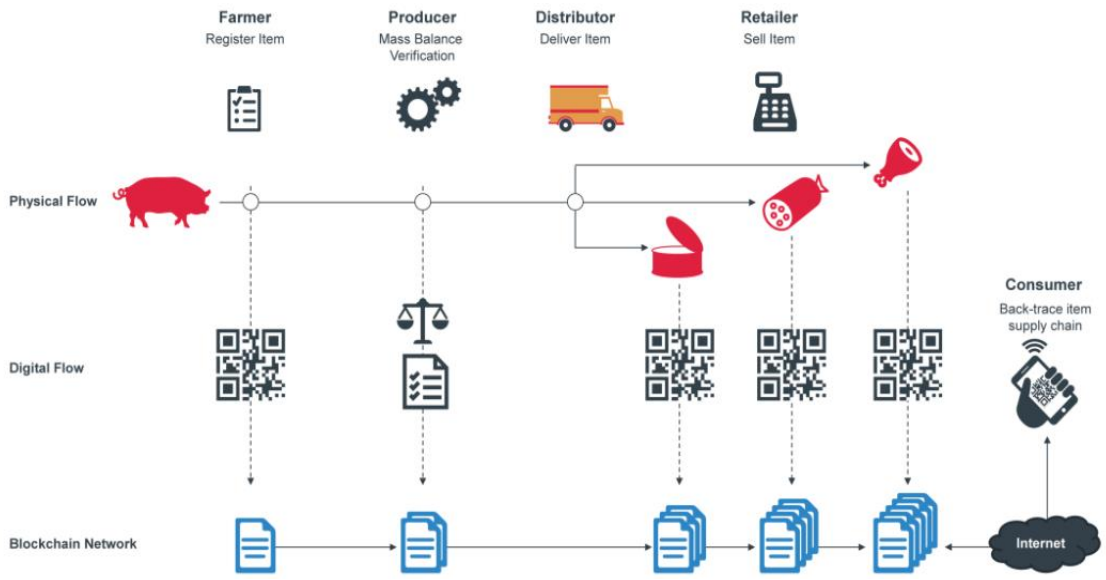

Figure 10 Visualization of blockchain-enabled food supply chain (Rooyen 2017)

Traditionally, the physical flow with, for example, agricultural products and processed food, has been existing to form the backbone of the food supply chain. Kehoe et al. (2017, 13) also give an illustration of this physical flow (Figure 11).

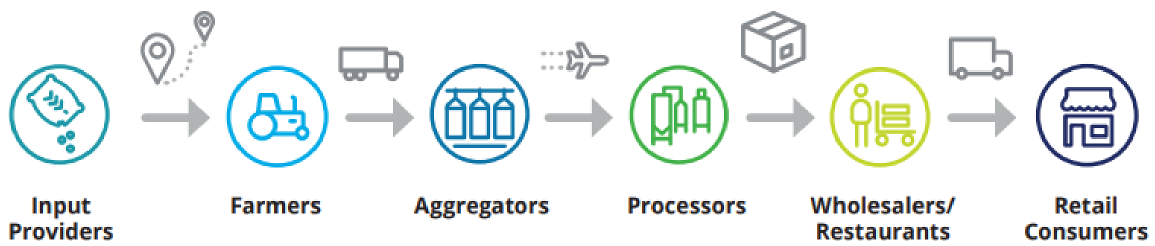

Figure 11 Physical flow in food supply chain (Kehoe et al. 2017, 13)

The advancement of digital age has transformed the physical data into technical information, which is later able to be recorded in the blockchain system, to reach customer. The chain of data is susceptible of forming a chain of blocks in blockchain system, and the exchange of data between actors in the food supply chain can be considered to be a transaction. In general, Figure 12 vividly depicts the longitudinal facet of a blockchain system adopted in food supply chain.

Viewed from a cross section, the system would indicate a more decentralized and distributed structure – the key attribute of blockchain technology. Forming a complete circle, every single actor in the food supply chain would connect to each other for information exchange. Regulator and logistics also join the blockchain system with the same position as the existing elements in food supply chain, such as producer and distributor. What mainly links all network participants is the distributed real-time update of information.

Specifically, an industry-wise blockchain based platform could be established by food stakeholders so as to onboard and manage supplier relationships, as well as examine the quality of food products. By using a digital identity, each user would access and participate in the platform. Smart contracts could be employed to store and manage meta-data and every event involved in supplier onboarding and relationship maintenance, such as supply chain details (products' data and related actions), quality certifications, and endorsements by food stakeholders. (Kehoe et al. 2017, 11.)

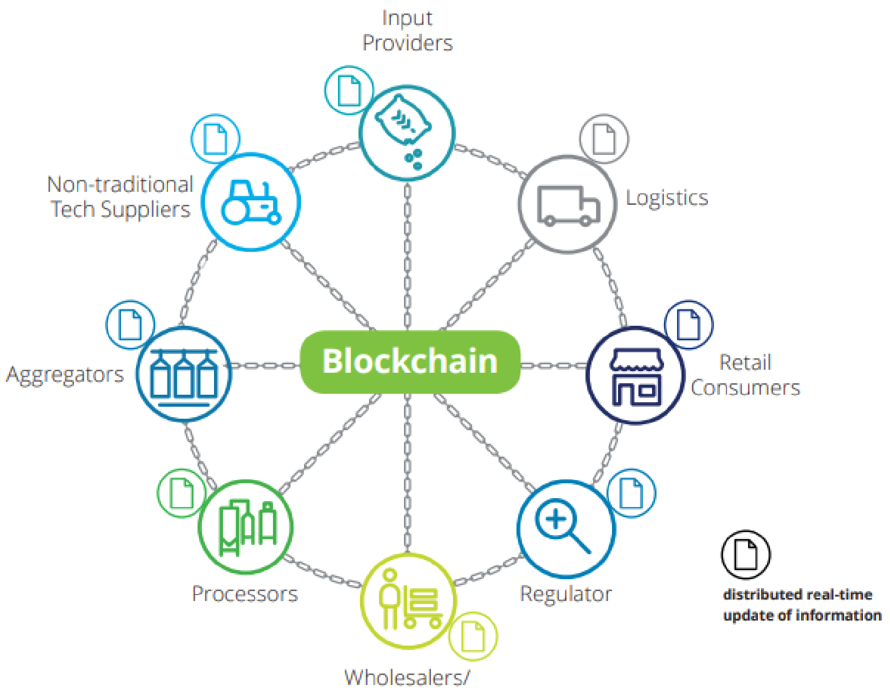

Figure 12 A cross section of blockchain in food supply chain (Kehoe et al. 2017, 13)

Thanks to the platform, participants possibly have end-to-end visibility over the supplier relationship with real-time access, which is currently impossible in the supply chain. A comprehensive audit trail of food ingredients would be close at hand for platform users. Providing that all the data, such as supplier profiles and food materials, added to the system are timestamped, a full history of the stakeholder relationship and associated activity could be conveniently retrieved. Under no circumstances should food suppliers lose quality certificates as they could be revoked and notified to everyone in the network in case of the failure of standard adaption. Furthermore, anyone with direct contact with the food ingredients could provide endorsements as a contribution of food critics' reviews and ratings to convey a multifaceted view on any food. (Kehoe et al. 2017, 12.)

Another question is addressed to the exchange of information among participants in the blockchain network for food supply chain. Combining the operating mechanism of blockchain in Chapter 2 with the modelling in this chapter, the authors try to demonstrate a potential data transaction in a food retailing-wise blockchain.

Firstly, two parties, for example consumer and retailer, want to exchange information, or consumer requires food ingredients' information from retailer, which creates a transaction. After that, the transaction would be broadcast to the network and validated. The verification could be proceeded instantly; otherwise, nodes assume the responsibility for determining the validity of transaction based on a set of pre-defined rules. The transaction is then placed into a new block, waiting for the approval of the network before being added to the chain. When a block is validated, the transaction is executed, indicating that the data of food ingredients have been transmitted from retailer to consumer. (Kückelhaus et al. 2018, 5; Deloitte Tech Trends 2016 as cited in Trouton, Vitale & Killmeyer 2016, 6.)

4.2 Impacts of blockchain on food retail supply chain

In this subchapter, the impact of blockchain on the retail supply chains of food will be discussed based on the following simplified supply chain model (Figure 13).

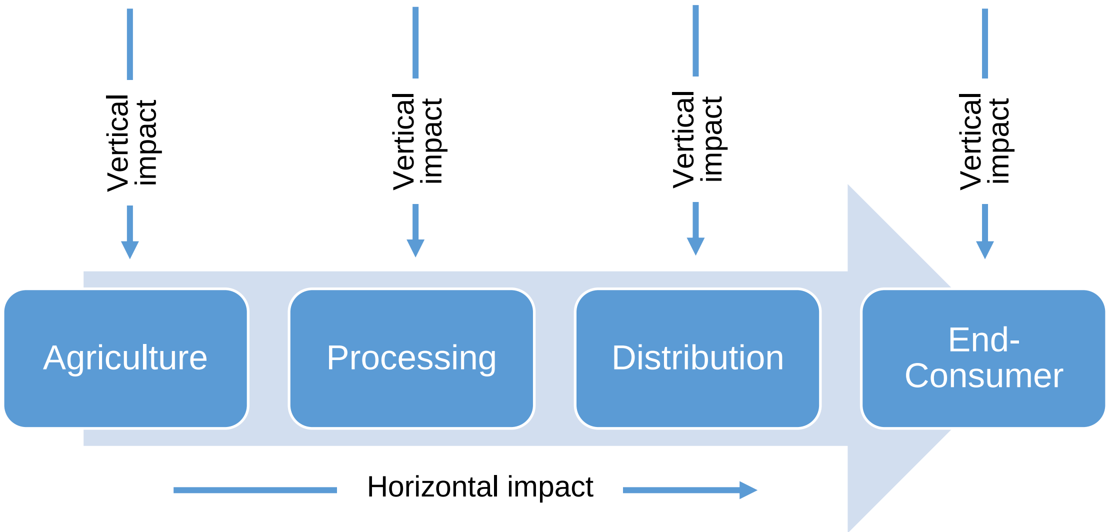

Figure 13 Two-dimensional impact of blockchain on food retail supply chain

The potential impact will be analyzed in two dimensions: horizontal and vertical. The horizontal impact indicates the impact of blockchain throughout the entire supply chain, in other words, how the supply chain will be affected as a whole. On the other hand, vertical impacts represent the ones that are posed individually on each actor in the supply chain.

4.2.1 Horizontal impact

As mentioned in subchapter 3.2, the supply chain is an integration of three flows: information flow, physical flow and financial flow. The major issues which prevent food supply chains from achieving optimal states such as the lack of transparency, food fraud or insufficient traceability are mostly related to the flow of information. In that context, the blockchain technology is expected to provide a reliable platform that will facilitate a more efficient and accurate information exchange along the supply chain. The first impact to be exerted is that the involvement of third-party data storage and transmission facilities in a supply chain will be eliminated thanks to blockchain's decentralization feature. Information is no longer centralized; hence the single point of weakness is also removed. This also helps to build better trust among the supply chain actors, resulting in lower supply chain risks and more efficient partner management. Secondly, as the data stored in a blockchain network is immutable or can only be altered when receiving consensus from all the participants, data-related fraudulent actions such as social engineering, hacking or extortion can be avoided. Finally, the blockchain network would allow every actor in the supply chain to easily get accessed to all the information that is related to a product. As a result, supply chain visibility is enhanced, creating a more transparent supply network.

Regarding physical flows, blockchain is predicted to affect food supply chain in a way that its smart contract properties will enable a faster and more efficient way to verify and enforce an agreement, thus saving time and cutting off lead times. In the food industry, where supply chains are characterized by short storage and processing time due to perishability, the shorter the lead time is, the better. With smart contracts, the physical flow will reach consumers at a faster pace, allowing them to enjoy a higher quality as well as a greater variety of food products. In addition, the amount of food waste will be reduced as demand forecast will be more accurate thanks to better supply chain visibility.

In terms of financial flow, blockchain is predicted to make the flow a more direct one, in which intermediate financial institutions will be removed. Especially in international trade, where transactions are usually made using a third-party service, or so-called Escrow to ensure that both parties are protected, the financial flow will be reformed significantly. With blockchain, necessary documents and certifications are uploaded onto the common database, which will be verified and can be accessed conveniently before any transaction is made. Therefore, two parties can transact business securely without the involvement of a middle-man.

4.2.2 Vertical impact

According to subchapter 3.3, the supply chain actors are categorized into four major groups: agriculture sector, processing sector, distribution sector and end-consumer.

Agriculture sector

Despite being the official starting point of the food supply chain, the agriculture sector acts as the consumer for such input materials as fertilizers, seeds, plant protection materials, feed materials, etc., therefore, farmers are also exposed to various supply chain risks. Among these risks, the ones that stem from suppliers of input materials are expected to be better mitigated with the presence of blockchain thanks to its exceptional features that make the data accurate, verifiable and easily accessible. Quality of the input materials can be assured, allowing the farmers to improve the overall quality of their agricultural products.

In addition, the agriculture information technology infrastructure also needs to be improved in order to adapt to the blockchain ecosystem, which consists of other major actors in the supply chain. According to the data analysis and expert interviews on the level of digital advancement conducted by McKinsey Global Institute (2016, as cited in Gandhi, Khanna & Ramaswamy 2016), the agriculture and hunting sector is currently among the least digitally advanced industries, due to the fact that it is highly-localized in scale and labor-intensive. Participating in the blockchain ecosystem, there can be a diverse set of hardware and software requirements to be fulfilled depending on the system provider selected, which signals a must for the agricultural bodies to upgrade their IT systems and conform to the general standards of the other industries in the chain.

With blockchain, information regarding the transactions will be verified when being input into the system, hence the accuracy of data must be thoroughly checked beforehand. Moreover, this would also encourage the farmers to comply with the agricultural policies and regulations in a stricter manner. Blockchain is believed to rigorously control the social and environmental responsibility aspects of the organization.

Processing sector

Along with the agriculture sector, the processing sector is the one that has a direct impact on the quality of food products which are consumed by the human beings. Therefore, the management of input materials plays a significant role in the managerial responsibilities of food processing companies. Similarly supported by the ability to make information verifiable of blockchain, blockchain-enabled food processing firms would be granted a substantial enhancement of input material quality, which results in higher-quality output products.

In addition to the input material quality issue, food fraud is another matter of the processing sector on which blockchain technology is expected to exert its immense influence. The notorious horse meat scandal in the UK in 2013 as well as another recent scandal related to the two giant mean production companies in Brazil have prompted a critical need for a fraud avoidance system (Grierson 2016; Gillespie, Darlington & Brocchetto 2017). A blockchain system would be able to tackle this problem by immediately detect and send notifications in case there is any attempt to modify a product and its related data before it is delivered to the following stages in the supply chain, thus pressuring the food processors into stringently conforming to the regulations and preventing unethical practices at most.

Distribution sector

Even though with the engagement of blockchain, the flow of product from farm to shelf is secured to be smooth at an optimal level, yet there is always a certain degree of risk that food products are contaminated unintentionally, without any party realizing it. In such cases, the process of tracing back the origin used to be complicated and time-consuming. With blockchain, the data can be pulled up in a few seconds, thus significantly reducing the costs for food distributors as well as retailers when identifying, removing and recalling the faulty products.

Furthermore, for retailers, adopting blockchain application is a way to show off their effort to incorporate into a transparent supply chain, to avoid food crime and thus to improve corporate social responsibility. Nowadays the consumers are more and more concerned with this aspect of a business. Especially when it comes to the food that they consume every day, which directly influence their health and safety. This somehow will help attract new customers who pay attention to this aspect of a retailer.

Regardless of the benefits, setting up a blockchain system can be extremely costly for small and medium-sized retailers. As discussed in subchapter 2.4, not only the initial capital is high but also the maintenance costs. Therefore, to compete with the large players in the food retail industry, these small enterprises are expected to make a considerable modification to their expenditure structure to afford having their own blockchain system, or another option is to subscribe to the third-party blockchain application.

Consumer sector

The consumer is probably the party that will benefit the most from the adoption of blockchain in the food supply chain. Firstly, the likelihood of food being contaminated or negatively affecting human's health will be decreasing considerably thanks to the accumulated effect of blockchain on the previous supply chain participants. The nature of a blockchain ecosystem constructively forces the relating organizations to adhere to the regulations concerning the production, processing and distribution of food. As the ultimate purpose of these regulations is to ensure that consumers are served with safe and good-quality food products, blockchain would certainly satisfy the consumers by this way.

Secondly, thanks to blockchain, consumers would be able to purchase and consume food in accordance with their personal needs regarding nutritional value, ingredients or place of origin. In fact, these kinds of information have already been included on the item label for a wide range of products, yet the accuracy of data cannot be verified easily. Blockchain helps information to become verifiable and reliable, thus making information on the product label useful for the consumers.

Finally, the transparency and accessibility of data that blockchain offers would raise customer's level of trust on the food suppliers. When the doubt over the quality of product and the unsafe feeling when purchasing are eliminated, grocery shopping would become a much easier and more pleasing activity to do.

4.3 Status quo

A recent notable project that cannot be overviewed is the collaboration between Walmart, JD.com, IBM and Tsinghua University in a Blockchain Food Safety Alliance to enhance food tracking, traceability and safety in China announced in 2017 (Slocum, Gartner & Lui 2017; Prisco 2017). Investigating the application of Distributed Ledger to provide real-time traceability throughout the blockchain, four companies have created a standard-based method of collecting data about the origin and authenticity of food. This will, therefore, strengthen accountability and provide food stakeholders with clearer insight and transparency into food-handling process from farm to end-use consumer, which has traditionally been a burden in the whole supply chain. (Slocum et al. 2017.)

Specifically, IBM takes charge of developing IBM Blockchain Platform and providing expertise, while Tsinghua University has their National Engineering Laboratory for E-Commerce Technologies counsel technical features and conduct in-depth research into food safety. In terms of Walmart, it is regarded as a world leader in global food safety working closely with suppliers, regulators, industry partners and research community, as well as investing aggressively in food safety research through the Walmart Food Safety and Collaboration Center. In China, Walmart also collaborates with JD.com, one of China's largest retailers to be able to leverage JD's expertise in the adoption of not only blockchain but also artificial intelligence (AI), big data and other disruptive technologies. (Slocum et al. 2017; Aitken 2017a; Churchill 2018.)

The first proof of concept is illustrated by the test of the pork supply chain in China, tracking it from farm to table (Craik 2017). They uplifted almost every piece of information related to the pork, such as processing, dispatching and temperature, to the blockchain so that anyone could witness all steps. Thereafter the pock-tracking project, IBM-Walmart continued with a completely different product, mangoes imported from South Africa. In this pilot, all supplier certificates were uploaded to the blockchain. Since it is challenging for retailers to keep the certificates up to date and audited, more than 50 people were employed to check certificates. Regarding the result, Walmart confirmed that they could simply display all the data associated with the movement of mangoes to the shelf. (Churchill 2018.) Yet success is far from assured, according to Popper and Lohr (2017).

Not only does IBM cooperate with Walmart, the company also has a group of more than 10 firms, including Unilever, Nestlé and Tyson Foods, joining to help develop its corporate blockchain platform in food supply chain (Churchill 2017). The expectation is that the technology improves visibility in order to, for example, quickly identify contamination source in case of incidents. Through the latest IBM initiative, all participants can gain "permissioned access" to trusted data about the origin and state of food for transactions (Aitken 2017b.)

The consortium development by IBM blockchain still came after the introduction of Ambrosus, which is claimed to be the world's first 'trusted' blockchain-based system for food supply chain. The ecosystem is the combination of blockchain technology and other innovative technologies such as high-tech sensors and smart contracts. The fathers of Ambrosus, Swiss-based CEO Angel Versetti and CTO Dr Stefan Meyer, touted the solution as being able to "reliably record the entire history of food from farm to fork". The project's effort won the endorsement of EIT Food and Swiss Quality and Safety Association. (Aitken 2017b.)

Another blockchain-based panacea for food supply chain is conducted by Provenance to track a tuna fish caught in Maluku, Indonesia from landing to factory. Supported by mobile and smarts tag, their blockchain is expected to offer the opportunity to share the truth between all stakeholders, from fishermen, factories, certifiers to consumers. This project has open the door to a new digital ecosystem for traceability with a united language and public infrastructure. (Provenance 2016.)

4.4 Summary

Supported by the verdicts given in Chapter 2 and 3, this chapter fully resolves the first research sub-question SQ1: What are the potential effects of blockchain on food retail supply chain?

On the whole, most of the impacts that blockchain is forecasted to exert on the food retail supply chain are positive. Among the three major flows of a typical supply chain, the information flow is expected to be affected most immensely with the elimination of third-party data storing organizations, the prevention of data-related corrupting activities and the augmentation of supply chain visibility. The blockchain-enabled physical flow of food will potentially move at a faster pace thanks to smart contract, and volume of food waste will decrease. Regarding the financial flow, it is predicted that the engagement of intermediate financial parties will be cut off to a certain extent.

In addition to the common effects that are seen throughout the entire supply chain, the authors also attempted to analyze the individual impacts of blockchain on each supply chain actor. For the farmers, blockchain would benefit them by easing the management of input materials supply. However, in order to adapt to the ecosystem, the agriculture sector would have to invest more on the information technology infrastructure to facilitate the installment of blockchain, which is costly and requires sufficient human resources. Furthermore, blockchain would also pressure this sector to improve the compliance with policies and regulations in a stricter manner. The processing sector is predicted to be influenced by blockchain in a similar way with the agriculture sector. Apart from that, the food fraud issue, which happens the most frequently in this sector compared to the others, is expected to be averted. For the distribution sector, blockchain would assist in identifying faulty products as well as allow retailers to attract more customers by improving the company image with strengthened social responsibility. Nonetheless, the costs of adopting this technology would be a headache for small players in the food retail industry. Lastly, with blockchain, the consumer sector would be able to do grocery shopping much more comfortably thanks to the ensured quality of products as well as the trustable information on the product label.

5 REVIEW OF CASE STUDY

The authors decide to choose a specific practical application of blockchain-enabled supply chain, in that it is much easier to access in concrete terms rather than in the abstract, especially when blockchain has still been such a massive vague concept to the majority of human cognition. However, being a nascent innovation with a vast landscape for development, the application of blockchain in food supply chain has widely gained the attention of the stakeholders within the chain, especially technological companies with professional experts who desire to build a breakthrough blockchain-based solution to food supply chain. Among those programs which have been previously named in Chapter 4, IBM would be selected mainly on the grounds of its popularity and company reputation. The company runs IBM Food Trust platform, which is exactly the blockchain machine behind IBM-Walmart project stated in the prior chapter. More details of the solution would be further discussed in subchapter 5.1.

Subchapter 5.2 is a picture of Malta as a whole, as well as a zoom shot of Maltese food supply chain, and hence will be bisected into two parts with corresponding contents.

5.1 Overview of IBM Food Trust Blockchain

This section aims to illustrate the chosen blockchain solution powered by IBM, specifically what IBM Food Trust stands for, its blockchain type, how it works, its data security and how much it costs.

5.1.1 What IBM Food Trust is

Founded in 1911, International Business Machines Corporation (abbreviated to IBM), is an American multinational technology company (IBM 2008). Having gone with the influx of Industry 4.0, specifically blockchain technology, this giant tech-emperor has developed IBM Food Trust Blockchain to ease the pains of food supply chain, especially food safety and traceability. IBM also claims itself to be one of the pioneering companies to provide the solution in-production using blockchain technology (IBM 2018b, 11).

Figure 14 is the illustration of IBM Food Trust display.

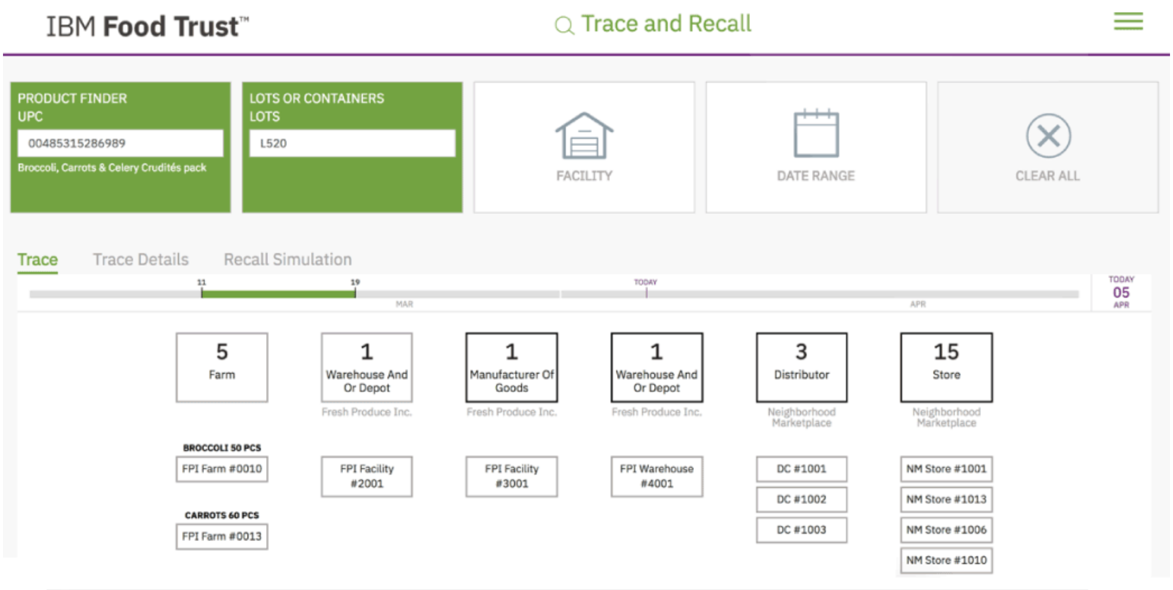

Figure 14 IBM Food Trust (IBM 2018c)

By definition, IBM Food Trust is "a collaborative network of growers, processors, wholesalers, distributors, manufacturers, retailers, and others enhancing visibility and accountability in each step of the food supply" (IBM 2018d). The Trust in Food is built on four new modularized standards that IBM Blockchain promises to ease the existing pains of food supply chain (IBM 2018b, 2.):

- Food Safety. By securely tracing products in seconds can food supply chain actors, such as consumers and retailers, alleviate waste, cross-contamination and spread of food-borne illness;
- Food Waste. IBM Food Trust provides a panacea for product loss and ecosystem unsustainability by sharing and managing data across the food supply chain;
- Food Freshness. Customers of IBM Food Trust are able to identify inefficiencies and ensure quality of goods thanks to the unprecedented visibility into supply chain data for valuable insights and analysis;
- Food Confidence. "Confidence" is gained through important digitalized certificates and documents, which potentially optimize information management, certify provenance and ensure authenticity.

5.1.2 Blockchain type of IBM Food Trust

Powered by IBM Blockchain Platform, IBM Food Trust is built on the Open Standard Hyperledger Fabric, which has been mentioned in Chapter 2 as a popular private blockchain (IBM 2018b, 3). Thus, the system mainly follows the core functions and operation of a permissioned blockchain, compared to those of widely-known permissionless public blockchain such as Bitcoin. This is visualized in Figure 15.

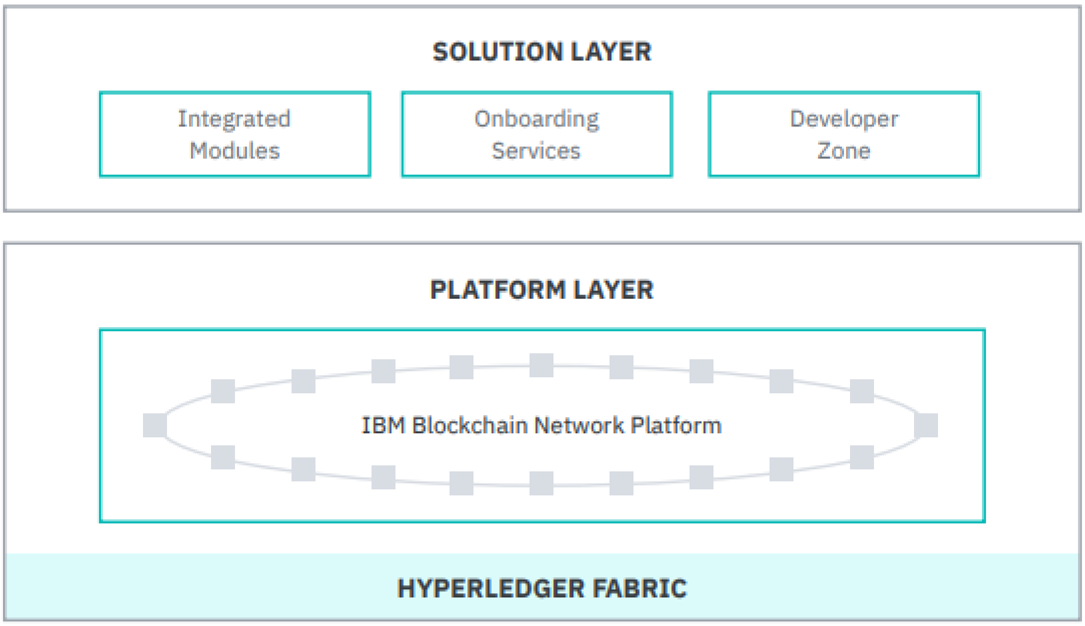

Figure 15 IBM Food Trust with blockchain type (IBM 2018b, 3)

Joining IBM Food Trust, participants are provided with a permission-based shared view of food ecosystem information for convenient data publishing and controlled data sharing, which is achieved by allowing all peers to enter and manipulate access to encrypted blockchain data. Therefore, the prominent features of permissioned blockchain are utilized as transaction partners can only get access to the data once they have been permissioned to view. Access controls also ensure the full control over access right of the data-owned organization. In IBM Food Trust, the access right to locate items from supply chain in real time could be given by querying food product identifiers, for example Global Trade Item Number (GTIN) and Universal Product Code (UPC) with the product name and filtered dates. All the product-related information is stored on blockchain ledgers and securely kept with “the highest level of commercially-available, tamper-resistant encryption”. (IBM 2018b, 3.)

5.1.3 How IBM Food Trust works

In order to take part in IBM Food Trust ecosystem, organizations are required to sign up online and purchase the most appropriate plans for themselves. Having accessed to the solution, the organization will formulate and authorize a specific team that assumes responsibility for registering and integrating all pertinent information. (IBM 2018b, 4.)

The team should be assigned predefined roles in order to execute network tasks representing their organization. An Account Administrator is who assigns a role to each user, including (IBM 2018b, 5.):

- Account Owner. This is the user who can manage organization account settings and subscriptions;
- Account Administrator. An Account Administrator can change users and organization settings;
- Certifications Manager. The user acts by adding, deleting and modifying certifications and documents;
- Food Safety Team Member. There can be more than one members that view data (at authorized organization-level), trace products and view certifications;
- Onboarding Team Member. The member(s) take(s) charge of creating product scenarios and uploading data.

After the process of team composition finishes, there are three essential modules that network participants should obtain to be system experts: Data Entry and Access, Trace, and Certifications.

Data Entry and Access

IBM Food Trust enables enterprises, such as retailers, distributors and processors, to upload or programmatically forward four key data elements:

- Supply chain events
- Transactions
- Master data
- Certificate data

With respect to existing business records (inventory lists, order records, supplier information, e.g.), automated data import is prepared with the help of the IBM Food Trust Connector API for the integration of legacy system data and network data. (API stands for Application Programming Interface, which technically supports IT teams to upload supply chain data from present data stores to new IBM Food Trust network.) (IBM 2018b, 6.)

Trace

Uploaded on IBM Food Trust ecosystem by participants, the provenance of a food product is now to be searched by an authorized user (retailers, suppliers, consumers, e.g.) through trace module. Apart from GTIN, product name and/or Purchase Order, a specific date also helps narrow down the search. The trace module can be seen as the most visible benefits to supply chain actors, especially end-consumers and supply partners as it paves the way for the quick and accurate determination of a given shipment. Hence, users have the ability to identify within seconds whether food is contaminated or safe to react immediately. In addition, product waste can be reduced while customer satisfaction and trust are increased. This module is also expected to give direct insight into inventory and supply chain inefficiencies, one of the sores of the whole supply chain for a long time. (IBM 2018b, 7.)

Certifications

The Certifications module serves as a place to upload and manage the facility certificates and other business-enabling documents, for instance, licenses, inspection results and authorizations. If there exists conflicting or outdated certificates, they are instantly flagged for review. (IBM 2018b, 8.)

In addition to these three modules, IBM Food Trust is planning to develop more functions for the approach in the near future (IBM 2018b, 4.)

5.1.4 Data security

As a permissioned ledger, IBM Food Trust employs the security benefits of the underlying IBM Blockchain platform and Hyperledger Fabric network. There is no required cryptocurrency such as Bitcoin and Ethereum or other processor-intensive computations in order to guarantee the legitimacy and permanence of network transactions. According to IBM experts, it is the owner of the data that totally controls who can see it on a Hyperledger Fabric network. (IBM 2018b, 10.)

5.1.5 Plans and pricing

Presently IBM offers four different modularized solutions as a subscription service traceability, three of which depend on business sizes. They specifically are: Trace for Small Business, Trace for Medium Business, and Trace for Large Enterprise and finally, Virtually-Guided Onboarding. More details are shown as below (IBM 2018c):

- **Trace for Small Business.** The service does wonders for businesses with the annual revenues of less than USD 50 million by helping them see the provenance, location as well as the status of food products on the supply chain. Retailers need to allow for at least EUR 96.50 per month as the expense to enjoy unlimited data upload, end-to-end traceability of supply chain and choice to add Certifications module to upload and manage certifications;

- **Trace for Medium Business.** This type of purchase is specifically designed for medium businesses with the annual revenues between USD 50 million and USD 1 billion. Basically, the advantages function in the same way as the first type, what differentiates is the prices starting at EUR 965.00 per month;
- **Trace for Large Enterprise.** As the name has suggested, Trace for Large Enterprise aims at Large Enterprise customers with annual revenues of more than USD 1 billion. Who wishes to join the service should spend EUR 9,650.00 per month;
- **Virtually-Guided Onboarding.** The payment for this designated solution is one time charge going from EUR 4,825.00 regardless of enterprise sizes. Being virtually-guided means engaging with IBM experts and receiving guidance from a set of virtual education sessions. Customers benefit from four additional hours of support and opportunity for Q&A session. In addition, there is one added option to buy more hours of onboarding guidance.

5.2 Malta country analysis

In this subchapter, by conducting PEST analysis, the authors would like to point out the country-specific features of Malta as the background for a more thorough study of the adoption of IBM Food Trust Blockchain.

Thereafter PEST analysis is completed, the emphasis is laid on the area of retailing in Maltese food supply chain. As explained in Chapter 3, the catering section would be excluded from food supply chain in the context of this thesis.

5.2.1 PEST analysis

All the actors, including those in supply chain, operate in a large macro-environment of turbulent and changing forces by which even the most giant emperors can be shaken. They can not only shape opportunities but also pose threats to any company. Unforeseeable and uncontrollable as some of these forces are, others can be predicted and handled. (Kotler & Armstrong 2014, 96.) Therefore, it is of paramount importance that the macro-environmental factors should be taken into account when examining the feasibility of a technological innovation.

Table 3 Factors of PEST analysis (Whalley 2010, 56-57)

Political factors	**Economic factors**
• Environmental regulation and protection • Taxation (corporate, consumer) • International trade regulation • Consumer protection • Employment law • Government organization/attitude • Competition regulation	• Economic growth (overall, by industry sector) • Monetary policy (interest rates) • Government spending (overall level, specific spending priorities) • Policy towards unemployment (minimum wage, unemployment benefits, grants) • Taxation (consumer disposable income, capital equipment, corporation tax rates) • Exchange rates (import, export) • Inflation (costs, selling prices) • Stage of business cycle • Economic mood – consumer confidence
Social factors	**Technological factors**
• Income distribution (change in distribution of disposable income • Demographics (age structure of the population; gender; family size and composition; changing nature of occupations) • Labor/Social mobility • Lifestyle changes (e.g. home-working, single households) • Attitude to work and leisure • Education • Fashions and fads • Health and welfare • Living conditions (housing, amenities, pollution)	• Government spending on research • Government and industry focus on technological effort • New discoveries and development • Speed of technology transfer • Rates of technological obsolescence • Energy use and costs • Changes in material sciences • Impact of changes in Information Technology • Internet

In the context of this thesis with Malta as the main focus, the authors would review macro-environmental features at national level with the aid of PEST analysis. It is one of the most common approaches for acquiring the understanding of the external business environment. PEST stands for Political, Economic, Social and Technological (factors). (Gupta 2013, 35.) The framework conveys the reflection of strategies and ideas requiring a fit between capabilities and external environment, thus indirectly suggests appropriate reactions from related parties. Table 3 summarizes the description of these four factors.

Among a number of elements of each factor, the authors will choose the fit and proper features to meticulously present in the subsequent parts on the scale of this thesis's researching purpose.

a. Political/Legal factors

Malta has been a European Union member since 2004 and four years later the country adopted the Euro as its currency. In 2007 it joined Schengen area. (European Union 2018.) It is reasonable to assume that Malta acquires a "full'' profile of an EU member.

Therefore, Maltese trade policy is fastened to EU regulations. The government of Malta, apart from building a national economic framework which emphasizes small and micro enterprises as well as creates a positive environment, follows EU-related activities with fullest participation. (Malta Ministry for the Economy, Investment and Small Businesses 2018.)

Malta also has a competitive tax regime attracting a lot of companies, as Malta's Junior Minister for Financial Services, Digital Economy and Innovation confirms (Wolfson 2018). Both individual residents and corporations can enjoy some of the EU's most tax-friendly systems, with 35% as standard corporate tax rate and that as low as 5% possible for non-resident companies. Moreover, no tax is levied at the provincial or municipal levels and company profits are only subject to corporate tax to eliminate double taxation. (Deloitte 2014, 10; Government of Malta 2017; Henderson 2018.)

However, what recently makes fame gravitate towards the small island is the earned name ''Blockchain Island'' mainly due to being the first jurisdiction around the globe to adopt three blockchain regulations concerning distributed ledger technology, cryptocurrency and digital assets (Aitken 2018). The blockchain regulatory framework, which was officially approved by Parliament in July 2018, is composed of the Malta Digital Innovation Authority Act, the Innovative Technological Arrangement and Services Act, and the Virtual Financial Asset Act. The Three Bills clearly reflects the Maltese Government's aspiration to become an economic pioneer through innovation, as well as the strong belief in technology addressed by Malta's Prime Minister: "I passionately believe technology revolutionizes and improves systems". (Pace 2018; Bambrough 2018.)

In addition to legal acts, Maltese Government will be allocating EUR 300,000 as scholarships for students with academic research in Blockchain and Distributed Ledger Technologies in the next three years. According to Malta Information Technology Agency's (MITA) Executive Chairman, the initiative serves as part of their national strategy to invest in new technologies and to become a center for blockchain. (MITA 2018.)

The strategy is further supported by the Malta Blockchain Summit taking place from October 3 - 4 and known as the first government-backed blockchain conference (Wolfson 2018). Under controversial circumstances with neutral vague perspectives or even negative actions on blockchain-related issues (such as Google's Bitcoin ad-ban), Maltese politicians strongly prove themselves to be the advocates for this disruptive technology. Recently Malta's Junior Minister for Financial Services, Digital Economy and Innovation even has emphasized that the blockchain community is more than welcomed in Malta (Wolfson 2018).

Compared to the rest of the European Union where cryptocurrency regulation is still a mixed bag despite of several basic precautions by the EU Parliament, the enacted holistic blockchain laws in Malta have blown up some concerns over widespread corruption and possible clashes with EU law (Golstein 2018). The Maltese regulatory institution has actually been facing increased pressure from European Banking Authority, the European Parliament and the European Central Bank, according to Aru (2018). Notwithstanding the suspicions, Maltese officials confidently state that they adopt EU-reflecting laws onto their blockchain laws, such as market integrity, consumer protection and industry protection (Wolfson 2018).

b. Economic factors

In spite of being the smallest country in Euro zone, its geographical location in the middle of the Mediterranean, between Europe and North Africa, makes the Maltese archipelago become a strategic position that fosters its development as an important trading economic post (BBC 2018). Some of basic statistics of Maltese economy in 2017 are summarized in Table 4.

Table 4 Basic statistics of Maltese economy in 2017 (CIA 2018)

Pattern	Value	World rank
Gross Domestic Product (GPD)	$19.31 billion	151
GDP – real growth rate	6.6%	28
GPD – per capita (PPP)	$42,000	43
GDP – exports of goods and services	145.4%	no data
GDP – imports of goods and services	-135.5%	no data
GDP – composition, by sector of origin (2016)	Agriculture: 1.3%; Industry: 10.6%; Services: 88.1%	
Imports	$5.191 billion	123
Exports	$2.627 billion	132
Unemployment rate	4.4%	63
Taxes and other revenues	35.8% of GDP	54
Budget surplus (+) or deficit (-)	-0.5% of GDP	53
Public debt	52.6% of GDP	97
Inflation rate (consumer prices)	1.3%	70

According to European Commission (2017a, 3), there were exceptional levels of Maltese economic growth in 2014 and 2015. Having slightly settled down in the subsequent years, the pace of growth remains buoyant and is among the highest in the Euro zone (6.6% in 2017, as shown in Table 4), compared to the EU average GDP growth rate – 2.4% in 2017. (European Commission 2017a, 3; The World Bank 2018b.) Over the past few years, the GDP growth has been further enforced by the increasing relocation of other EU and European migrants for employment. In addition, Malta maintains one of the lowest unemployment rates in Europe (4.4% in 2017) with low inflation (1.3% in 2017). (CIA 2018.)

Being an archipelago dominated by sea water, the free market of Malta is strongly dependent on foreign trade and tourism when it produces less than a quarter of the country's food need and the fresh water supplies as well as domestic energy sources are scarce (CIA 2018). Therefore, Malta is considered to be one of the most open economies in the world with exports and imports rising from 200% of GDP in the 1980s to approximately 300% in recent years (Grech 2015, 22).

With regard to export sector, the three biggest export partners are EU Members, which are Germany (17.3%), France (10.2%) and Italy (9.4%). The US and Asian countries, namely Singapore, Hong Kong and Japan also act as important exporting markets of Malta. (CIA 2018.) The five largest commodity groups of Maltese exports in 2017 are (Malta National Statistics Office 2018, 3):

- Mineral fuels, lubricants and related materials (39.0%)
- Machinery and transport equipment (27.0%)
- Chemicals (10.5%)
- Miscellaneous manufactured articles (10.4%)
- Food (7.7%)

The most important import partners of Malta are Italy (23%), Germany (7.9%), UK (7.7%) and Spain (5%), Canada (4.5%), US (4.3%) and France (4.2%) (CIA 2018). It is markedly seen that almost of the strategic traders of Malta are from Europe and North America. The five largest commodity groups of Maltese imports in 2017 are (Malta National Statistics Office 2018, 3):

- Machinery and transport equipment (36.6%)
- Mineral fuels, lubricants and related materials (29.0%)
- Food (10.2%)
- Chemicals (8.5%)
- Miscellaneous manufactured articles (7.7%)

It is apparent from the information that food products account for rather a considerable sector of foreign trade in Malta, implying an indispensable part with possibly complex work for supply chain. Interestingly, while the total value of imports in Mata decreased from EUR 6,447.0 million in 2016 to EUR 6,121.9 million in 2017, that figure of food witnessed a slight increase by EUR 52.8 million (Malta National Statistics Office 2018, 3). In terms of food import partner share, European countries continue to dominate the landscape, according to Figure 16 below.

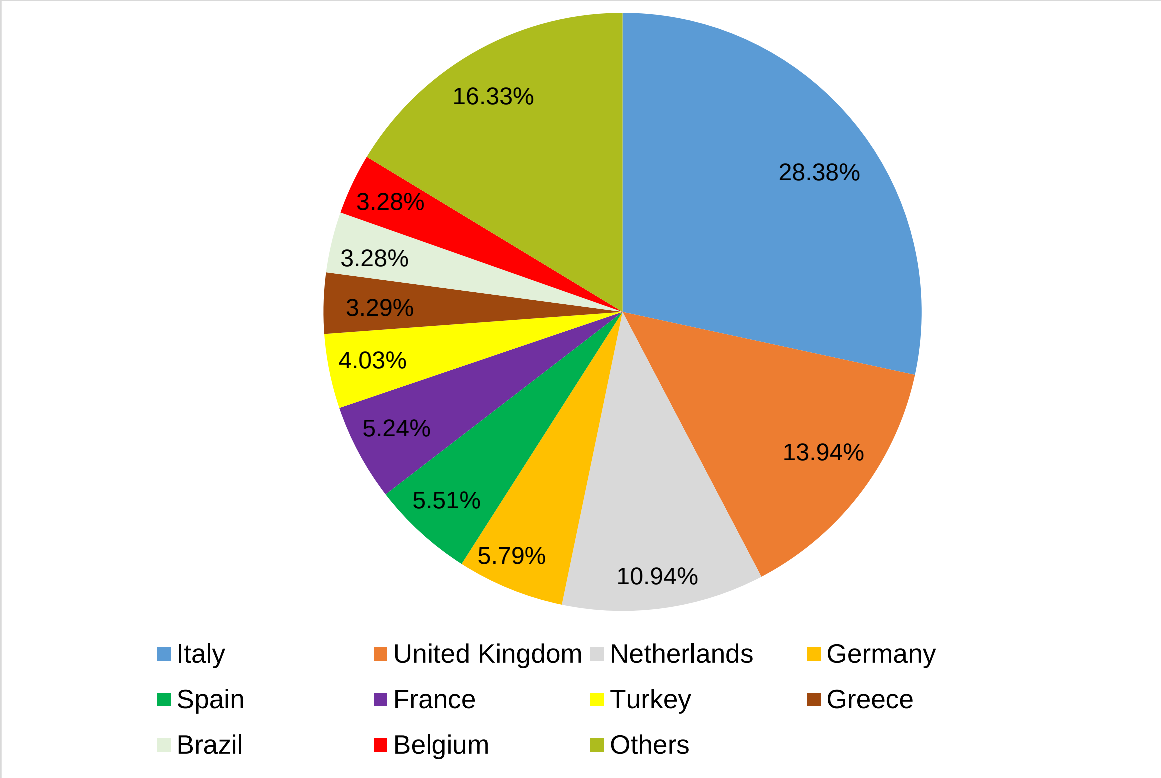

Figure 16 Malta food import partner share 2016 (World Integrated Trade Solution 2018)

Another considerable factor in the Maltese economy is the significant comparative advantage in gaming sector thanks to i-gaming framework. Some argue that the Government passing blockchain laws reminds EU of the event in 2004 when the State was the first EU Member to regulate i-gaming, which helped attract foreign investments to develop technical skills for local operators. This green industry was calculated to reach a gross value added (GVA) of 899.6 million euro in 2015, accounting for 11.1% of total GVA. (European Commission 2017, 8.)

c. Social factors

Tiny as the Maltese Islands are, the country is still famous for an extremely rich culture with the eclectic history. The society, in general, enjoys a wide variety of lively activities and events, such as annual feasts and special occasions. (Government of Malta 2015). In terms of other essential social information, Table 5 indicates some basic statistics of Malta in 2017.

Table 5 Basic social statistics of Malta in 2017 (CIA 2018)

Population	416,338 (world rank: 175)
Ethnic groups	Maltese
Official languages	Maltese and English
Religions	Roman Catholic
Age structure	0-14 years: 15.04% 15-24 years: 11.44% 25-54% years: 39.98% 55-64% years: 13.98% 65 years and over: 19.56%
Median age	41.8 years
Population growth rate	0.26%
Net migration rate	2 migrants/1000 population
Major urban areas – population	Valletta (capital) - 213,000
Urbanization	94.6% of total population
Heath expenditures	9.7% GDP
Literacy (age 15 and over can read and write)	94.4% of total population

With a population of less than half a million, Malta is one of the smallest countries in the world but one of the most densely populated (1367.37 people per km^2), compared to that figure of EU (120.91 people per km^2) (Malta population 2018; Statista 2018). Among the three inhabited islands of the country, namely Malta, Gozo and Comino, the eastern half of Malta is home to most of the population. Urban citizens constitute the majority of the total population with more than 90%. (CIA 2018.)

Apart from the positive figures, Malta is somewhat shadowed by several social issues. One of the most long-standing labor problems is low female activity rate. Although the free childcare has been introduced to specific categories, its existing conditions are likely to work against deprived unemployed families. What cannot be left out is the poverty especially among four groups: children, the old, the unemployed and the working poor, in spite of the general well-being at large. The main causes are addressed to the inadequate pensions and increased rents. Another current phenomenon is the immigration flows, which are categorized into three types: migrants from sub-Saharan nations; immigrants from EU member states, and third country nationals outside EU. The streams have formed some social challenges to the Maltese government, such as medical care for migrants, migrants and childcare, and public debate. (Vassallo 2016, 13-14; 28-29.)

Regarding cultural aspects, Malta is an individualist society with high levels of uncertainty avoidance and indulgence according to Hofstede's cultural dimensions (Hofstede Insight 2018). This can be illustrated in Figure 17.

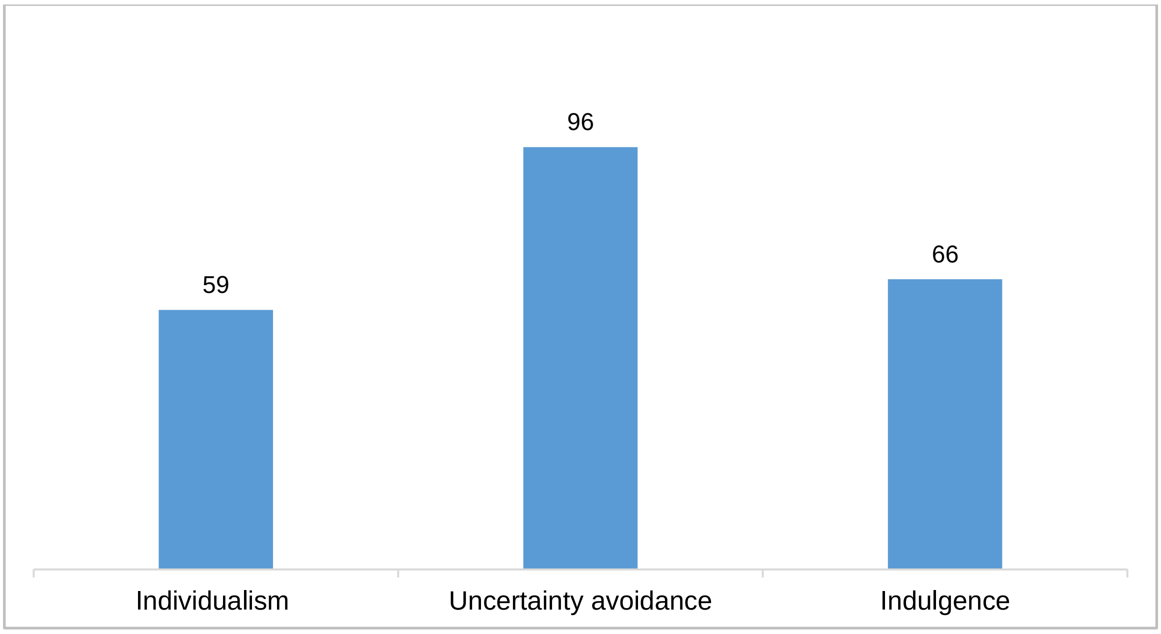

Figure 17 Maltese cultural indicators (Hofstede Insight 2018)

A score of 59 in Individualism indicates that Malta highly prefers a loosely-knit framework where individuals are expected to care for themselves and their close families only. In workplace, the relation between employer and employee is simply and straightly based on mutual advantage.

Malta scores a nearly absolute number (96/100) on uncertainty dimension, which means a preference for avoiding uncertainty. There maintain rigid codes of belief and behavior, as well as an emotional need for rules. People regard time as money and require precision and punctuality. Innovation is possibly resisted and security plays as a vital element in individual motivation.

With a relatively high score of 66, Malta's culture is signified to be one of Indulgence. They are said to have a positive attitude with a tendency towards optimism. More emphases are also placed on leisure time. (Hofstede Insight 2018.)

d. Technological factors

Malta possesses a total of 320,902 Internet users, making up 77.3% of the population. As for broadband-fixed line subscriptions, there are 181,318 people, which is equivalent to a ratio of 44 subscriptions per 100 inhabitants. (CIA 2018.)

In 2017, Malta spent 0.19% of GDP (21.29 million euro) on research and development (R&D). The budget appropriations witnessed a slight decrease compared to that figure in 2015 with 0.26% of GDP (24.29 million euro) (European Commission 2018a). Nonetheless, the country is planning ahead to boost its research and innovation (R&I) performance by designating *The Peer Review of the Maltese Research and Innovation System* with the aid of a group of experts from Switzerland, Belgium, Slovenia, Portugal, the Netherlands and Ireland (European Commission 2018b).

As mentioned in the previous part, Malta has been constructing the “Blockchain Island”, implying the multifaceted supports not only for legal factors but also technical ones. There has been an increase in the take-up of high-speed broadband as well as the availability of mobile broadband – Long Term Evolution (LTE) / 4G. In addition, Maltese IT experts widely adopt Software as a Service (SaaS), cloud computing and big data. (Herrera & Woods 2014, 6-23.)

5.2.2 Food supply chain in Malta

As the authors have mentioned in Chapter 3, the food supply chain can be described as the composition of retailing and catering sectors. As a matter of fact, the latter part would be ironed out in the best interests of this thesis with the focal point in unprocessed and semi-processed foods sold by different food retail formats.

On the other hand, the authors would give a brief description of the European food supply chain before digging deep into the Maltese food retailing supply chain. The supply chain itself definitely involves foreign trade, not to mention the fact that Maltese economy has been experiencing import surplus when only less than a quarter of food need can be domestically produced, as distinctly evidenced by the PEST analysis. Additionally, almost all of the import partners of the countries are from European Union, such as Italy, the United Kingdom, the Netherlands and Germany (as shown in Figure 16) and being an EU member ties the knot of Malta and the movement of EU as a whole. Thus, in order to penetrate into the Maltese food retailing supply chain, the knowledge of EU food supply chain is of the essence.

To put it in a nutshell, this section will be divided into two parts. After the first part has outlined the big picture of the food supply chain in the whole European Union, there comes the second part with a revealing analysis of the Maltese food supply chain.

a. EU food supply chain

In terms of jobs and value added, the food and drink industry is fully recognized as the EU's biggest manufacturing sector and has yet to show the suspicion of a slowdown. Over the last decade, EU has witnessed a twofold increase in the revenue of food exports to reach over EUR 90 billion, positively balancing the external trade's total value of EUR 30 billion. (European Commission 2018c.) Thus, the European food chain, as a huge part of the food and drink industry, is a vast hectic influential landscape that is worth investigating.

Regarding the scope of the thesis, the authors would view the EU food supply chain from three different facets: the EU actors of the food supply chain, EU regional trade and world markets, and finally, current grocery retailing-related trends and activities in the whole EU.

Actors of the food supply chain in European Union

According to the literature review in Chapter 3, the food supply chain is composed of three sectors: the agricultural sector, the food processing industry and the distribution sectors (wholesalers and retailers). EU food supply chain follows the same format with the number of actors greatly varying at each level. Approximately 11 million farms are producing agricultural goods that are later processed by around 300,000 food-specializing companies. Those companies are vendors of 2.8 million enterprises operating in food distribution and service industry, which serve half a billion EU consumers. (European Commission 2017b, 2.) Markedly, much more concentration is laid on the food processing industry and the distribution sectors than on the agricultural sector.

With regard to employment, the food supply chain accounts for a 10% share in EU employment, which means there were 24 million people working in the field in 2014. The total turnover numbers EUR 3.9 trillion, adding up to EUR 700 billion in the value added, and making 6% share in EU gross value added. (Food Drink Europe 2017, 9.) The breakdown of driving forces in the 2014 food supply chain is depicted in Table 6.

Table 6 Breakdown of driving forces in the EU food supply chain 2014 (Food Drink Europe 2017, 9)

	Agriculture	Processing	Wholesales	Retail
Turnover (EUR billion)	414	1,095	1,254	1,114
Value added (EUR billion)	211	219	104	164
Number of employees (million)	11.2	4.2	1.9	6.3
Number of companies (1000 units)	10,800	292	341	803

It is interesting to note from the table that even though there are by far the most number of employees and companies in the agricultural sector, the turnover it achieves is by far the lowest. The three remaining actors generate rather equal revenues, but quite different value added. While the wholesales of agricultural products enjoy the highest turnover (EUR 1,254 million), the greatest value added goes to the processing sector (EUR 219 million).

EU regional trade and world markets

The EU market itself, or the Single Market, is the biggest customer of the EU food and drink products when almost three fourths of regional food and drink exports are consumed inside EU. Intra-EU exports amount to EUR 254.6 billion, contributing to more than a quarter of the turnover, whereas that figure of extra-EU exports is just EUR 102 billion, which is even less than half of the intra-EU’s revenue. (Food Drink Europe 2017, 12.)

The top 15 intra-EU food and drink exporters are represented in Figure 18.

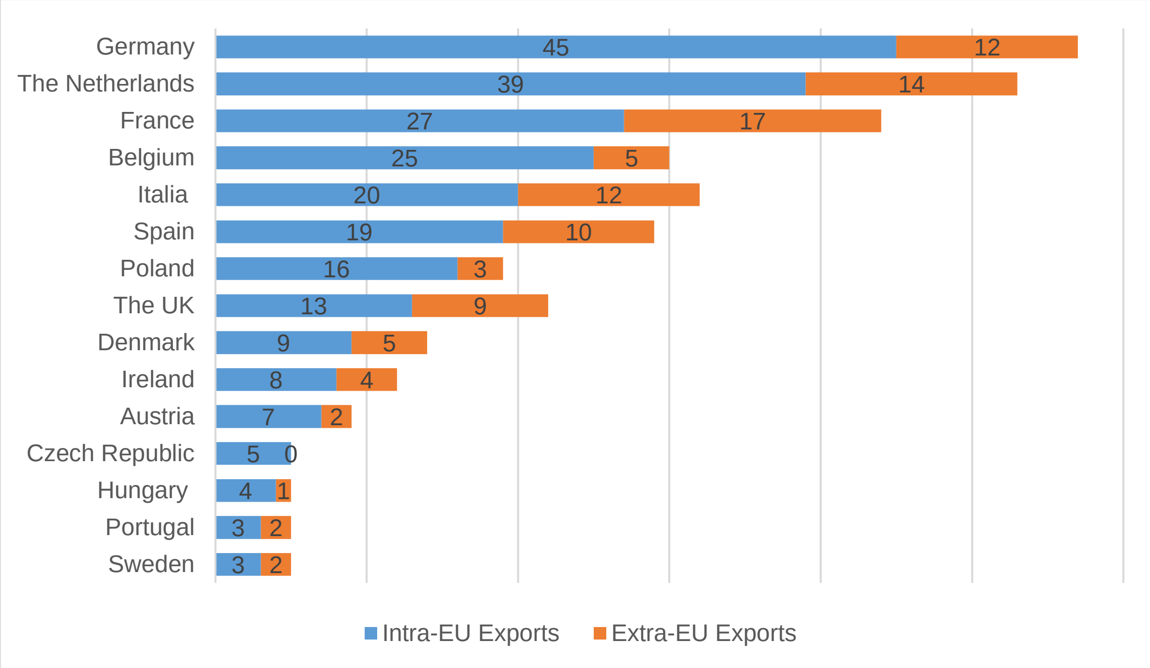

Figure 18 Intra and extra-EU food and drink exports for the top 15 intra-EU exporters (2016, EUR billion) (Food Drink Europe 2017, 12)

Seen from the above chart, Germany dominates the import and export landscape within the Single Market. All the countries in the top 15 follow the same trend as the whole Europe when the revenues of intra-EU exports outnumber those of extra-EU exports. There is even no income from extra-EU exports in Czech Republic.

Turning to world markets, international trade plays a crucial role in the development of the industry. After seven consecutive years of positive growth, EU food and drink exports continued to experience a plus change to reach EUR 102 billion in 2016, in contrary to imports that decreased by 1% compared to 2015 (EUR 71.9 billion in total). Key markets in terms of exports include US, China, Switzerland, Norway, Japan, Russia, Australia and Canada. When it comes to imports, apart from the first four names just mentioned, the top trading partners are Brazil, Argentina, Indonesia, Thailand and Turkey. (Food Drink Europe 2017, 14-15.)

Current trends and activities

In general, the EU food and drink industry is assumed to be rather competitive in a global scale thanks to the high-quality, healthy and safe food products. However, recent years has seen a reduction in the relative competitiveness largely due to the slowdown in labor productivity and added value. Further, the transparency-related issues and suboptimal business-to-business relationships have been reported all over the food chain. (European Commission 2018c.)

In response to the challenges, the EU officials have strived to implement some strategies to harmonize the situation as well as to upgrade the competitiveness of the Single Market. By illustration, a new High Level Forum for a Better Functioning Food Supply Chain was set up to support the policy development in the food sector, especially food supply chain (European Commission 2018d). In addition, the European Commission has undertaken an initiative to improve the food supply chain by a series of activities, such as the legislative proposal concerning Unfair trading practices in the food chain, and a workshop on market transparency in May 2018 (European Commission 2018e; European Commission 2018f).

What cannot be overviewed is Brexit, the acronym of Britain leaving EU in the near future. The UK is the largest trading partners of EU27, including Malta with rather a close link to this nation. With the total value of food exports amounting at EUR 31.3 billion (2016), EU27's exports turnover for the UK doubles the exports to the US and trebles the exports to China (Food Drink Europe 13). Thus, Brexit has been a matter of concern to the EU food supply chain.

b. Maltese Food Supply Chain

Being a small yet densely populated island, the food supply chain in Malta, apart from being impacted by some main characteristics with that of the whole mainland EU, definitely bears unique distinct features. In this part, the authors focus on evaluating some of those elements: Maltese retail distribution sector, the constraints of Maltese food supply chain, and its high dependence on imports.

Maltese retail distribution sector

As respects retail type, small local shops and street vendors mainly selling fruits and vegetables are commonly found on every corner of the islands. Small trading companies, mostly family businesses, gain the domination of the market. These individual companies act as importers, wholesalers and distributors. However, the entry into the EU with the increasing presence of European retailers has blown the wind of forced reforms to the country. For instance, two of the major French retailers, Carrefour and Auchan, through their Italian subsidiaries, can bring their products into several local supermarkets which have long been lonely players in food retail business. There are about ten shopping malls in Malta, including stores of UK retailer MARKS & SPENCER and German retailer Lidl. (Biasetti 2010, 3.) Notwithstanding that, the food and drink sector is absolutely dominated by pure-Maltese companies with 80% being Maltese-owned. (Trade Malta 2016, 3).

A survey conducted by MaltaToday, a local newspaper, partially shows the consumption tendency of Maltese people towards several retail formats, as illustrated in Figure 19.

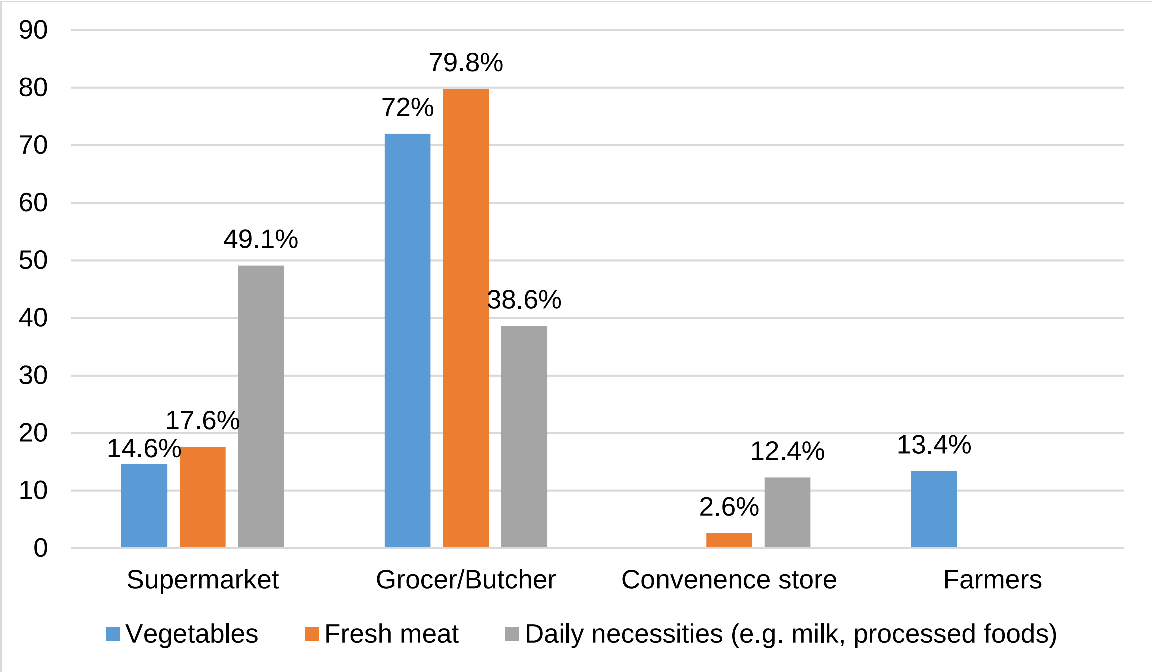

Figure 19 The consumption tendency of Maltese people towards several retail formats (Debono 2016)

It is evident from the chart that generally supermarkets only account for a limited share of the whole food market. Maltese consumers still gravitate towards green grocer and butcher to purchase vegetables and fresh meat. The percentage of people who buy directly from farmers are even nearly equivalent to that of who buy from supermarkets (13.4% and 14.6% respectively). However, when it comes to processed food and other daily necessities, supermarkets are what dominate the food landscape with nearly half of the respondents choosing this retail format. Convenience stores serve the lowest proportion of people, implying the smallest market share in Maltese food supply chain.

Among the supermarkets in Malta, Lidl is proven to be by far the most common, according to the result of the same survey mentioned before. This is visualized in Figure 20, which clearly shows that the German retailer is the first store of choice of almost half of the respondents, implying that the giant discount chain is the biggest player in the field of food supply chain in Malta. 15.4% prefer Pavi located in Qormi and nearly 11% goes for Smart supermarket in Birkirkara. In addition, 63% of Lidl's customers also shop from other supermarkets, suggesting its complementing role (Debono 2016).

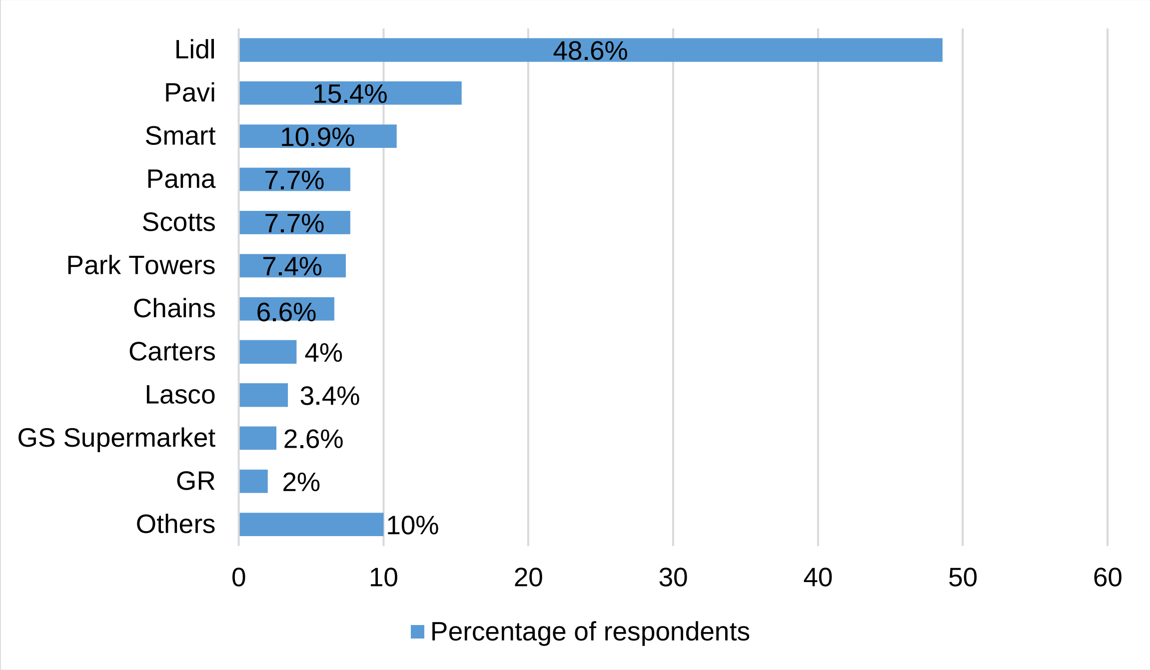

Figure 20 Supermarkets where respondents buy food from (Debono 2016)

As a reflection on retail type and format, 41% of the food-involved companies fall into the category of micro enterprises with less than 10 employees. As for the middle and large segments, only 29% belong to the former (between 10 and 100 employees) and 32% go to the latter (over 100 employees). These figures indicate that the majority of companies (around 71%) are either quite small or quite large based on Maltese standards. The characteristics of retail size in the Maltese food landscape are also depicted in the turnover figures. The companies which achieve a turnover of less than EUR 1 million account for 35% while more than a half (53%) earn EUR 5 million annually. The whole food sector is expected to be a stable playground with inconsiderable changes in market share. (Trade Malta 2016, 3-4.)

Some long-standing constraints of Maltese food supply chain

Mainly due to the geographical features, Malta has been suffering from a number of lasting structural constraints limiting the food supply chain’s competitiveness. First and foremost, land scarcity, further compounded by fragmentation and poor soil quality, gives rise to a high economic rental value of land, which indirectly rises the cost and even reduces the quality and productivity of agricultural products. Second comes the lack of fresh water reserves that forces the farming community to tap all water aquifers for irrigation. Third, the chain is also stressed by the lack of feed material options when Malta has to completely import cereals and other feed materials in the setting of increased costs for sea transports and logistics because of relatively small parcels. Last and by no means least, the small size of the local market leads to low economies of scale and high costs throughout the production and food supply chain. (George & Anthony 2008, 298; Buttiġieġ & Zahra 2012, 40; Atriga Consult 2018, 33.)

High dependence on imports

The geographical position of Malta once again attributes to its high dependence on imports when domestic agricultural production cannot adapt to the country's needs. Figure 21 clearly visualizes its complete reliance on imported food products.

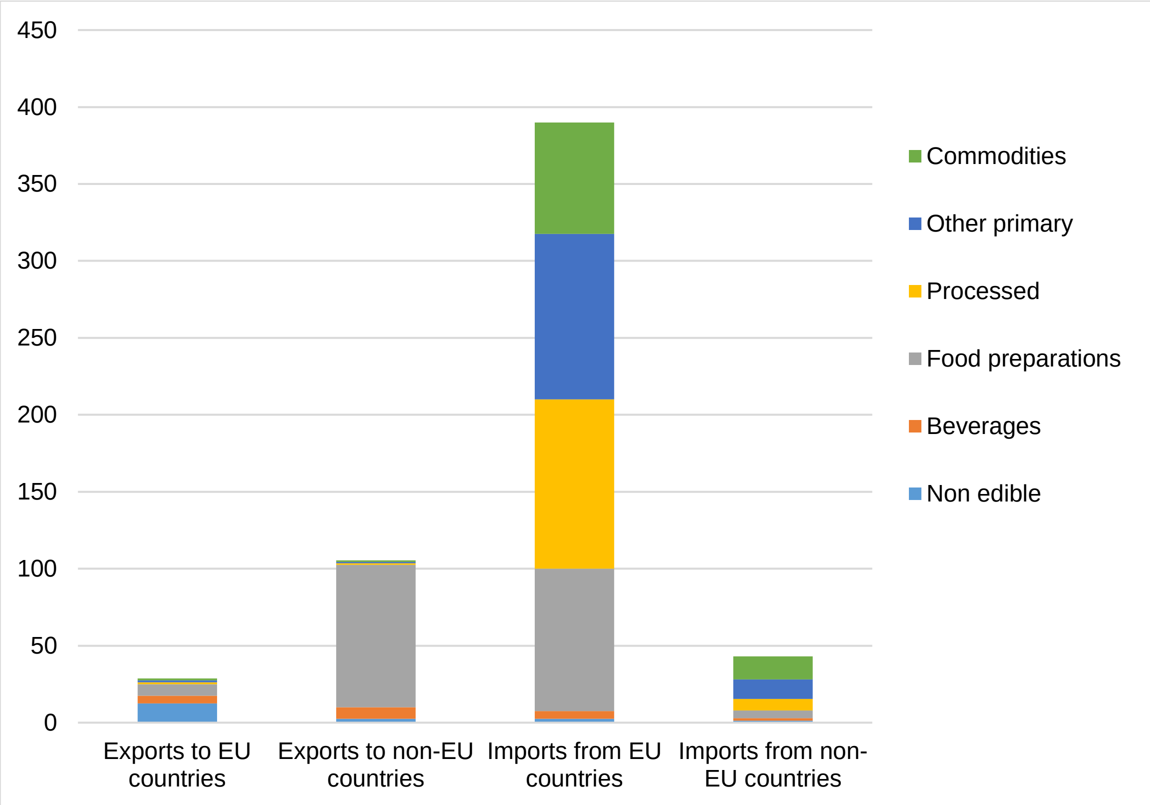

Figure 21 High dependence on imports (total agricultural products in EUR million, 2014) (European Commission 2016, 6)

According to the chart, the imports from EU countries obviously outnumber the rest of the patterns. Food preparations, processed products and other agricultural primary products indicate what are imported with the largest quantities into Malta, on an average value of around EUR 100 million in 2014. In comparison with those products, most of the goods types in the other patterns are inconsiderable. However, there is an exception for food preparations when their value in the exports to non-EU countries was relatively equal to that in imports from EU countries in 2014.

On the other hand, only a few Maltese food companies have been successful in internationalization through an export strategy, the majority express a crystal clear preference for the domestic market. Only a fifth of the companies confirmed 45% or more of the turnover as exports revenue. 10-20% and 1-5% were reported by 15% and one or two companies respectively, which implies either budding export ventures or sporadic exports. (Trade Malta 2016, 4.) This fact, associated with the high dependence on imports, is attributed to the import surplus of Malta food supply chain.

5.3 Summary

Chapter 5 directly answers the second sub-question SQ2: How does the macro-environment affect the adoption of blockchain in food retail supply chain in Malta?

By investigating a set of macro-environmental factors (political, economic, social and technological) and separately the food supply chain in Malta, the authors have come up with potential effects that macro-environment is able to impose on the adoption of blockchain in the grocery retailing in Malta. The effects are forcefully expressed in the form of supportive and deterrent conditions that the surroundings can create and are shown in Table 7.

Table 7 Supportive and deterrent conditions

Supportive conditions	**Deterrent conditions**
• There is a competitive tax regime that can attract a lot of companies, possibly blockchain companies. • Malta is a “Blockchain Island” and the government approved the blockchain regulatory framework, appearing to be a blockchain advocate with a strong belief in the technological revolution. • Malta is a Euro zone economy with sustainable economic growth, providing a steady environment for blockchain. • Malta is strongly dependent on foreign trade with import surplus. Food is one of the largest commodity groups of Maltese imports with the biggest import partners from EU countries. As for a food supply chain	• Malta is a member of EU where cryptocurrency regulation is still a mixed bag despite of several basic precautions by the EU Parliament. Therefore, some concerns over widespread corruption and possible clashes with EU law have been blown up. • According to Hofstede’s cultural dimensions, Malta shows a preference for avoiding uncertainty, in which innovation is possibly resisted.

tied with foreign trade, the issues of transparency, traceability and food safety, the current challenges of the field, are increasingly questionable. Further, the transparency-related issues have been reported all over the food chain in the Single market. Meanwhile, blockchain promises to resolve the matter of transparency.	

It is clearly seen from the table that Malta and the Maltese food supply chain, in general, offer an auspicious condition for the adoption of blockchain technology in that the supportive features outnumber the deterrent ones. Therefore, it is reasonable to refer that the macro-environment in Malta is likely to positively affect the adoption of blockchain in the food supply chain. However, this does not prove sufficient for the guarantee of the viability of the blockchain adoption due to the panoramic scope of the macro-environmental research and the dearth of micro-level determinants.

6 RESEARCH MODEL AND EMPIRICAL RESEARCH

This chapter is designed in pursuance of undertaking in-depth empirical research into the adoption of blockchain by seeking the opinions of retailer and end-consumer, two dominant actors in the food supply chain. First, in subchapter 6.1 the authors review a range of theories of technology acceptance with a view to selecting the base research model.

Second, subchapter 6.2 intensively concentrates on the analysis of distribution sector by covering four contents: research method and research model, data collection, data analysis and results.

Third, subchapter 6.3 follows the same concept as the previous one and supplements the part about hypothesis development.

Finally, the authors will summarize the results in subchapter 6.4.

6.1 Theories of technology acceptance

When studying the feasibility of applying a new technology into a specific field, it is important to examine how people would accept using it and intent to adopt it. Understanding the technology acceptance level of users would help the technology to be well designed and developed, thus fitting user's expectations optimally. Because of the high demand from both researchers and practitioners, many theories and models regarding technology acceptance have been introduced. These models, which serve as essential analytical tools to study the adoption of technology, consist of factors that are assumed to contribute to the acceptance or rejection of a technology from the user's perspective.

This subchapter provides a review of the relevant theories regarding the acceptance of technology.

6.1.1 Technology acceptance model

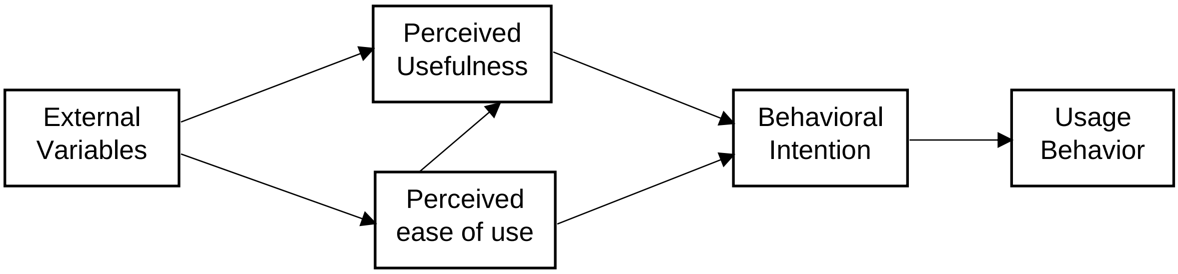

Figure 22 Technology Acceptance Model (Venkatesh & Davis 1996, as cited in Lai 2017, 27)

Technology Acceptance Model (TAM) was developed by Fred Davis in 1986, and was finalized in 1996 by Venkatesh and Davis with a view to explaining the usage behavior and intention of using a technology (Figure 22) (Lai 2017, 26-27). This model originates from the Theory of Reasonable Action (TRA) by Fishbein and Ajzen (1975, as cited in Lai 2017, 26), which states that behavioral intention of an action is influenced by attitudes toward a behavior and subjective norms and that actual behavior is determined by behavioral intention. TAM is a modified and adapted version that is specifically tailored to the technology context only. The main idea of the theory is that the perceived usefulness and perceived ease of use have positive impacts on one's intention of adopting a technology and thus indirectly influence his usage behavior.

There are two principal constructs that are expected to directly contribute to the behavioral intention to use, which are Perceived Usefulness (PU) and Perceived Ease of Use (PEU). PU is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance." In other words, it means the potential benefits of technology from the perspective of the user. Meanwhile PEU is "the degree to which a person believes that using a particular system would be free of effort". In the model, PEU puts a direct effect on PU, meaning that the less effort required to use the technology, the stronger the advantage is perceived to be. Besides this model also include external variables that directly influence the two major constructs. In fact, this final version of TAM in 1996 has excluded the "Attitude toward Using" construct from the original version as it was found redundant after Davis tested the reliability and validity of the model through a longitudinal study. (Rinta-Kahila 2013, 13-14.)

Technology Acceptance Model is amongst the most common theoretical frameworks to be used in studies regarding technology adoption (Taherdoost 2018, 962).

Four years after the first official TAM was introduced, Venkatesh and Davish (2000, as cited in Taherdoost 2018, 963) proposed an extension version TAM 2 as illustrated in

Figure 23. TAM 2 was developed by adding two categories of variables to the original version: social influence (image, subject norms, voluntariness) and cognitive (result demonstrability, job relevance and output quality). Both were brought to the original model to give further explanation to PU, thus enhanced the predictive ability of this construct. Besides, the moderating variables, i.e. experience and voluntariness appear as important additions to the original model, as they help strengthen the predictability of the theory by giving the researchers another dimension to analyze the context.

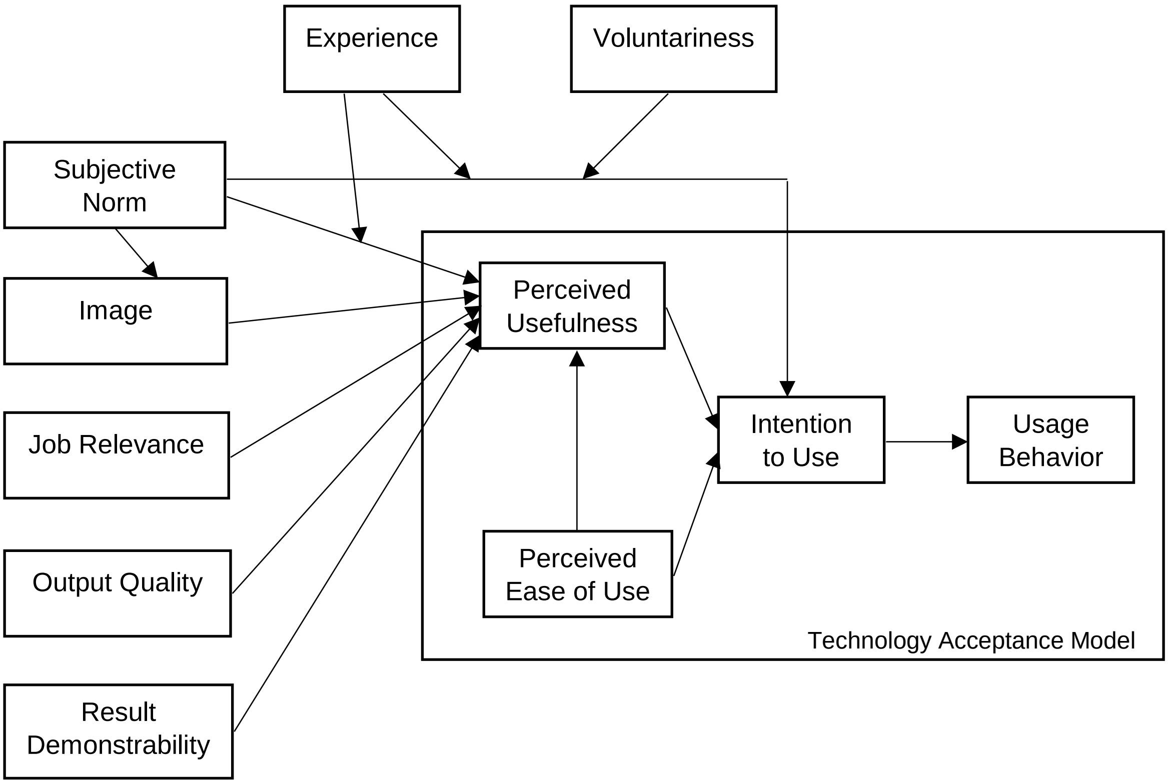

Figure 23 Technology Acceptance Model 2 (Venkatesh and Davis 2000, as cited in Lai 2017, 28)

The full extension of the Technology Acceptance Model, TAM 3 (Figure 24), was proposed in 2008 by Venkatesh and Bala. This is an integrated model that combines TAM 2 and the model of the determinants of perceived ease of use. (Venkatesh 2000, as cited in Lai 2017, 28.) In particular, six new constructs which are grouped into two groups, Anchor and Adjustment, have been added, acting as the determinants for PEU. It is noticeable that this full version of the Technology Acceptance Model clearly surpassed the previous versions in the level of complexity.

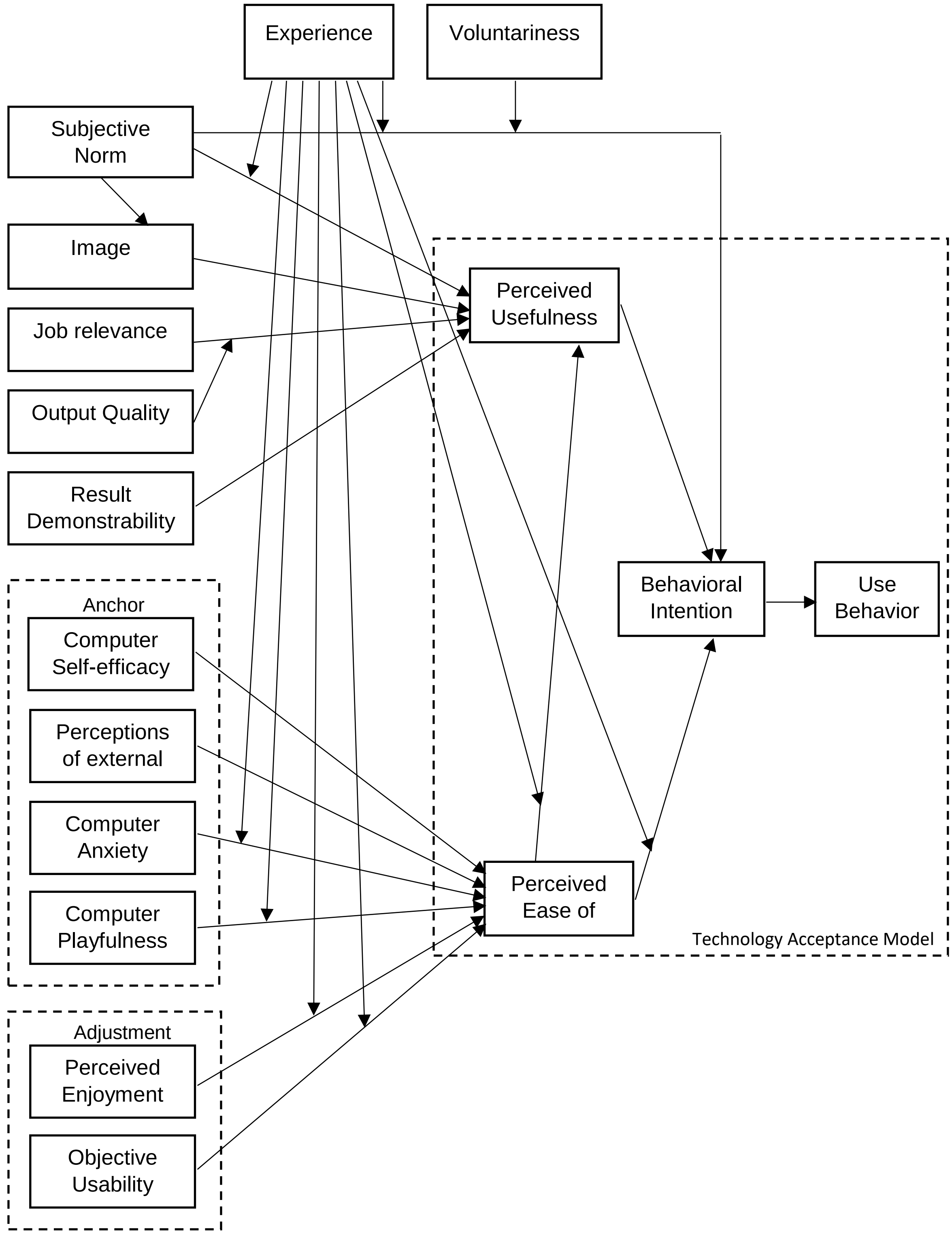

Figure 24 Technology Acceptance Model 3

6.1.2 Unified theory of acceptance and use of technology

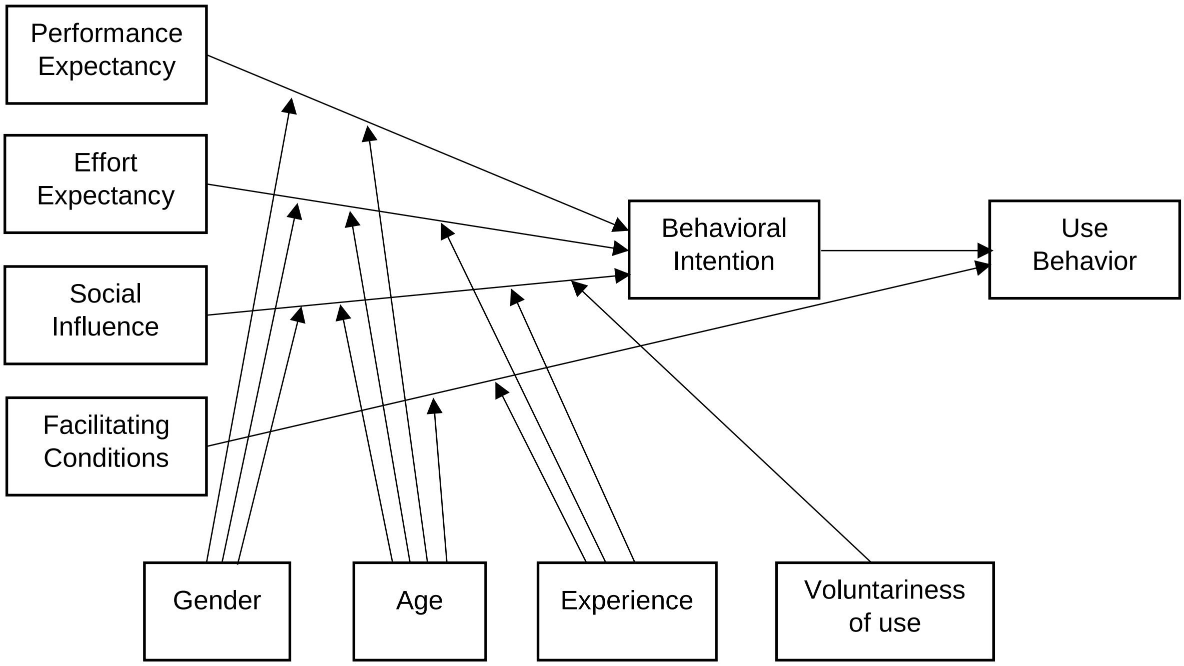

Figure 25 The Unified Theory of Acceptance and Use of Technology

The Unified Theory of Acceptance and Use of Technology (UTAUT) was developed by Venkatesh, Morris, Davis and Davis in 2003 after synthesizing the previous models and theories about technology acceptance. The most essential constructs taken from prior models were unified into UTAUT, which aims at predicting user's behavioral intention and actual use behavior towards a technology. The model consists of four determining factors (Performance Expectancy, Effort Expectancy, Social Influence and Facilitating Conditions) and four moderating factors (Gender, Age, Experience and Voluntariness of use).

Among the former four factors, Performance Expectancy, Effort Expectancy and Social Influence directly affect Behavioral Intention, while Facilitating Conditions has a direct connection to Use Behavior. These determinants are defined as follows (Venkatesh et al. 2003, 447-453):

- **Performance Expectancy:** the extent to which the users are benefited from using the technology to perform particular tasks;
- **Effort Expectancy:** the extent to which the users feel easy and effortless to use the technology;
- **Social Influence:** the extent to which the users perceive that people who are important to them and influence their decision-making think that they should adopt the technology;

- **Facilitating Conditions:** the extent to which the users believe that there are sufficient resources to facilitate their adoption of technology.

Meanwhile, the role of the four controlling variables is to moderate the relationships between the determining factors and behavioral intention or actual usage. According to the model, the Gender factor affects how performance expectancy, effort expectancy and social influence get connected with behavioral intention. The Age factor is theorized to pose effects on all the four relationships. Experience is linked to how effort expectancy, social influence and facilitating conditions relate to behavioral intention and usage behavior. Finally, Voluntariness of Use is believed to solely have impact on the relationship between social influence and behavioral intention. These controlling variables allow the researchers to explain better how relationships between each determinant and the behavioral intention or actual use may vary due to individual differences on gender, age, etc.

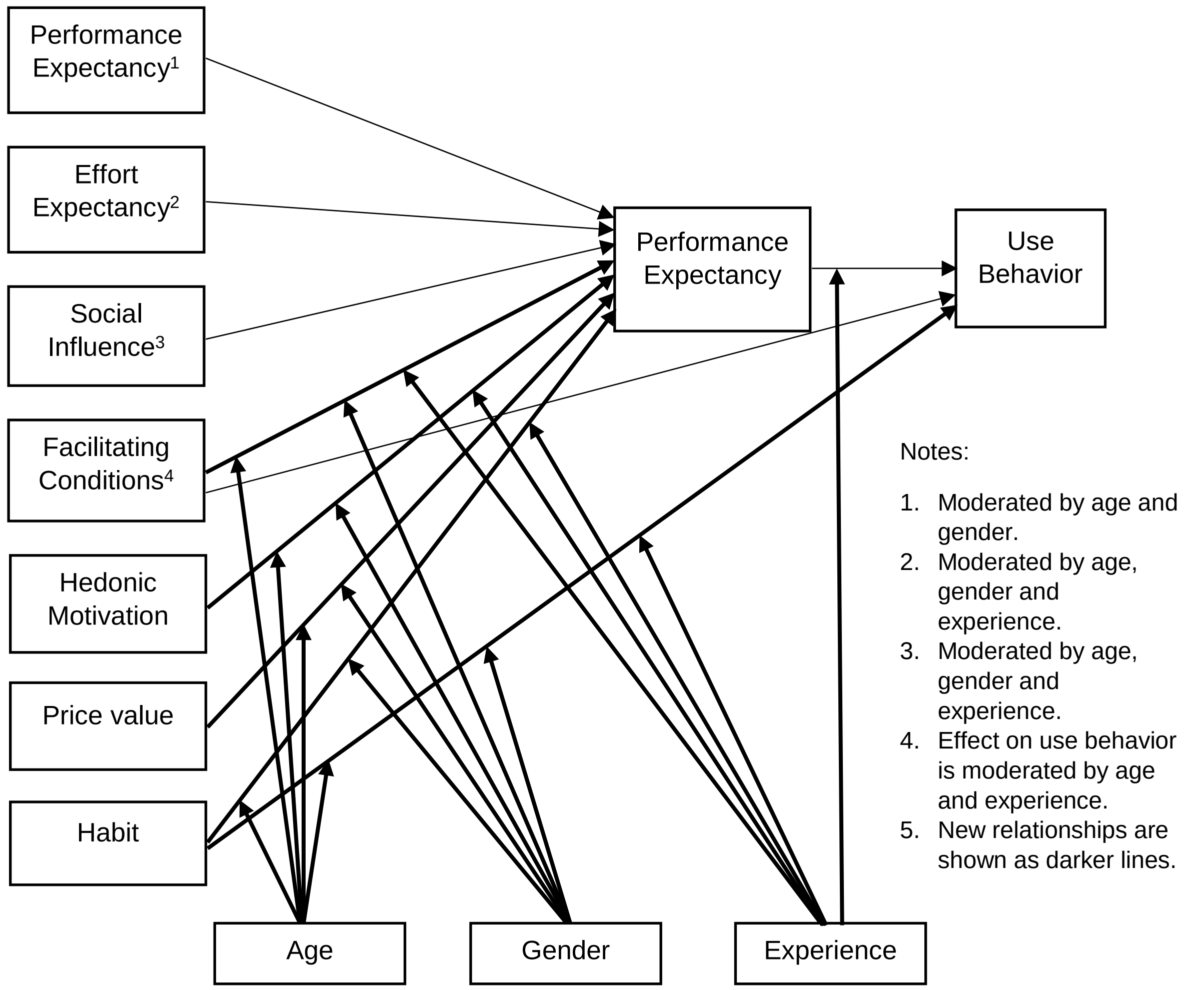

Figure 26 The Unified Theory of Acceptance and Use of Technology 2 (Venkatesh et al. 2012)

In 2012, Venkatesh, Thong & Xu introduced an extension of UTAUT, which tailored specifically to technology adoption studies with consumer use settings. In UTAUT2, three new constructs, i.e. Hedonic Motivation, Price Value and Habit were included as determining variables, while the control variable Voluntariness of Use was omitted. Besides, a new relationship between Facilitating Conditions and Behavioral Intention has been added.

6.1.3 Selection of base research model

Being the pioneer in the series of technology acceptance theories, TAM is no doubt one of the most frequently used models in technology adoption studies. Yet there are several limitations to be noted. Bagozzi (2007, as cited in Rinta-Kahila 2013, 15) criticizes the model for being too basic, which may cause some important factors being left out. Sun and Zhang (2006, as cited in Alshehri 2012, 50) also point out that TAM possesses weak explanatory power. The original TAM model is only able to explain about 40 percent of the variance in usage intention and behavior while that of its descendent, TAM2, is roughly 52 to 60 percent (Venkatesh & Davis 2000, 186). Compared to UTAUT, TAM is even at a weaker position. The unified model explained approximately 70 percent of the variance in user’s behavior intention in longitudinal field studies of organizational technology acceptance (Venkatesh et al. 2012, 157).

Regarding the extensions of TAM, i.e. TAM2 and TAM3, while they are superior to the original model in terms of complexity and predictability, it is claimed that these models are likely to be in favor of the workplace context, rather than consumer use context or any wider context. Some constructs such as Job Relevance, Output Quality, etc. are not relevant to the study of blockchain adoption in supply chain.

Because of the reasons above, the Technology Acceptance Model and its extended versions will not be used in this research as a theoretical framework. Considering that the study of blockchain technology in food supply chain involves consumer behavior exploration to some extent, such factors as social influence and habit are important and are projected to pose huge impact on usage intention. Therefore, the UTAUT and UTAUT2 models will be selected as the base theory for the retailer analysis as well as end-consumer analysis in the following sub-chapters. According to Venkatesh et al. (2012, 158), there are three main types of UTAUT extensions or integrations: applying to new contexts, adding new constructs or adding external predictors of the original variables. In this study, the model will be modified, in other words, some constructs will be added or removed to better adapt to each particular setting.

6.2 Retailer analysis

Having chosen the pertinent research model, the authors proceed to the analysis phase by embarking upon Maltese food retailers. The research method and research model will open the subchapter, followed by data collection, data analysis, and results.

6.2.1 Retailer research method and research model

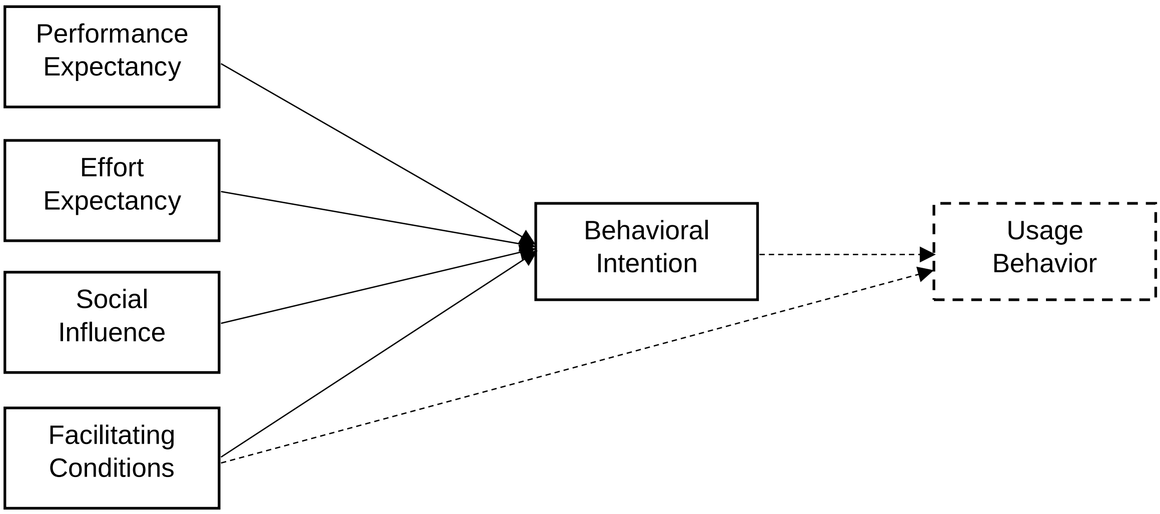

Figure 27 Retailer research model based on UTAUT model

For retailer analysis, a qualitative research will be conducted by means of an open-ended question survey with representatives from relevant organizations. Due to the small sample size, it is not possible to test the relationships between the controlling variables and the ones that are supposed to get affected by these variables. Hence, the four constructs Gender, Age, Experience and Voluntariness will be excluded from this model.

Besides, as the technology under examination has not yet come into use in the case country, there is no means to measure the actual use behavior of the organizations. The purpose of this research is solely to predict the behavior intention of adopting the blockchain technology, therefore, the Usage Behavior construct, which is marked with dash line in Figure 27, will also be left out of the research scope.

6.2.2 Retailer data collection

Based on the research model with four constructs (Performance Expectancy, Social Influence, Facilitating Conditions and Behavioral Intention), the authors decide to design a questionnaire with open-ended questions for the retailers.

Initially, the participants are provided with an introduction to the research and a brief description of IBM Food Trust platform. The main content of the survey is divided into two different parts. First, the participants are asked about the basic information related to their company: retail format, the complexity of their food supply chain, the problems caused by their supplier side, and their need to improve the supply process. Second comes a set of five open-ended questions based on the constructs in the UTAUT model to dig out their perspectives on the adoption of IBM Food Trust in the Maltese food supply chain. Specifically, the authors pursue this objective by directing the question towards the potential benefits of IBM Food Trust (Performance Expectancy), possible learning and using effort (Effort Expectancy), the stakeholders' driving force (Social Influence), facilitating resources (Facilitating Conditions) and intention to use this system (Behavioral Intention).

The data collection process lasted from late October to the middle of November. The survey was online, using Google Form. As the targeted food retailers are in Malta, the authors tried to gather the contact information of Maltese distribution and retailing companies via yellow.com.mt, a Local Discovery Search Tool. The emails including the survey were then sent to fifty Maltese retailers and distributors. Two answers were received, both of which are valid. One response will be marked as Company X according to the requirement of the respondent while one is from the representative of L-Arka Shop in Valletta, Malta.

6.2.3 Retailer data analysis

Using qualitative method, this section explores the collected answers from two retailers. Their general background is examined first before moving to the main part regarding construct analysis, which acts as the focal point of the whole retailer data analysis.

a. General background analysis

The background analysis consists of four features including the retail type, the complexity of the company's food supply chain, the issues from the supplier side, and the demand for improving the present-day food supply chain.

In terms of retail format, both are categorized as independent grocery store, which is confirmed in Chapter 5 as the dominant sector in the grocery retailing landscape in Malta. To a certain extent, it helps to validate the writing and convey part of the opinions of the largest actor in the Maltese food retail supply chain.

However, there exists a difference between two retailers when they are asked to describe the complexity of the food supply chain in their companies. While company X mainly purchases from local food importers, wholesalers and local producers' agencies, L-Arka imports the prepackaged food from two Italian organizations who gather the stocks from different communities around the world. The authors would like to point out two comments from the answers. Firstly, it can somehow reflect the dependence of the Maltese food supply chain on imports, especially Italy, which is supposed to be the nearest neighboring country of Malta among the EU countries. Secondly, small and middle-sized retailers do not directly import food products but use large importers and wholesalers as the intermediaries, possibly and predictably requiring the utmost transparency within the chain. As for L-Arka, it is slightly more special and different due to operating under Koperattiva Kummerċ Ġust, a voluntary organization that works in Fair Trade, which benefits farmers in developing countries. This gives rise to the distinction in nature and operation between two respondents.

With respect to the issues from the supplier side, it is extremely interesting to note that the problems that both retailers have suffered from are related to time. Company X reports the delay in delivery which leads to the shortage of stock and the loss of customers. Meanwhile, L-Arka has experience of items that are about to expire or become rotten and moldy as soon as goods are received. In contrast, L-Arka expresses the satisfaction with the certificates of origin on the grounds that the suppliers have a fair trade certification monitored by the World Fair Trade Organization.

Turning to the need to improve the supply process, while L-Arka sees no improvement that needs to be made or can be made in their field of Fair Trade, company X firmly believes that there is a need to improve the process as they suspect that the delay in delivery has the root lie at some problems with the supplier's source. To judge the dissimilarity of the answers, their operational environment should be taken into account. L-Arka works more directly with foreign partners and is assured of the certificates by a global reputable organization, whereas company X virtually relies on more local intermediaries, possibly implying a lack of prompt and transparent information.

b. Construct analysis

This part is designed to meticulously analyze the second layer of the survey with five open-ended questions, each of which corresponds to the respective construct in the UTAUT model (Performance Expectancy, Effort Expectancy, Social Influence, Facilitating Conditions and Behavioral Intention). Based on the available information of IBM Food Trust, they are asked to give detailed answers to those five questions.

Performance Expectancy

Both retailers agree that the blockchain system is able to help increase the transparency of the supply chain but with different facets. From the standpoint of company X, IBM Food Trust can open new doors for them to cooperate with more reliable suppliers, hence widen the range of the products in their shop. Despite the doubt as to whether the on-time delivery can be ameliorated, company X is of the opinion that the amount of paperwork should be reduced owing to the certifications uploaded by the suppliers to the system. In the viewpoint of L-Arka, the blockchain platform, besides the existing the Fair Trade and organic certifications, might assist their customers in understanding the origins of the food more clearly.

It can be inferred that no matter how different viewpoints the retailers stand from, both of them arrive at the consensus on transparency as the visible benefit that IBM Food Trust can bring about.

Effort Expectancy

When asked if learning how to use IBM Food Trust would be easy, both the companies give an answer bound to several external factors. Those factors, according to company X, are the required time to be acquainted with the system and the guidance (the more detailed, the less difficult). The guesswork is due to the fact that the respondent has never had a chance to try IBM Food Trust. Meanwhile, L-Arka presumes that it would be easy for the younger generation and for computer-literate people. It can be deduced from the statement that learning to use IBM Blockchain could be burdensome for the elderly and anyone without sufficient IT knowledge.

In general, despite agreeing that IBM Food Trust can be easy to learn, two retailers still remain careful with the answer by adding other influential elements. Nevertheless, the elements are more time-connected or related to acquired skills (except for age), which are able to be achieved by education.

Social Influence

Both retailers give a yes answer to the question as to whether they would consider using IBM Food Trust if their customers and suppliers want them to adopt it. Company X even adds that the system’s popularity and the adoption by their competitors are more likely to enhance the chance.

Seen from the affirmative responses, social influence seems to play a significant role in the adoption of blockchain technology for the Maltese retailers, possibly due to the nature of a food “chain” with end-consumers as the intense concentration, as well as a domino effect.

Facilitating Conditions

A variation is witnessed in the answers to the question about facilitating conditions. If L-Arka explicitly states that they do not have enough resources (finance, human, technology, etc.) to employ IBM Food Trust, company X produces rather a detailed answer implying that they could afford the system. As a simple and small family business, company X uses a Point-of-Sales (POS) system to manage sales activities, which presumably can handle IBM Food Trust. It is also fairly reasonable for them to spend roughly EUR 96.50 per month on the blockchain platform. As for human resource, if IBM can support them in fixing random systematical errors, it is acceptable.

Categorized in the same retail format as the two respondents are, they give opposing replies, let alone a variety of companies differentiating from, for example, retail types and sizes. However, with a fifty-fifty situation, it is by some means and other assumed that the facilitating conditions of IBM Food Trust are not such a far-fetched story (at least one small-sized family-owned company has confirmed this).

Behavioral Intention

The final question is concerned with the behavioral intention of the retailers, asking them whether the company will adopt IBM Food Trust in the near future (10 years). In general, the same situation as the part about Effort Expectancy takes place when a “probably yes” answer with independent factors is submitted. Provided that the customers and suppliers of company X urge them to adopt the system, they will act accordingly. However, it is not their belief that the stakeholders really require it as hardly have they seen any customer asking about the origin of the products. In addition, until now there has not been any major problem with the quality of the products in their shop. As for L-Arka, the independent factor substantially lies at the human resources as their cooperative is based on volunteer workers. Suppose them to have sufficient human resources, they would adopt the system.

It is markedly shown in the answers that Behavioral Intention of different retailers strongly relies on different constructs. In the context of this survey, it could be Social Influence (company X) or Facilitating Conditions (L-Arka) which exerts an excessive influence on the intention to use IBM Food Trust.

6.2.4 Results

Based on the retailer data analysis, this section will deliver several important results.

First and foremost, the intention to use IBM Blockchain is likely to be significantly impacted by social influence and facilitating conditions. What is also intriguing are the facts that the company going for social influence seems to be more reliable on intermediaries and that the company blaming for facilitating conditions confirms their lack of sufficient resources to adopt IBM Food Trust. Even though L-Arka claims there is no room needing improvement in their operating field at the moment, they still opt for adopting blockchain in the next ten years. However, due to the small sample size (two respondents from independent grocery stores), the significance of different constructs can vary.

Second, Performance Expectancy is a construct where the opinions are remarkably homogeneous, concurring in the transparency that IBM Food Trust can give rise to. This feature probably enforces its positive coefficient with the intention to use the blockchain platform.

Lastly, Effort Expectancy is also, in general, a consensual construct as both respondents are of the same opinion that it would be easy to learn to use IBM Food Trust. However, the driving force of the construct is not so crystal clear as that of Social Influence or Facilitating Conditions.

6.3 End-consumer analysis

After the retailer analysis comes the examination of end-consumer, which is, along with the former, considered to be the kernel of Chapter 6. The authors will also explore the research method and research model first before moving to the hypothesis development. The data collection and data analysis are then to be conscientiously scrutinized, leading to results in the final section.

6.3.1 End-consumer research model

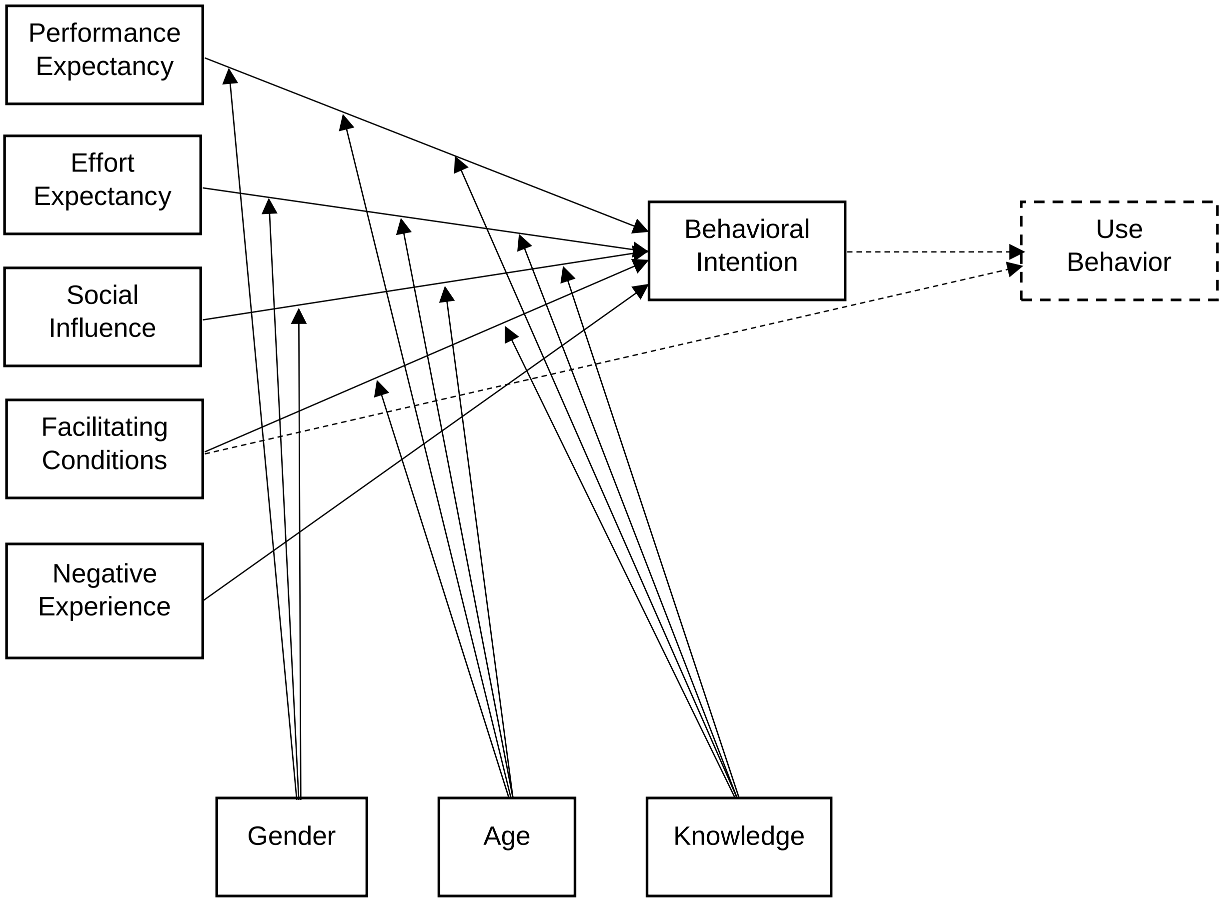

Figure 28 End-consumer analysis research model based on UTAUT and UTAUT2

For end-user analysis, quantitative research will be implemented. Based on the adapted research model, a questionnaire will be created and distributed to the end-consumers of the food supply chain in Malta.

Compared to the original UTAUT2 model in Figure 26, two determining variables Hedonic Motivation and Price Value are removed because firstly, using IBM Food Trust blockchain is unlikely to bring any joyful feelings to the users and secondly, there is no monetary cost when one starts using the system as a consumer. Besides, the authors incorporated a new construct, i.e. Negative Experience to the model. Negative Experience refers to the degree to which the users have undergone bad experience performing a certain activity when not using the technology. For example, in regard to food consumption, a negative experience can be an encounter with food poison. Even though this variable has not been tested in prior studies, it is relevant to the context of this study to a certain degree, hence, the authors decide to include it in the model.

Similar to the distribution sector research model, since the technology has not been applied completely in reality in Malta yet, it is impossible to estimate the actual usage. Therefore, the Use Behavior construct will not be taken into account, only Behavioral Intention will be measured. Additionally, the Experience moderating variable, which indicates the accumulation of times when the users directly use the technology, will also be omitted for the same reason. The authors replace Experience with Knowledge, which appears to be more sensible in this context as it relates to the users' understandings of the technology rather than actual usage.

The full modified model is illustrated in Figure 28.

6.3.2 Hypothesis development

Performance Expectancy

Performance Expectancy has been proven through many studies to be the most powerful predictor of behavioral intention of using a technology (Venkatesh et al. 2012, 160). In the study of blockchain effect on food retail supply chain, the authors expect that the end-consumers' intention to use IBM Food Trust Blockchain would be higher if they think that the application could bring more benefits. Thus, the idea is hypothesized as below:

H1: Performance Expectancy has a positive impact on the user intention to use IBM Food Trust Blockchain.

The way Performance Expectancy influences Behavioral Intention is expected to vary depending on individual characteristics of users. In the grocery shopping context, for instance, women may perceive more benefits from the Blockchain technology than men as they traditionally do more grocery shopping than men (Goodman 2008, 1). It is also argued the performance expectancy of men should be higher as they tend to be more task-oriented and focus on the accomplishments (Venkatesh et al. 2003, 449). Because of the unclearness, the authors decide to verify the moderating role of Gender in this study with hypothesis H1a. Similarly, age is also theorized to be an important controlling variable in technology acceptance studies. This lead to the hypothesis H1b. Regarding knowledge of blockchain, the authors expect that the more one understands about blockchain, the more he will find this technology useful for performing relevant tasks. Thus, hypothesis H1c is built. The three hypotheses related to controlling variables are listed below:

H1a: The impact of Performance Expectancy on Behavioral Intention is moderated by Gender.

H1b: The impact of Performance Expectancy on Behavioral Intention is moderated by Age.

H1c: The impact of Performance Expectancy on Behavioral Intention is moderated by Knowledge.

Effort Expectancy

According to Venkatesh et al. (2003, 450), Effort Expectancy is also a substantial determining factor in the intention to adopt a technology. It is reasonable that people have more intention to start using something if it does not require much effort in learning how to use and actually using it. The below hypothesis is proposed based on the original UTAUT model:

H2: Effort Expectancy has a positive impact on the user intention to use IBM Food Trust Blockchain.

Similar to Performance Expectancy, it is suggested that Effort Expectancy is moderated by individual characteristics of users. Venkatesh and Morris (2000, as cited in Venkatesh et al. 2003, 450) have drawn from their studies a conclusion that the effect of Effort Expectancy on Behavioral Intention is stronger for women than men. To verify this statement when applying the model to the study context, hypothesis H2a is formed. Besides, Age is also projected to affect how Effort Expectancy influences Behavioral Intention. A study on age-related differences in technology adoption shows that younger adults are likely to be faster to adopt new technologies than the older ones (Rogers, Mitzner, Boot, Charness, Czaja & Sharit 2017, 1026). An older age is correlated with a higher difficulty in allocating attention to details as well as in processing complex stimuli, which are needed when using technology systems (Plude & Hoyer 1985, as cited in Venkatesh et al. 2003, 450). Therefore, it is predicted that the impact of Effort Expectancy on Behavioral Intention might be stronger for older people. Thus, hypothesis H2b is built. Regarding the last moderator Knowledge, it is worth noting that the Effort Expectancy determinant is time-sensitive. Effort-related constructs are only significant in the starting stage of a behavior. As time goes by, effort expectancy becomes less important than the other factors as the users have now got used to the process and the ease of use is no longer an issue. In other words, the less knowledge the users have about a technology, the stronger the effect of Effort Expectancy on Behavioral Intention appears to them. Hence, the authors hypothesize this idea with H2c.

H2a: The impact of Effort Expectancy on Behavioral Intention is moderated by Gender.

H2b: The impact of Effort Expectancy on Behavioral Intention is moderated by Age.

H3c: The impact of Effort Expectancy on Behavioral Intention is moderated by Knowledge.

Social Influence

Comparing the figures from the previous models such as TAM, MPCU or IDT, Venkatesh et al. (2003, 451) find that the Social Influence factor is not significant when the technology adoption is voluntary but is significant in mandatory contexts. In this study, the use of IBM Food Trust Blockchain is clearly a voluntary decision, which is dependent upon personal needs of having quality guaranteed prior to purchasing. However, when buying foodstuff, usually one is not buying only for himself but also for his family or a group of people, which means his purchase decision would affect other people as well. As a result, it is likely that the others' opinions do matter to any action that he takes during the buying process. This behavior lies within the scope of Social Influence. Thus, the authors expect that the intention to adopt IBM Food Trust Blockchain is affected by Social Influence in a way that stronger Social Influence leads to higher Behavioral Intention. Hypothesis H3 is formed as below:

H3: Social Influence has a positive impact on the user intention to use IBM Food Trust Blockchain.

Concerning the moderating variables, Gender, Age and Knowledge are all predicted to have an impact on the effect of Social Influence on Behavioral Intention. Regarding the Gender factor, scientific studies suggest that men tend to be less sensitive to other people's opinions than women, hence the impact of Social Influence on Behavioral Intention is weaker for compared to the opposite (Miller 1976; Venkatesh et al. 2000, as cited in Venkatesh et al. 2003, 453). About the age differences, the effect of Social Influence is expected to be more salient to older people. Finally, similar to the Effort Expectancy construct, the impact of Social Influence is time-sensitive in a way that the more experience or knowledge on the technology, the less likely is a person affected by Social Influence. Three hypotheses regarding moderating factors are formed as below:

H3a: The impact of Social Influence on Behavioral Intention is moderated by Gender.

H3b: The impact of Social Influence on Behavioral Intention is moderated by Age.

H3c: The impact of Social Influence on Behavioral Intention is moderated by Knowledge.

Facilitating Conditions

Being a high-tech computer-based application, the employment of a smart device is inevitably compulsory. As a consequence, the lack of a mobile phone or tablet could become a hindrance to the intention to use of the consumers. Therefore, hypothesis H4 is developed as below:

H4: People who own a mobile device have higher intention to use IBM Food Trust Blockchain than those who do not.

Negative Experience

It is rationally presumed that who used to suffer from food contamination would be more cautious about the origins and quality of products which blockchain promises to satisfy. On the grounds of this reasoning, hypothesis H5 is formed as below:

H5: People who used to be poisoned by food have higher intention to use IBM Food Trust Blockchain than those who did not.

6.3.3 End-consumer data collection

The research model shows that there are six research constructs to be measured. Performance Expectancy, Effort Expectancy, Social Influence and Behavioral Intention are measured with two to three research items per construct, while Facilitating Conditions and Negative Experience are measured with only one indicator. Most of the research items, despite being generated specifically tailoring to this study, are based on the foundation of the previous research which also employed UTAUT as the base model. The detailed research items for each construct are exhibited in Table 8.

Regarding measurement methods, Likert scale is utilized for the majority of the research items. The role of Likert scale in this questionnaire is to measure the degree of agreement with each statement. The authors adopt a five-point scale, in which level 1 represents “Totally Disagree” and level 5 represents “Totally Agree”. Besides, Yes/No questions are used for measuring Facilitating Conditions and Negative Experience constructs.

Before starting answering the questions, the respondents are given an overview of the research as well as a brief insight into how IBM Food Trust Blockchain functions. The questions are divided into two parts. The first part covers demographic background of the respondents with questions regarding age, gender and duration of stay. Other background questions concerning the respondents’ knowledge about blockchain, whether they own a smart device and negative experience with food poison are also included in this part. The second part consists of ten questions whereby the respondents are asked to rank their opinions on the statements regarding IBM Blockchain adoption based on the five-point Likert scale. Respondents are required to answer all the questions to avoid missing or useless data when analyzing. In addition, there is no option for such open answers as

“Others” or “I don’t know”. Respondents answer the blockchain-related questions based on their own perceptions of the technology, which are formed by either the introductory information given in the beginning section, or their own prior knowledge.

Table 8 Research Items

Research Construct	Item	Statement
Performance Expectancy	PE1	I would be provided with a wider range of product-related information by using IBM Blockchain.
	PE2	I would get access to the information that I need more easily by using IBM Blockchain.
	PE3	I would be able to ensure the accuracy of information by using IBM Blockchain.
Effort Expectancy	EE1	Learning how to use IBM Blockchain would be easy for me.
	EE2	Scanning a code (barcode, QR code, etc.) with a mobile device (smartphone, tablet, etc.) would be simple.
	EE3	Scanning a code (barcode, QR code, etc.) with a mobile device (smartphone, tablet, etc.) would be effortless.
Social Influence	SI1	People who influence my behavior believe that I should check the product-related details carefully before purchase.
	SI2	I have a habit of checking the product-related details carefully before purchase, which is somehow influenced by the people around me.
Facilitating Conditions	FC	Do you have a smart device (smartphone, tablet, etc.)?
Negative Experience	NE	Have you ever had food poisoning during your stay in Malta?
Behavioral Intention	BI1	I think grocery stores and supermarkets in Malta should use IBM Food Trust Blockchain.
	BI2	I would use IBM Food Trust Blockchain if it becomes available.

The data collection process for end-consumer analysis lasted approximately two months, from the end of August till the beginning of November. The survey took place on both online and offline platforms. The online questionnaire was created with Google Form, after which the authors uploaded the link to the survey onto different relevant Facebook groups, targeting at the residents on the Maltese islands. Since performing on online platforms only may cause a substantial lack of demographic diversity by leaving out an important age group, i.e. the group of people older than 54 years old who are not that active on social media, the authors decided to conduct a face-to-face survey in addition to the online one. Respondents were randomly picked when they were doing shopping at the supermarkets. Besides, the authors also collected responses from people living in their neighborhood and those whom they met in public locations, such as public parks, shopping malls or bus stations. Offline respondents were asked the same set of questions with the online ones with the introduction of the research and IBM Food Trust Blockchain explained orally. The data was then manually input into the online survey link. In the end, there were in total 203 responses, none of which were considered invalid for further analyzing steps.

6.3.4 End-consumer data analysis

This section aims to analyze the harvested data from the survey for end-consumers by thoroughly examining five layers: (a) basic data analysis, (b) data reliability and validity, (c) structural model, (d) the effects of moderators on each construct and (e) testing Facilitating Conditions and Negative Experience. IBM SPSS Statistics 23 and Excel Data Analysis are employed to process the data. Except for Facilitating Conditions (FC) and Negative Experience (NE) solely analyzed in part (e), the other constructs in the model would be statistically explored in all parts from (a) to (d).

a. Basic data analysis

The data would be reviewed at the ground level with general background analysis and the internal consistency denoted by Cronbach α to demonstrate the relation among the items within a construct.

General Background Analysis

Table 9 summarizes the demographic background of 203 respondents in terms of Gender, Age, Knowledge about blockchain, Ownership of Smart Devices, Food Poisoning Experience and Intention to Use.

The gender distribution figures show that there are more men participating in the survey than women, accounting for 58% of the total number. Regarding age, the majority of the respondents (56%) are young adults from 22 to 41 years old. This fact reflects the Maltese social statistics to a certain extent when 39.98% of people fall into the 25 to 54 age bracket. Those statistical numbers are also visualized in Figure 29.

As for the ownership of smart devices, the respondents who possess at least a certain hi-tech tool assert dominance over those who do not (94% versus 6%). 10 out of 13 people without smart phones or tablets are aged over 54, implying a social phenomenon that seniors do not as frequently and popularly own technological equipment as youngsters and middle-aged people. At first glance, the figure partially signifies a positive condition for the launch of any technological advancement, let alone blockchain technology. In addition to the technological support mentioned in the previous chapter (e.g. the availability of mobile broadband – Long Term Evolution (LTE) / 4G), the implementation of blockchain technology is likely to be technologically supported.

Table 9 Descriptive Analysis of Samples

Item	**Category**	**Frequency**	**Percentage**
Gender	Female	86	42%
	Male	117	58%
Age [years]	Less than 22	30	15%
	22 to 41	115	57%
	42 to 54	32	16%
	54+	26	13%
Knowledge about blockchain [1 - I have no idea about blockchain; 5 - I'm a blockchain expert]	1	110	54%
	2	25	12%
	3	40	20%
	4	24	12%
	5	4	2%
Ownership of Smart Devices	Yes	190	94%
	No	13	6%
Experience of Food Poison	Yes	37	18%
	No	166	82%
Intention to use IBM Food Trust	1	11	5%
	2	7	3%
	3	62	31%
	4	70	34%
	5	53	26%

Turning to the experience or food poisoning, 82% of respondents claim to have yet to suffer from foodborne illness, indicating a vast majority. However, there are still nearly a fifth of answers marked as having experienced contaminated food, by some means or other sounding the alarm to the food safety in the food supply chain. Predictably, the negative occurrence is able to give rise to the demand for a traceable solution like IBM Food Trust to clarify the food's origin, as well as to ensure the food quality.

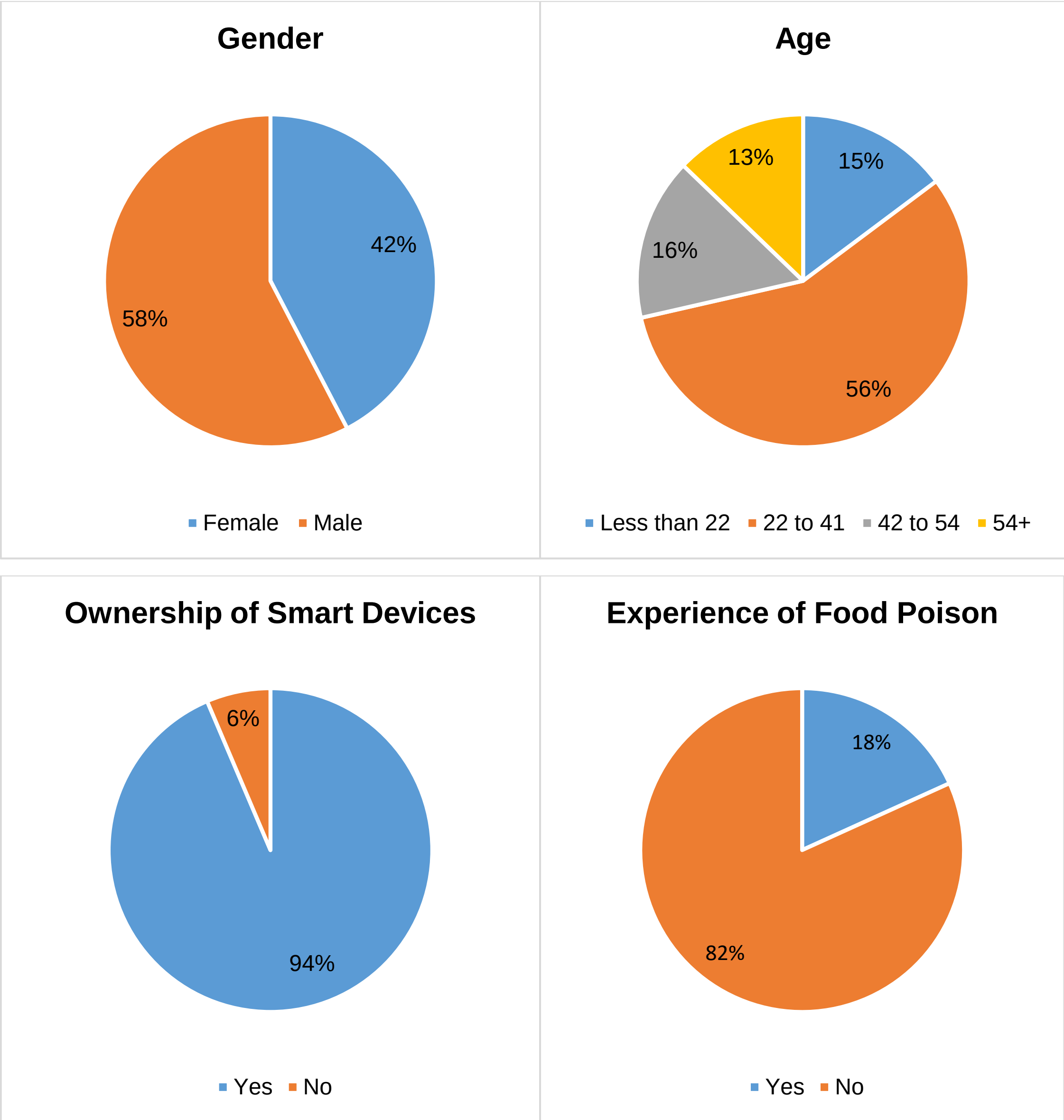

Figure 29 Respondents' demographic charts

The knowledge about blockchain of the respondents is revealed in Figure 30. There are 110 respondents with no idea of blockchain, constituting by far the largest proportion of 54% whilst only a minority of 4 reply that they are blockchain experts. This finding is completely rational as blockchain is such a wholly nascent technology that even tech-experts have not fully acquired its mystery and capacity.

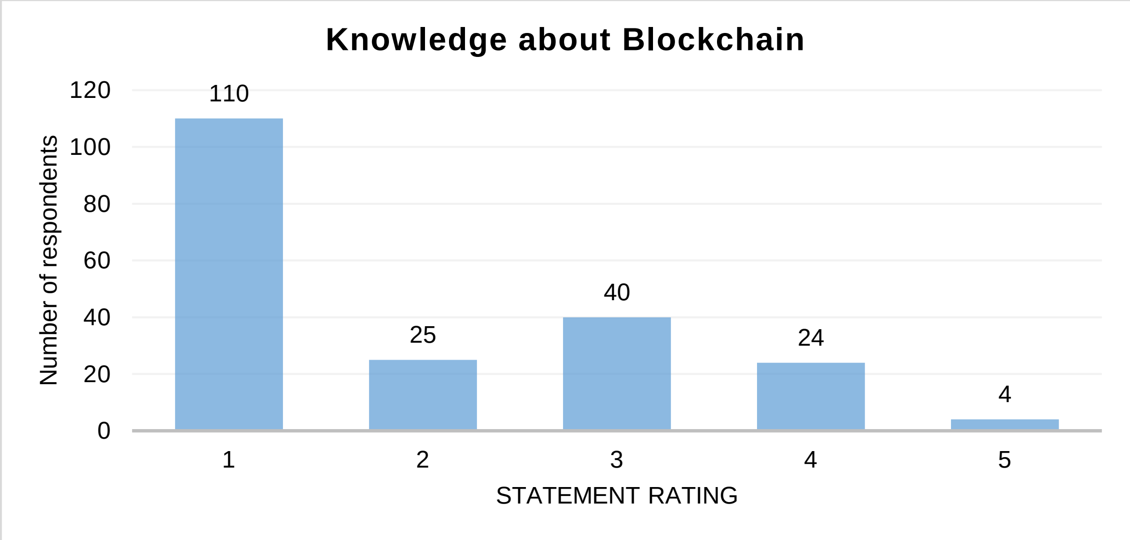

Figure 30 Respondents' knowledge about blockchain rating on a 5-point scale

Apropos of the intention to use IBM Food Trust, which is visualized in Figure 31, only a minority of the respondents refuse to adopt the platform (11 people marked 1 point and 7 marked 2 point, corresponding to 5% and 3% respectively). Although grade 4 dominates the chart with 34% of the respondents, the proportion of people with neutral opinion (grade 3) is nearly as high as that figure (31%). However, thanks to 26% of the voting for 5 point, the intention to use IBM Food Trust is still, by and large, placed in a positive position where almost of the respondents look with the favor upon the blockchain application.

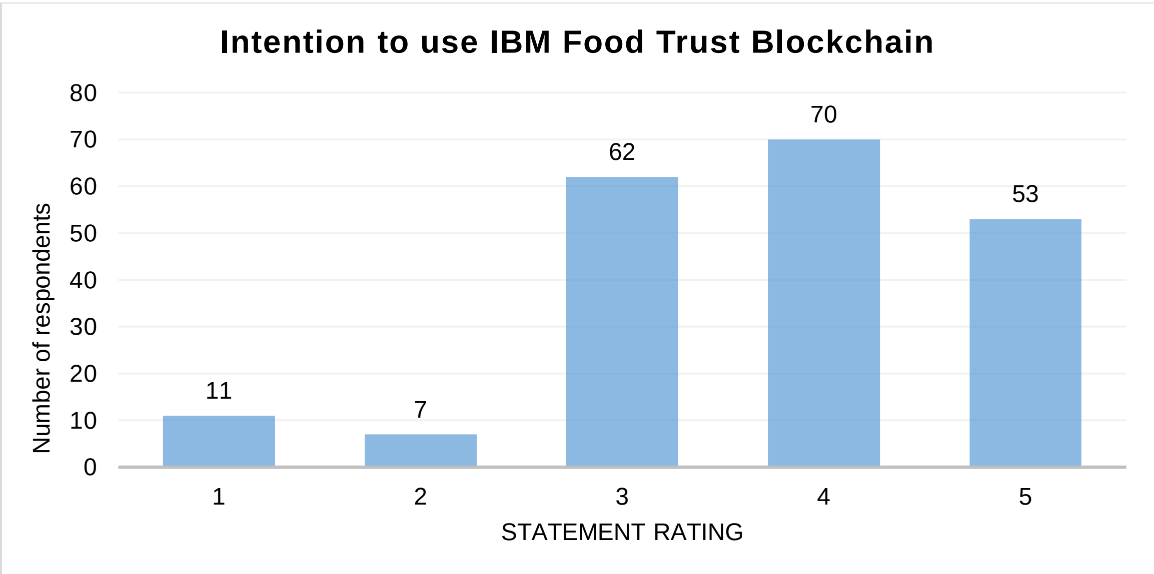

Figure 31 Respondents' intention to use rating on a 5-point scale

Internal consistency - Cronbach α

As for internal consistency test, the authors use Cronbach alpha (α) by Cronbach (1951) in order to evaluate the extent to which all the variables of a set of scale items are positively related to each other since it is one of the most popular measures of reliability in social science studies. The meanings of Cronbach α are described in Table 10.

Table 10 Ranges of Cronbach α (Hinton, Brownlow, McMurray & Cozens 2004, 364)

Reliability	**Range**
Excellent reliability	$\alpha \geq 0.90$
High reliability	$0.70 \leq \alpha < 0.90$
Moderate reliability	$0.50 \leq \alpha < 0.70$
Low reliability	$\alpha < 0.50$

The overall Cronbach α of four constructs PE, EE, SI, and BI in the thesis is 0.7954, suggesting a high reliability of the questionnaire. Cronbach α of each single construct is shown in Table 11.

Table 11 Reliability of each construct

Construct	**Cronbach α**
Performance Expectancy (PE)	0.8672
Effort Expectancy (EE)	0.8337
Social Influence (SI)	0.6001
Behavioral Intention (BI)	0.8805
Overall	0.7954

The constructs PE, EE and BI fall into the category of high reliability while that score of SI is moderate reliability. However, Hinton et al. (2014, 363) claim that 0.50 to 0.75 can be generally accepted. Therefore, all of the items within all constructs are considered to be positively related to each other and to be developed with acceptable to good internal consistency.

b. Reliability and validity

The authors continue by checking the reliability and validity of the hypothesized relations. In terms of reliability, the composite reliability (CR) for each construct is examined. Next, the authors evaluate convergent validity to investigate the extent to which different items in the same construct correlate with each other. Convergent validity is established by the item reliability and the average variance extracted (AVE). (Hair, Ringle & Sarstedt 2011). The cut-off values of each criterion are exhibited in Table 12. Should a construct achieve an equal or higher value than the threshold, it is regarded as reliable.

Table 12 Evaluation criteria for the measurement of reliability (Hair et al. 2011)

Reliability type	**Criterion**	**Threshold**
Construct reliability	Composite Reliability (CR)	≥ 0.7
Convergent validity	Item loadings	≥ 0.7
	Average Variance Extracted (AVE)	≥ 0.5

Table 13 shows the results of the criteria of each construct in the model.

Table 13 Item loadings, average variance extracted (AVE) and composite reliability (CR)

Construct	**Item**	**Item loadings**	**AVE**	**CR**
Performance Expectancy (PE)	PE1	0.924	0.731	0.891
	PE2	0.807		
	PE3	0.830		
Effort Expectancy (EE)	EE1	0.813	0.709	0.880
	EE2	0.837		
	EE3	0.875		
Social Influence (SI)	SI1	0.826	0.703	0.826
	SI2	0.851		
Behavioral Intention (BI)	BI1	0.869	0.873	0.879
	BI2	0.901		

First, the authors test the item reliability by looking at item loadings. As seen from Table 13, all of the items have those values higher than 0.7, ensuring the variance captured by the latent construct. Second, the AVE values for each construct are calculated, including the variance of the items controlled by the assigned construct relative to the total amount of the variance. All the constructs exceed the cut-off value of the AVE pattern. Third, the authors calculate the composite reliability (CR) and came up with satisfactory results of all constructs. Those three elements confirm sufficient convergent validity of the questionnaire.

Apart from convergent validity, reliability and validity are also presented by discriminant validity, which is “the extent to which a construct discriminate from other constructs” (Campbell & Fiske 1959, as cited in Segura 2016, 88). If the AVE for each construct is bigger than its shared variance with any construct, which equals to the square of the correlation between any constructs, there exists discriminant validity. In order to check this element, the authors need to find out the maximum shared variance (MSV) – the highest value among all shared variance to make comparison between the AVE and the square of correlation matrix. For the sake of simplification and due to the high proven reliability between different items within one construct, as well as the limited facilitating conditions, the authors decide to calculate the correlation matrix of the constructs through the mean of each item in the constructs. Table 14 displays the correlation matrix and the MSV of all constructs.

Table 14 Construct correlation matrix and maximum shared variance (MSV)

	MSV	**PE**	**EE**	**SI**	**BI**
PE	0.2105	1			
EE	0.1884	0.3364	1		
SI	0.0311	0.1764	-0.0206	1	
BI	0.2105	0.4588	0.4340	0.1763	1

Markedly, the AVE of each construct outnumbers its corresponding MSV. Therefore, discriminant validity is supported.

c. Structural model

After all items within the constructs and the constructs themselves have tested positive for reliability and validity, the authors move on with the structural model built of path coefficient and hypotheses results without moderators. The essential figures and results are given in Table 15.

Table 15 Coefficients and hypothesis results

Hypothesis	Relationship	Coefficient β	t Stat	p-value	Result
H1	PE → BI	0.3933***	5.1452	0.0000	Supported
H2	EE → BI	0.3009***	5.2194	0.0000	Supported
H3	SI → BI	0.1301*	2.1041	0.0366	Supported

*Notes: *** p < 0.001; ** p < 0.01; * p < 0.05*

According to Fenton & Neil (2012, 10) the coefficient β is a number between -1 and 1, determining if two paired sets of data are related. The more asymptotic to zero the result, the less evidence of relationship. As the table shows, all of 3 hypotheses have positive coefficient β but H3 represents the lowest (β=0.1301). Considering t stat and p-value, which respectively measures the size of the difference related to the variation and the significance, H1 and H2 have high t-value (>2) with small p-value (<0.05) and thus are supported. H3 is also supported as the coefficient β is positive, t stat is over 2, while the p-value is small (p<0.05).

The full structural model is presented in Figure 32.

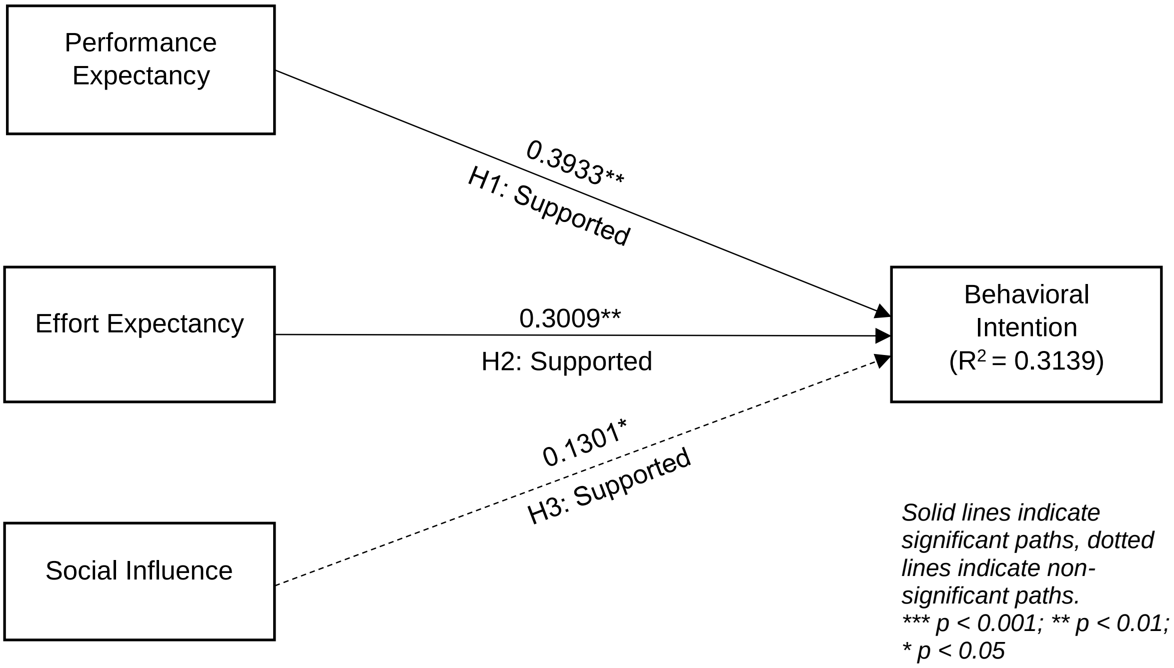

Figure 32 Structural model with path coefficients

The path coefficient R^2 measures “the fraction of the total variation in the outcome explained by the explanatory variable”, running from 0 to 1 with 1 showing perfect prediction of dependent construct from independent construct (Brase & Brase 2013, 159). R^2 of 0.3139 indicates that 31.39% of the variation in the dependent variable (BI) can be explained by the independent variables (PE, EE and SI). The remaining 68.61% of the variation can be explained by the two constructs left (Facilitating Conditions and Negative Experience) and other factors that are not taken into consideration in this research.

d. The effects of moderators on each construct

Moderation analysis is utilized to examine whether the relationship between the independent variable and the dependent variable is affected by a third variable, which is known as the moderating variable. The variable can be categorical (e.g. Gender) or continuous (e.g. ratings on a five-point scale).

It is worth noting that a moderation is basically an interaction effect. It means, in order to investigate whether there is a moderating effect of variable X on the relationship between independent variable Y and dependent variable Z, researchers can test if there is an interaction between variable X and variable Y. The only difference is that when a moderation is examined, variable X is assigned with a specific role of being a moderator.

In this study, Knowledge, Performance Expectancy, Effort Expectancy, Social Influence are measured with five-point scale, therefore they are considered continuous variables. To conduct a moderation analysis between two continuous variables, the first step is to center these two variable in order to avoid problems with multi-collinearity (Aiken, West & Reno 1991, 182). The next step is to create an interaction term by multiplying the centered value of two variables. Finally, a regression analysis is performed to identify if there is a significant interaction effect between the two on the dependent variable.

For Gender, which is a categorical variable, since SPSS cannot read non-numerical values, the Gender values are dummy-coded with 0 and 1. Female is coded with 0 and Male is coded with 1. Dummy codes will note be centered. The last two steps are the same with the moderation analysis of Knowledge.

For Age, which has been categorized into four groups, the four categories of it are coded from 0 to 3, in which the lowest age group is assigned to 0 and the highest one to 3, making Age a continuous variable. The last two steps are the same with the moderation analysis of Knowledge.

Gender as a moderator

Table 16 Statistical testing of the interaction between Effort Expectancy and Gender

	Coefficients	**Standard Error**	**t Stat**	**P-value**
Constant	3.9262	0.0928	42.3002	0.0000
EE	0.3065	0.0831	3.6891	0.0003
Gender	-0.4845	0.1221	-3.9666	0.0001
EE*Gender	0.3414	0.1212	2.8159	0.0054

As shown in Table 16, the interaction between Effort Expectancy and Gender (EE*Gender) reaches the significant level ($p < 0.01$). Therefore, it can be concluded that there is a moderating effect of Gender on the relationship between Effort Expectancy and Behavioral Intention. Thus, hypothesis H2a is supported.

Moreover, since the regression coefficient of the interaction term EE*Gender on Behavioral Intention is positive, it is indicated that the moderating variable strengthens the causal effects of Effort Expectancy on Behavioral Intention. In this case, it can be concluded that the impact of Effort Expectancy on Behavioral Intention is stronger for men than women.

Table 17 Statistical testing of the interaction between Performance Expectancy, Social Influence and Gender

	Coefficients	**Standard Error**	**t Stat**	**P-value**
Constant	3.8800	0.0935	41.4978	0.0000
PE	0.3872	0.0986	3.9287	0.0001
Gender	-0.3620	0.1232	-2.9391	0.0037
PE*Gender	0.1147	0.1255	0.9139	0.3619
	Coefficients	**Standard Error**	**t Stat**	**P-value**
Constant	2.8715	0.4138	6.9396	0.0000
SI	0.2615	0.1047	2.4987	0.0133
Gender	0.3955	0.5490	0.7204	0.4721
SI*Gender	-0.1890	0.1434	-1.3175	0.1892

The figures from Table 17 indicate that there is no significant interaction effect ($p > 0.05$) between Gender and Performance Expectancy as well as between Gender and Social Influences on the dependent variable Behavioral Intention. Therefore, hypotheses H2a and H3a are unsupported.

Age as a moderator

Table 18 Statistical testing of the interaction between Performance Expectancy, Effort Expectancy, Social Influence and Age

	Coefficients	**Standard Error**	**t Stat**	**P-value**
Constant	3.8221	0.1115	34.2671	0.0000
PE	0.5767	0.1248	4.6209	0.0000
Age	-0.1329	0.0741	-1.8786	0.0618
PE*Age	-0.1291	0.0938	-1.3753	0.1706
	Coefficients	**Standard Error**	**t Stat**	**P-value**
Constant	3.6729	0.1232	29.8007	0.0000
EE	0.3694	0.1453	2.5420	0.0118
Age	0.0107	0.0879	0.1223	0.9028
EE*Age	0.0336	0.0706	0.4754	0.6350
	Coefficients	**Standard Error**	**t Stat**	**P-value**
Constant	3.1669	0.4912	6.4477	0.0000
SI	0.2401	0.1310	1.8333	0.0683
Age	-0.2919	0.3526	-0.8278	0.4088
SI*Age	-0.0015	0.0886	-0.0173	0.9862

The figures from Table 18 indicate that there is no significant interaction effect between Age and the other three independent variables on the dependent variable Behavioral Intention. In other words, the moderating role of Age is not significant in this research model. Therefore, hypotheses H1b, H2b and H3b are unsupported.

Knowledge as a moderator

Table 19 Statistical testing of the interaction between Performance Expectancy and Knowledge

	Coefficients	**Standard Error**	**t Stat**	**P-value**
Constant	3.7286	0.0648	57.5658	0.0000
PE	0.4859	0.0651	7.4677	0.0000
Knowledge	-0.0285	0.0678	-0.4201	0.6749
PE*Knowledge	-0.1665	0.0642	-2.5926	0.0102

As shown in table 19, the interaction between Performance Expectancy and Knowledge (PE*Knowledge) reaches the significant level ($p < 0.05$). Therefore, it can be concluded that there is a moderating effect of Knowledge on the relationship between Performance Expectancy and Behavioral Intention. Thus, hypothesis H1c is supported.

Moreover, since the regression coefficient of the interaction term PE*Knowledge on Behavioral Intention is negative, it is indicated that the moderating variable (Knowledge) weakens the causal effects of Performance Expectancy on Behavioral Intention. In other words, an increase in the knowledge about blockchain would lessen the impact of Performance Expectancy on Behavioral Intention of the users.

Table 20 Statistical testing of the interaction between Effort Expectancy, Social Influence and Knowledge

	Coefficients	**Standard Error**	**t Stat**	**P-value**
Constant	3.7137	0.1254	29.6031	0.0000
EE	0.5842	0.1193	4.8979	0.0000
Knowledge	-0.0053	0.0578	-0.0917	0.9271
EE*Knowledge	-0.0969	0.0668	-1.4498	0.1487
	Coefficients	**Standard Error**	**t Stat**	**P-value**
Constant	2.1455	0.5499	3.9016	0.0001
SI	0.3786	0.1451	2.6093	0.0098
Knowledge	0.4101	0.2251	1.8218	0.0700
SI*Knowledge	-0.0922	0.0586	-1.5751	0.1168

The figures from Table 20 indicate that there is no significant interaction effect ($p > 0.05$) between Knowledge and Effort Expectancy as well as between Knowledge and Social Influences on the dependent variable Behavioral Intention. Therefore, hypotheses H2c and H3c are unsupported.

e. Testing Facilitating Conditions and Negative Experience

These two constructs are measured with the answers Yes or No. The Facilitating Condition construct is represented by whether the respondents own a smart device or not, while the Negative Experience construct is constituted of only one item, which is whether the respondents have encountered food poisoning in Malta.

To test hypotheses H4 and H5, the authors use Independent Samples t-test to examine if there is a statistically significant difference between the means of two groups of responses in terms of Behavioral Intention scores. The Behavioral Intention construct, which consists of two research items, is measured by the sum of the two items’ scores in this test.

In order to conduct the Independent Samples t-test, the data must meet the following prerequisites (Kent State University 2018):

- The dependent variable is a continuous variable;
- The independent variable is a categorical variable;
- The samples are independent;
- The dependent variable is normally distributed;
- The variances are roughly equal across the categories, i.e. the variables are homogeneous;
- There is no outlier.

The data collected satisfy the above requirements, except for the Homogeneity of variances test, which will be done along with the t-test using IBM SPSS Statistics.

Table 21 Group statistics of Facilitating Conditions

	Ownership of smart devices	**Total**	**Mean**	**Std. deviation**	**Std. error mean**
BI SUM	No	13	5.31	1.974	0.548
	Yes	190	7.48	1.910	0.139

Table 22 Independent samples test of Facilitating Conditions

		Levene's test for equality of variances		**t-test for equality of means**						
		F	Sig.	T	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% confidence interval of the difference: Lower	95% confidence interval of the difference: Upper
BI SUM	Equal variances assumed	0.199	0.656	-3.967	201	0.000	-2.177	0.549	-3.258	-1.095
	Equal variances not assumed			**-3.854**	**13.58**	**0.002**	**-2.177**	**0.565**	**-3.391**	**-0.962**

Table 22 shows the test summary and results for Levene's test as well as t-test. The significance level in Levene's test is p>0.05, indicating that the two variables are homogenous. In other words, there is no significant difference in the variances of the two groups, which qualifies them to the next step, i.e. the independent samples t-test. In the t-test, the significance level is 0.000 (p<0.001), which indicates that there is a significant difference between the means of two groups. That means whether the respondent owns a smart device does affect the behavioral intention to use IBM Food Trust Blockchain.

Indeed, it can be referred from Table 21 that the mean total score in Behavioral Intention questions of the "No" group is substantially lower than that of the "Yes" group. In other words, people who have a smart phone have higher intention to adopt IBM Food Trust Blockchain than those who do not. Therefore, hypothesis H4 is supported.

Table 23 Group statistics of Negative Experience

	Food poison experience	**Total**	**Mean**	**Std. deviation**	**Std. error mean**
BI SUM	No	166	7.24	2.016	0.156
	Yes	37	7.81	1.777	0.292

Table 24 Independent samples test of Negative Experience

		Levene's test for equality of variances		**t-test for equality of means**						
									95% confidence interval of the difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	Lower	Upper
BI SUM	Equal variances assumed	2.231	0.137	-1.587	201	0.114	-0.570	0.359	-1.278	0.138
	Equal variances not assumed			**-1.720**	**58.56**	**0.091**	**-0.570**	**0.331**	**-1.283**	**0.093**

Table 24 shows the test summary and results for Levene's test as well as t-test. The significance level in Levene's test is $p>0.05$, indicating that the two variables are homogenous. In other words, there is no significant difference in the variances of the two groups, which qualifies them to the next step, i.e. the independent samples t-test. In the t-test, the significance level is 0.114, which is higher than the acceptable p-value ($p<0.05$), indicating that there is no significant difference between the means of two groups. That means whether the respondents used to have negative experience of food poisoning does not affect the behavioral intention to use IBM Food Trust Blockchain. Hence, hypothesis H5 is unsupported.

6.3.5 Results

Table 25 Synthesis of hypothesis testing results

Hypothesis		**Result**
H1	Performance expectancy has a positive impact on the user intention to use IBM Food Trust Blockchain.	Supported
H1a	The impact of Performance Expectancy on Behavioral Intention is moderated by Gender.	Unsupported
H1b	The impact of Performance Expectancy on Behavioral Intention is moderated by Age.	Unsupported
H1c	The impact of Performance Expectancy on Behavioral Intention is moderated by Knowledge.	Supported
H2	Effort Expectancy has a positive impact on the user intention to use IBM Food Trust Blockchain.	Supported
H2a	The impact of Effort Expectancy on Behavioral Intention is moderated by Gender.	Supported
H2b	The impact of Effort Expectancy on Behavioral Intention is moderated by Age.	Unsupported
H2c	The impact of Effort Expectancy on Behavioral Intention is moderated by Knowledge.	Unsupported
H3	Social Influence has a positive impact on the user intention to use IBM Food Trust Blockchain.	Supported

H3a	The impact of Social Influence on Behavioral Intention is moderated by Gender.	Unsupported
H3b	The impact of Social Influence on Behavioral Intention is moderated by Age.	Unsupported
H3c	The impact of Social Influence on Behavioral Intention is moderated by Knowledge.	Unsupported
H4	People who own a mobile device have higher intention to use IBM Food Trust Blockchain than those who do not.	Supported
H5	People who used to be poisoned by food have higher intention to use IBM Food Trust Blockchain than those who did not.	Unsupported

Table 25 summarizes the results of the end-consumer data testing. It can be concluded that the theories of technology acceptance strongly support the empirical outcome of this research regarding the main effects of the four identified factors, namely Performance Expectance, Effort Expectance, Social Influence and Facilitating Conditions, on the usage intention of potential users with IBM Food Trust Blockchain system. However, the moderating effects of user's individual characteristics, i.e. gender, age and knowledge are not fully applicable to the study. In particular, the authors found that gender is only proved to moderate the influence of Effort Expectancy on Behavioral Intention, while the level of initial knowledge about blockchain only moderates the effect of Performance Expectancy on Behavioral Intention. No moderating effect of age has been identified. In addition, negative experience about food poisoning does not have an impact on Behavioral Intention, contradicting to what the authors expected.

6.4 Summary

This chapter is designed to tackle two final research sub-questions: SQ3 (subchapter 6.2) and SQ4 (subchapter 6.3) by conducting two separate analyses for retailers and end-consumers. The detailed answers will be proffered as below.

SQ3: Do Maltese retailers intend to use blockchain application?

On the whole, the likelihood is that Maltese retailers have an intention of using blockchain application in the future.

For the time being, there seems to be no alarming demand or noticeable force for Maltese retailers to increase the transparency and quality of the food supply chain in Malta, hence no motive for the adoption of blockchain. Moreover, this technology remains to be such a vague concept with little real practical experience for the retailers that they manifest the cautiousness when talking about the blockchain application. Nonetheless, thanks to the exceptional characteristics of blockchain, for instance transparency and the reduction of paperwork, a bullish mood is still signified for the adoption and can be further encouraged provided that there is a kick from other factors, such as social influence and facilitating conditions. As for the former, the requirement of stakeholders, such as end-consumers and supply partners, can manipulate retailers into employing the blockchain application. Considering the latter, the technological innovation can be considerably buoyed up by sufficient facilitating conditions in terms of human resources, finance and technology. This factor relies on the retail format and size of the companies as well and thus may vary accordingly. All in all, the Maltese retailers are not really eager enough to adopt blockchain technology at the moment, yet the situation can change in the future when they are more knowledgeably and conditionally ready and in case of the enormous demands from end-consumers and suppliers.

SQ4: Do end-consumers of food intend to use blockchain application? What factors affect their intention to use?

Overall, there is an optimistic prospect that the end-consumers of the food supply chain in Malta will accept using IBM Food Trust Blockchain technology with great willingness. The majority of the survey respondents agreed that the food retailers in Malta should adopt the blockchain system, which corresponded well with how they rated the statement concerning their intention to use.

In terms of factors that influence their usage intention, the authors found that Performance Expectancy, Effort Expectancy, Social Influence and Facilitating Conditions do have direct positive impacts on Behavioral Intention. Among these predictors, Performance Expectancy appears to exert the strongest effect on whether the potential users would adopt the application. This implies that the end-consumers would have a higher intention to use the technology when the benefits they perceive are greater. The result also points out that this influence of Performance Expectancy is weaker for people who have had some prior knowledge about blockchain. Similarly, the likelihood of adopting the system becomes more significant if learning how to use IBM Food Trust Blockchain is perceived to be easy and the actual usage is expected to be effortless. In this aspect, the usage intention of men is affected by Effort Expectancy more than women. With regard to the Social Influence factor, the result indicates that the potential user is more likely to accept the application if the people who are close to him think that he should use it. The last conclusion drawn from the analysis of end-consumer is that people who have at least one mobile device, which gives support to the code scanning step when using IBM Food Trust Blockchain system, have a higher intention to adopt the system.

7 DISCUSSION AND CONCLUSIONS

The final chapter is putting the finishing touches to the thesis by holding an extensive discussion and conclusion, which commence first by the answers to the research questions. Next, the theoretical and practical implications are to be mentioned. The authors also include the reliability and validity of the research. Lastly, some suggestions for future research will be ventilated.

7.1 Answers to research questions

Moving backwards or forwards, the ultimate motivation behind this thesis is to investigate and evaluate the feasibility of blockchain technology in the food retail supply chain in Malta. The purpose flows throughout the thesis, clearly mirrored by a core research question and four research sub-questions in Chapter 1. Having completed the research process, the authors shall first fathom out all of the research sub-questions in sequence, and then elucidate the answer to the research question.

SQ1: What are the potential effects of blockchain on food retail supply chain?

From the horizontal perspective, blockchain is predicted to positively influence all the three major flows of a supply chain. The information flow would experience such changes as the exclusion of third-party data storage, the great improvement in supply chain visibility and the decrease in data-related fraudulent practices. The physical product flow is expected to reach the end-consumer faster and witness a decline in the amount of food waste. The financial flow would become less dependent on third-party financial institutions in international transactions.

From the vertical perspective, the agriculture sector and processing sector would potentially see optimistic changes in the management of input material supply. Besides, the food fraud problem would also be resolved. For the distribution sector, the job of identifying faulty products would be eased with blockchain. In addition, retailers would also benefit from the enhanced corporate image brought about by blockchain. To all the three supply chain actors, the costs of adopting blockchain are seen as the only significant drawback, especially for the small and medium-sized firms in the industry. For consumers, the quality of products and the verifiable product information are what blockchain would benefit them.

(A more detailed answer is provided in subchapter 4.4.)

SQ2: How does the macro-environment affect the adoption of blockchain in food retail supply chain in Malta?

The macro-environment in Malta, on a large scale, expresses a sanguine view on the adoption of blockchain in the food supply chain with the deterrent features overshadowed by the supportive conditions. On the bright side, the Maltese government's advocacy of blockchain technology is considered one of the most valuable encouragements. On the down side, the concerns over widespread corruption and possible clashes with EU law have been articulated when Malta has passed the blockchain jurisdictions.

(A more detailed answer is provided in subchapter 5.3.)

SQ3: Do Maltese retailers intend to use blockchain application?

Based on the results harvested from the survey for Maltese retailers, it is rational to state that they are not really zealous in the adoption of blockchain in the food supply chain at the moment. However, should there be a demand from consumers and suppliers, as well as adequate facilitating conditions, this technology can be applied in the future.

(A more detailed answer is provided in subchapter 6.4.)

SQ4: Do end-consumers of food intend to use blockchain application? What factors affect their intention to use?

After analyzing the survey results of the Maltese residents, it is concluded that there is a strong demand from end-consumers for applying blockchain in the grocery supply chains, despite the fact that the concept of blockchain still appears vague to the majority. The intention to use is affected by four main factors: Performance Expectancy, Effort Expectancy, Social Influence and Facilitating Conditions.

(A more detailed answer is provided in subchapter 6.4.)

Core research question: How feasible is it to adopt blockchain technology in the food retail supply chain in Malta?

Having answered all of the sub-questions, the authors now gather all the information to unravel the core research question. All things considered, they are of the opinion that it is, on the surface, tolerably feasible to adopt blockchain technology in the food retail supply chain in Malta. Blockchain promises to positively change the face of the food retail supply chain with the tremendous influences on every single actor and seems to enjoy the macroenvironmental support in Malta. Further, the end-consumers of food in Malta show the signs of willingly adopting the blockchain platform. Meanwhile, that the Maltese retailers will employ the system appears to be tied with the demand from their customers.

However, the actual launch of the blockchain approach undoubtedly needs preparing comprehensively and thoroughly. Otherwise, it could be just close, but no cigar.

7.2 Theoretical implications

The central theories which guided along the research and assisted in drawing conclusions are PEST analysis and UTAUT. While PEST allowed the authors to implement a critical analysis of four external factors (political, economic, social and technological) then evaluate the macro-environmental impacts on the adoption of blockchain effectively, UTAUT has well facilitated the discovery of retailer and end-consumer's perspectives on their intention to use the technology.

The empirical research has shown a partial consistency between the study's results and the original UTAUT model. Specifically, the main effects of four predicting factors, i.e. Performance Expectancy, Effort Expectancy, Social Influence and Facilitating Conditions have been confirmed to influence the potential users' behavioral intention. Among these factors, the relationship between Performance Expectancy and Behavioral Intention is the strongest, accurately reflecting the theory. What was not compatible with the theory was the moderating role of Gender and Age. The only moderating effect detected was between Gender and the impact of Effort Expectancy on Behavioral Intention.

Regarding the variables that were added in the adapted research model, while the Negative Experience factor showed no significant impact on Behavioral Intention, the moderating effect of Knowledge was found in the relationship between Performance Expectancy and Behavioral Intention.

7.3 Practical implications

As the adoption of blockchain needs to be implemented on an ecosystem-scale, this research has attempted to examine the views of different supply chain participants. Thus, the results of the study would be relevant to multiple parties, especially the retailers, the retailers' supply side and the blockchain technology developers.

The results from end-consumer analysis indicate that there is a call for applying blockchain into the food retail sector from the end-consumer perspective. This is what the retailers should take into account as the technology could become a competitive advantage for them in the market. Apart from the general demand from customers, it is vital that the factors orientating towards their intention to use be cogitated in depth. Among the four factors mentioned in Chapter 6, Performance Expectancy and Effort Expectancy can be under the control of retailers. The more functions and benefits that blockchain applications can provide, the more likely the customers will use it. Also, the user interface of the application will highly matter as the customers expect the application to be easy to use. Considering the finance aspect, it would be a monetary burden for small and medium-sized retailers to develop their own blockchain-based system due to the extravagant initial capital and maintenance fees. Hence, these companies may need to consider the option of outsourcing blockchain platform to a specialized solution provider.

Referring to the retailer analysis, it has been concluded that Social Influence is a crucial factor affecting the adopting intention of retailers. In other words, the retailers would be more likely to utilize blockchain if their stakeholders, for instance customers and suppliers, expect them to use. This can be a strong indication for the farmers, food processors and wholesalers that the adoption of blockchain in the food retail supply chain somehow depends on their decisions. It is worth emphasizing that to construct a blockchain ecosystem, a certain level of contribution from each of the supply chain participants is needed. Given all the potential impacts of blockchain on the supply chains, in which the benefits outweigh the limitations, along with the optimistic macro-environment supporting conditions, this disruptive technology has the possibility to be widely utilized in the future ten to twenty years.

For blockchain developers, Malta is one of the most potential and welcoming markets to invest in. There are not only demands from the end-consumers, from the retailing companies, but also the great support and encouragement from the governmental parties.

7.4 Reliability and validity

It is of paramount importance that researchers should take into account the quantification of human behavior, or in other words, using reliable and valid measurement instruments to discern reality (Smallbone & Quinton 2004, as cited in Drost 2011, 105). These features are reflected by the reliability and validity of the thesis. The former refers to “the extent to which measurement are repeatable”, which specifically means that the same results should be basically obtained no matter who performs the measurements, when and under which conditions the measurements are performed, and which alternative instruments are employed. The latter is concerned with the meaningfulness of research components. Researchers should consider whether they are measuring what they intended to measure and develop strong support for the validity of the measures accordingly. (Drost 2011, 106-114.)

As for the reliability of the thesis, the authors are confident of the research methodology, including data collection and data analysis. Firstly, qualitative data are collected from the open-ended questionnaire with the Maltese retailers, both of which belong to the category of independent grocery store – the largest retail component in Malta. Secondly, quantitative data are harvested not only from the online platform but also through face-to-face interviews with random people so as to ensure the demographic diversity. In addition, the time for data collection approximately stretched over a period of two months from October to November, which is sufficient in the context of the thesis. After the data have been collected, the authors treat them with the utmost caution. The quantitative data are especially processed with standard statistical techniques to check the reliability and validity first before really stepping into the analyzing phase (and the data tested positive for both features). Therefore, to put it in a nutshell, similar outcomes shall be produced by other researchers using different methods on other occasions.

Considering validity, the thesis is written with a guarantee of sound findings. The secondary data are directly related to the research question and research sub-questions and originate from qualified sources such as published books, professional journals, academic articles, white reports, government documents and reliable websites. Additionally, the information is virtually issued no earlier than 2012 to ensure the thesis's topicality, accuracy and up-to-date value. With reference to the primary data, the authors are fully responsible for the data collection by designing and implementing both of the surveys for retailer and end-consumer. Whoever participates in the surveys is provided with an overview on IBM Food Trust before entering into the questioning process in order for trustful and solid answers. There is no invalid response and all of the answers are given by the targeted respondents. All in all, the validity of the research is assured.

7.5 Suggestions for future research

What have been ruled out of the scope of this research can potentially be examined in future studies. In particular, this paper takes Malta as the geographical limit. Future research on other EU countries can be conducted in order to draw some conclusions on the potential of adopting blockchain in food retail supply chain in the EU as a whole.

Additionally, in this study, the focus points under empirical examination were retailer and end-consumer, the rest of the supply chain were only reviewed based on prior literature. Therefore, a more in-depth investigation on the agriculture and food processing sectors in Malta as well as in the EU is strongly recommended. Moreover, when conducting the retailer survey, only data from independent grocery shops were managed to be collected.

Thus, it is advisable that future empirical research eliminate this limit by exploring further the perspectives of other food retail formats.

As noted when developing the research models in Chapter 6, since the utilization blockchain has not yet been realized in the food retail supply chain in Malta, the authors factored out the construct of Actual Usage as well as its relationship with Behavioral Intention in the study. For further research, it is suggested to employ the full UTAUT model once the users' actual use of the system is available to be measured.

8 SUMMARY

Living in the age of Industry 4.0, hardly can any stratum of the society be the outsider of this tornado. Among the archetypes of a disruptive technology, blockchain, the power behind Bitcoin, has stretched the wingspan transcending the boundaries of financial sector to reach other fields of business. Therefore, it is not beyond the bounds of possibility that blockchain will pervade and change part of the face of the food supply chain. On realizing the potential, the authors have written this thesis to explore a new promising horizon, using IBM Food Trust Blockchain and the food retail supply chain in Malta as the case study.

There are two main parts covered in this thesis: theoretical and empirical part.

The theoretical part flows throughout Chapter 2, Chapter 3, and Chapter 4 and also appears in Chapter 5 as a small part and in the first subchapter of Chapter 6. The contents that the authors discuss are: the basic knowledge about blockchain, the fundamentals of food retail supply chain, blockchain-enabled food supply chain, the features of IBM Food Trust, PEST analysis, and the theories of technology acceptance (TAM and UTAUT).

The empirical part is executed in Chapter 5 and Chapter 6. Chapter 5 covers the desk research of the macro-environment in Malta and the Maltese food supply chain. Moving on with Chapter 6, the authors conduct two thorough analyses, one for Maltese retailers with qualitative data, and one for the country's end-consumers with quantitative data, using IBM SPSS Statistics 23 and Excel Data Analysis. While the data of the retailers are collected completely from online platform, the data of the end-consumers trace the origin back to the online survey and face-to-face interviews.

To close the thesis, all the findings are discussed in Chapter 7 in the shape of answers to the core research question and four sub-questions mentioned in the first chapter. The hypothesized statement that it is feasible to adopt blockchain in the food retail supply chain in Malta in the beginning of the thesis is carefully elaborated before the theoretical and practical implications are mentioned. The authors are confident that the findings are passably reliable and valid. Several constructive suggestions for future related research are also included in the end.

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APPENDICES

Appendix 1 Internet survey with Maltese food retailers

(A brief description about IBM Food Trust is included in the emails.)

Part 1: Background information

1. Company name?

2. Do you want the company name to be replaced with "Company X" (i.e. stay anonymous) in the research paper?

- Yes
- No

3. Retail type?

- Hypermarket
- Supermarket
- Discounter
- Convenience store
- Independent grocery store
- Online supermarket
- Others

3. How would you describe the complexity of the food supply chain of your company at the moment?

4. Have you ever encountered any problem caused by the supplier side? (For example, providing inadequate certifications of origin, bad product quality, etc.)

5. Do you think there is a need to improve the supply process, why?

Part 2: IBM Food Trust Blockchain (IBM FTB) questions

1. How do you think this blockchain system will benefit your company operations? (For example the transparency in your supply chain, the management of suppliers, the amount of paperwork, etc.)

2. Based on the information you have got about IBM FTB, do you think learning how to use IBM FTB would be easy, why?

3. If your customers and suppliers want you to adopt this system, would you consider using it, why?

4. Do you think your company has sufficient resources (like Finance, Human and Technology) to employ this system? Please explain.

5. Do you think your company will adopt IBM FTB in the near future (10 years)?

Appendix 2 Internet survey with Maltese end-consumers

Blockchain-enabled food supply chain in Malta: consumer insight

Hello!!

We are two students from Finland. We are conducting a research project regarding the adoption of Blockchain (specifically Food Trust Blockchain powered by IBM) in food supply chain in Malta. As the opinions of end-consumers matter a lot to the validity of the project, we sincerely wish to listen to your voice.

On the next page you will find a short overview of IBM Blockchain in case you have zero knowledge about it. After that, there will be 15 multiple-choice questions related to yourself and your grocery shopping behavior, which are very simple and will just take about 3-5 minutes to complete.

NOTE: This survey is for people who live in Malta only.

Let's start!

IBM Food Trust Blockchain

A distributed system powered by IBM to digitally trace and authenticate food products, leading to a more transparent, authentic and trustworthy food supply chain.

Participants

Farmers, Processors, Distributors, Retailers

Activity

Putting all verified product-related information into the system (where it is grown, how it is processed, who distributes it, relevant certificates, etc.)

Your role as a consumer

Using a mobile app to scan codes (barcodes, QR codes, RFID codes, etc.) and get access to all reliable information of the food product. Transparent food, safe and sound life.

Part 1: Background information

1. Gender

- Female
- Male

2. Age

- Less than 22
- 22 to 41
- 42 to 54
- 54+

3. Your knowledge about blockchain

	1	2	3	4	5	
I have no idea about Blockchain	○	○	○	○	○	I'm a Blockchain expert

4. Do you have a smart device (smartphone, tablet, etc.)?

- Yes
- No

5. Have you ever had food poisoning during your stay in Malta?

- Yes
- No

Part 2: Please show your opinion on the statements below by rating on the scale from 1 to 5 (1: strongly disagree, 5: strongly agree).

1. I would be provided with a wider range of product-related information by using IBM Blockchain.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

2. I would get access to the information that I need more easily by using IBM Blockchain.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

3. I would be able to ensure the accuracy of information by using IBM blockchain.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

4. Learning how to use IBM Blockchain would be easy for me.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

5. Scanning a code (barcode, QR code, etc.) with a mobile device (smartphone, tablet, etc.) would be simple.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

6. Scanning a code (barcode, QR code, etc.) with a mobile device (smartphone, tablet, etc.) would be effortless.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

7. People who influence my behavior believe that I should check the product-related details carefully before purchase.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

8. I have a habit of checking the product-related details carefully before purchase, which is somehow influenced by the people around me.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

9. I think grocery stores and supermarkets in Malta should use IBM Food Trust Blockchain.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

10. I would use IBM Food Trust Blockchain if it becomes available.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree