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EXPLORING DISTRIBUTED COLLABORATION AND THE POTENTIAL OF BLOCKCHAIN AS AN ENABLING TECHNOLOGY

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Supervised by:
Prof. Philip O'Reilly, Prof. Rob Gleasure, and Prof. Joseph Feller

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Declaration

This is to certify that the work I am submitting is my own and has not been submitted for another degree, either at the University College Cork or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork concerning plagiarism.

Acknowledgements

Completing this thesis would not have been possible without the help and support of a team of individuals, who, in a variety of ways, contributed to this work since I undertook my research in July 2016.

First, I would like to thank my supervisors, Prof. Philip O'Reilly, Prof. Rob Gleasure, and Prof. Joseph Feller, for their time and effort. I am extremely grateful for their wealth of knowledge and expertise, as well as their endless patience.

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"Naïve enough to start, but stubborn enough to finish" – Ross Edgley

Abstract

Since the emergence of the internet, the growth and development of communication technologies have presented new opportunities for collaboration. Practitioners in almost every industry can now collaborate with the skilled personnel across a range of fields, regardless of their geographic location. This contemporary working arrangement is referred to as *Distributed Collaboration,* which I define as *the pursuit of a shared objective by groups that include non-proximate members, whose participation is facilitated by ICT*. However, Distributed Collaboration is not without drawbacks. The dispersed and volatile nature of numerous participants makes these groups vulnerable to many challenges, primarily, free-riding, production blocking, evaluation apprehension, and perceptions of fairness.

Meanwhile, Blockchain technology has emerged over the last decade, initially to facilitate the cryptocurrency market. However, research interest has recently focused on its potential to support non-financial use-cases such as the ability to track assets, both digital and physical, in a secure, transparent, and immutable manner. These technological capabilities of Blockchain would suggest it has the potential to support Distributed Collaboration by tracking individual contributions across a distributed ledger. Therefore, the objective of this thesis is to *explore Distributed Collaboration and the potential of Blockchain as an enabling technology*.

This research was initiated by examining the potential of Blockchain to enable Distributed Collaboration from a macro-level perspective through the lens of the cryptocurrency market. The market can be considered a network of distributed participants, communicating to evaluate Blockchain as a technology. The findings show that in the absence of established factors and methods to evaluate cryptocurrencies, market participants rely on social cues to evaluate the assets.

Next, I conducted a first iteration of Design Science Research (DSR) by exploring the potential for Blockchain to address the issue of free-riding in cross-functional groups. This endeavour found that there was potential. However, a more comprehensive understanding of the components of this research was required in order to extract theoretical and practical contributions.

Therefore, a systematic literature review was performed to synthesise a comprehensive definition of Distributed Collaboration, as well as developing an understanding of the factors which lead to the success of these groups.

Following this, qualitative interview data were gathered and analysed from practitioners operating in Distributed Collaboration to develop an understanding of the challenges faced when operating in this environment and the necessary components for a potential system to alleviate these issues.

Finally, I completed a second iteration of DSR to rigorously investigate the potential of Blockchain to support Distributed Collaboration. A Blockchain-enabled system was developed, implementing the design construct of *Creative Ancestry* to improve perceptions of fairness in Distributed Collaboration. Findings show that Blockchain increases perceptions of fairness and thus improves overall collaboration.

My research has implications for theory, practice, and future research. I provide a core model for successful Distributed Collaboration and detail how to implement a Blockchain-enabled system that addresses key issues. I also illustrate the presence of herding

behaviour in the cryptocurrency market and how market participants are prone to amplified reactions to changes in the price of assets. These findings and their implications are discussed at length in the final chapter.

Chapter 1. Introduction

1.1 Introduction to this study

The objective of this research is to *explore Distributed Collaboration and the potential of Blockchain as an enabling technology*. This study provides contributions to both our understanding of Distributed Collaboration as well as the application of Blockchain as an emerging technology with vast potential across a host of industries. This is a thesis by publication and is structured as the following introduction chapter, a collection of five completed research papers, and a discussion and conclusion chapter. In this chapter, I will begin by contextualising my research through an overview of Distributed Collaboration, Blockchain, and the relationship I see between the two. Then, I will discuss what motivated me to undertake this research. Following this, I will give an overview of my research philosophy, research approach, and a summary of each of the five completed research papers. Finally, I will provide an insight into the major contributions of my study.

1.2 Research Context

To achieve my research objective an understanding of Distributed Collaboration, Blockchain, and the relationship between them is required to set the context for the Chapters to follow.

1.2.1 What is Distributed Collaboration

Distributed Collaboration is a term which has been developed over the course of this research to encapsulate collaborative arrangements whereby large numbers of participants work with one another in order to achieve a shared objective or collectively decide on a particular course of action. Distributed Collaboration is, therefore, defined as *the pursuit of a shared objective by groups that include non-proximate members, whose participation is facilitated by ICT*. The methodology for developing this definition is detailed in Chapter 3. Distributed Collaboration has been adopted by a plethora of industries, including Open Source Software development, the sharing of information through sites such as Wikipedia, the design of clothing, and even developing new flavour combinations for food (Forbes & Schaefer, 2017). A full discussion of the different forms of Distributed Collaboration is detailed in Appendix 9.2. However, these examples are instance-specific. Although the size of these groups can be large in numbers, and members can be dispersed across the globe, their 'shared objective' is specific to their particular group. Distributed Collaboration can also occur between dispersed participants across an entire market (e.g. the cryptocurrency market) whereby participants collectively reach consensus regarding the value of the market's assets.

1.2.2 What is Blockchain

Blockchain, at a fundamental level, is a chronological database of transactions recorded by a network of computers, the term 'Blockchain' refers to these transactions being grouped in blocks, and the chain of these blocks forms the accepted history of transactions (Peters & Panayi, 2016). This research examines Blockchain both as the technology which supports cryptocurrencies and also as a platform for decentralised applications.

Upon undertaking this research, the Blockchain industry was still very much in its infancy. It had been 8 years since Satoshi had released the Bitcoin whitepaper (Nakamoto, 2008), and the cryptocurrency was perhaps best known for its infamous role in controversies relating to Mt. Gox and Silk Road in the previous years. Simultaneously, the first cryptocurrency network to support smart contract development, Ethereum, had been launched a mere 11 months previous and Blockchain-enabled applications were few and far between.

Blockchain owes its popularity to its role as the underlying technology of major cryptocurrencies. The largest Blockchain-based cryptocurrency at the time of writing and the technological foundation on which other cryptocurrencies are built is Bitcoin. Bitcoin was designed to allow individuals from anywhere in the world to send funds to one another in a truly peer-to-peer nature without needing a central intermediary (Nakamoto, 2008). The Bitcoin protocol was released during the global financial crisis when trust in the traditional, centralised banking system was low (Earle, 2009; Weber, 2014).

Other assets then emerged on the market. Litecoin was released in October 2011 by Charles Lee to improve on perceived shortcomings of Bitcoin (Sapuric, Kokkinaki, & Georgiou, 2017). Specifically, Litecoin sought to address slow transaction times, the predetermined coin supply cap, and the reliance on powerful and specialised equipment to participate in the network (Sapuric et al., 2017; Sovbetov, 2018). Ethereum was introduced to transcend purely financial uses and instead facilitate smart contracts and distributed applications (Ethereum, 2018). Ethereum does this by building an abstract foundational layer: a Blockchain with a built-in Turing-complete programming language, allowing anyone to write smart contracts and decentralised applications (Sapuric et al., 2017).

As a platform for the development of decentralised applications, Blockchain is a way of recording interactions in a structured and secure manner, offering increased fault tolerance and availability (Peters & Panayi, 2016; Swan, 2015; Tapscott & Tapscott, 2016). Several companies including Microsoft, IBM and Maersk have conducted their own research to develop a proof-of-concept Blockchain solutions to fit their respective needs (Beck & Müller-Bloch, 2017; Hyvärinen, Risius, & Friis, 2017; Nærland, Müller-Bloch, Beck, & Palmund, 2017). I, therefore, saw the potential for how the same security, scalability, and scrutiny which Blockchain has brought to these industries could also benefit Distributed Collaboration

1.2.3 The potential impact of Blockchain for Distributed Collaboration

As with any technology, Blockchain becomes redundant without an appropriate use-case. I became increasingly interested in the potential of Blockchain to secure intellectual property. Early-stage applications demonstrated the power of Blockchain; for example, proofofexistence.com showcased how any file could be immutably, securely and transparently stored on the Blockchain. Similarly, Ujomusic provided an interesting example of how Blockchain could be used to disintermediate the production of music, creating a platform which paid musicians directly for the sale of their IP. Distributed Collaboration is another use-case where intellectual property disputes are a common issue.

Distributed Collaboration evolved from what was traditionally co-located teams (Eppinger & Chitkara, 2006; Gupta, Mattarelli, Seshasai, & Broschak, 2009). The emergence and development of communication technologies afforded these groups the opportunity to broaden their scope beyond their immediate geographic proximity and harness resources from dispersed locations. This presented an opportunity for traditional organisations to expand but also for individual participants to join different organisations or even collaborate independent of formal organisations to achieve their shared goal.

In this increasingly disintermediated or ‘flat’ world, Blockchain has emerged as a seemingly ideal solution. Tracking individual contributions in Distributed Collaboration is essentially supply chain management for intellectual property. Thus, I examined Blockchain applications which had implemented supply chain management tools to capture the origins of component products, for example, *Provenance* in product assembly

(Provenance, 2015) and *Everledger* in the diamonds industry (Everledger, 2017). Blockchain boasts the ability to remove the need to intermediaries and central authorities and eliminate the reliance of trust between collaborating parties.

Blockchain also supports Distributed Collaboration on a macro-level in the form of the cryptocurrency market. Over the course of this research lifecycle, the cryptocurrency market experienced extraordinary growth, from less than 600 cryptocurrencies in July 2016 to over 2300 cryptocurrencies available in June 2019 (Graphics, 2019). As well as this, the leading cryptocurrency, Bitcoin, underwent a price increase from approximately $600 to approximately $12,000 in this same time frame, reaching a peak of almost $20,000 (coinmarketcap.com, 2019). I analyse the cryptocurrency market as a Distributed Collaboration network whereby movements in the price of different cryptocurrencies is a reflection of the consensus public perception of each of the assets available in the market. The public, permissionless nature of leading cryptocurrencies including Bitcoin, Litecoin, and Ethereum makes this particularly interesting to analyse because of the low barrier to entry for new market participants.

1.3 Research Motivation

My motivation for undertaking this research can be categorised as theoretical and pragmatic. Theoretically, the focus of this research was motivated by the nascent stage of Blockchain literature. In particular, this research was motivated by the lack of research investigating Blockchain as a technology for non-financial applications. Given the obvious association between Blockchain and cryptocurrencies, research in this domain has primarily focused on finance and related fields (Holub & Johnson, 2018). Blockchain had been suggested as an appropriate technology to secure intellectual property (Swan, 2015; Tapscott & Tapscott, 2016) and Distributed Collaboration certainly requires an efficient

IP management solution given the volume of contributions in these groups (Ren & Kraut, 2011; Tsai & Bagozzi, 2014). The potential for individuals to collaborate in organised groups has evolved from exclusively co-located, face-to-face environments, to distributed, digitally-enabled groups with the growth and development of ICT (Gallupe et al., 1992). Blockchain, as an emerging, disruptive technology, could be the catalyst for the next evolution in this domain. As such, the potential for Blockchain to enable Distributed Collaboration presented itself as an intriguing theoretical proposition.

Pragmatically, I was motivated to conduct this research as it was an opportunity to work with and educate practitioners who were looking to learn what Blockchain as a disruptive technology could do for their business. I consider this to be an essential element of my research as it is important for practitioners to not only be aware of Blockchain, but also to understand how it operates, how it differs from traditional technologies, and the benefits it can offer.

Therefore, in addition to the academic outputs which will be presented in the following Chapters, I was conscious of pursuing an active approach to developing a comprehensive understanding of Blockchain and cryptocurrencies, which I could then share with practitioners. I saw this research as a unique opportunity to gain expertise in an emerging, disruptive domain. Therefore, I participated in a number of extra-curricular activities to enhance my research.

First, considering the incredible growth of cryptocurrencies over the course of the last three years, especially in 2017, I was keen not to miss the opportunity. I bought a small amount of cryptocurrency in February 2017 and revelled in the excitement of speculating what I was going to spend my fortunes on, only to stubbornly follow the 'HODL' (Hold on for Dear Life) strategy and watch my profits dwindled in 2018.

Second, in an effort to expose myself to every element of Blockchain, I purchased a Raspberry Pi computer, joined a mining group, and began to mine smaller cryptocurrencies. Needless to say, given the highly competitive nature of cryptocurrency mining over the last three years and my extremely limited computing resources I did not yield any profits worth mentioning, but again I saw this as a valuable learning experience.

Third, I quickly came to understand that Blockchain was developing at a much faster pace than I could ever keep up with. Therefore, the best way to remain up to date with the latest advancements was, in the spirit of Distributed Collaboration, sharing what I had learned and collaborating with others who were interested in the technology. I wrote speculative, industry-focused articles detailing my opinions on the development, growth and adoption of cryptocurrencies and Blockchain, two of which were published in Cutter and the Sunday Business Post (Appendix 9.5). I also discussed my thoughts at length during a local podcast in February 2018 and presented at a number of Meetup events for Blockchain in Cork City. These settings were an excellent opportunity to discuss developments with other interested parties without the pressure of adhering to academic rigour. I was also asked to present an *Introduction to Blockchain* guest lecture on a number of occasions in UCC, the Irish Management Institute (IMI), and National University of Ireland, Galway (NUIG), as well as giving the opening presentation for Blockchain Ireland Week in UCC in May 2019, where I presented on *Blockchain 101 and Threats to Future Growth*. In addition, I attended countless lectures and presentations on Blockchain, most notably at the World Blockchain Summit in Shanghai, 2016. Again, these were priceless learning experiences to expose myself to the latest developments in the industry.

1.4 Research Philosophy

The research presented in this thesis assumes a critical realist ontology. A critical realist understands that our knowledge of reality is a result of social conditioning and, therefore, is dependent on the social actors involved in deriving this knowledge (Krauss, 2005). Critical realism makes a distinction between the real, the actual, and the empirical. The definition of the real notes two things; first, the real domain consists of structures of objects, both physical and social, with capacities for behaviour called mechanisms. Mechanisms are simply defined as a causal structure that explains a phenomenon (Bygstad & Munkvold, 2011). These mechanisms may (or may not) trigger events in the domain of the actual. Second, the real is the realm of objects, their structures and powers (Sayer, 1999). To build our knowledge of a stratum – that is, to find out what explains it – we need to examine the mechanisms of underlying strata. In the natural sciences, mechanisms are more tangible and easier to measure, for example, gravity or air pressure. However, in social settings it may not be possible to see or physically touch the mechanisms represented, norms and roles, personality and attitude, and culture are all examples of mechanisms in social settings (McAvoy & Butler, 2018).

The methodological approach of a critical realist, contrary to positivist research, is to uncover and describe the mechanisms that produced these events. This is achieved through retroduction; the process of taking an empirical observation and hypothesize a mechanism that might explain that particular outcome (Danermark, Ekstrom, & Jakobsen, 2002). For example, while we may observe buyers and sellers agree on prices and volumes, the underlying market mechanism is unobservable. Mechanisms are proposed to constitute the “nuts and bolts” of middle range theory, however, if a mechanism is too general it loses explanatory power, if it is too specific it becomes relevant only in the single context where it was identified (Bygstad & Munkvold, 2011). Critical realists emphasize that the outcome of a mechanism is contextual, i.e. dependent on other mechanisms. Thus, a mechanism may produce an outcome in one context, and another in a different context.

In the context of my research a number of mechanisms were identified, for example, in Chapter 2, while we observe that the cryptocurrency market is extremely volatile, the unobservable mechanism has been the presence of herding in the market and the social amplification of risk being caused by insufficient information. Also, in Chapter 6 we observe that the application of Blockchain had a positive influence on Distributed Collaboration, the application of a mid-range causal theory highlighted social justice as the underlying mechanism which is facilitated through Creative Ancestry.

The actual is the realm of practices/processes and events, i.e., the result of what happens when those powers are activated (Sayer, 1999). Finally, the empirical refers to the realm where social actors experience the real and the actual which may be observable or not (Sayer, 1999). Crucially, critical realism recognises the possibility that what has happened or been known to have happened does not exhaust what could happen or have happened (Sayer, 1999).

Critical realism is particularly applicable in the IS field as Information Systems is a practice-based research domain, which encourages the use of both natural and social science (Zachariadis, Scott, & Barrett, 2013). Critical realism is compatible with a wide range of research methods and rejects prescribed methods which allow a researcher to apply them without scholarly knowledge of the study in question (Sayer, 1999). While critical realism endorses a variety of research methods, it implies that the particular choices should depend on the nature of the object of study and what one wants to learn about it (Sayer, 1999).This was particularly empowering for the purpose of my research. Blockchain and Distributed Collaboration are developing, multi-faceted domains and, therefore, require a mixed methods research approach, the specifics of the approaches adopted are detailed in section 1.5.

The purpose of this section is to introduce the main research paradigms applied in IS research and to justify the selection made for this thesis. A research paradigm is the "basic belief system or worldview that guides the investigator not only in choices of a method but in ontologically and epistemologically fundamental ways" (Guba & Lincoln, 1994). Inquiry paradigms are dictated by the response given by proponents of any given paradigm to three fundamental questions. The three questions are:

1. The ontological question, which concerns the forms and nature of reality and, therefore, what can be known about it?
2. The epistemological question, which concerns the nature of the relationship between the researcher and what can be known.
3. The methodological question, which concerns how the researcher can go about finding out whatever they believe can be known.

Table 1.1 below illustrates the responses to these questions, adapted from Guba and Lincoln (1994), these three fundamental questions are interconnected so that the answer to any one question constrain how the others must be answered.

Table 1.1 Basic beliefs of alternative inquiry adapted from Guba and Lincoln (1994)

Item	Positivism	Critical Theory	Post-positivism	Constructivism
Ontology	Naive realism- "real" reality but apprehendable	historical realism virtual reality shaped by social. political, cultural, economic, ethnic, and gender values; crystallised over time	Critical realism- "real" reality but only imperfectly and probabilistically apprehendable	Relativism- local and specific constructed realities
Epistemology	Dualist/objectivist; findings true	Transactional/ subjectivist; value mediated findings.	Modified dualist/ objectivist; critical tradition/community; findings probably true	Transactional/ subjectivist; created findings
Methodology	Experimental/ manipulative; verification of hypotheses; chiefly quantitative methods	Dialogic/ dialectical	Modified experimental/ manipulative; critical multiplism; falsification of hypotheses; may include qualitative methods	Hermeneutical/ dialectical

Under the positivist research paradigm, the object of study is independent of researchers; knowledge is discovered and verified through direct observations or measurements of phenomena; facts are established by taking apart a phenomenon to examine its component parts (Krauss, 2005). In other words, the data and its analysis are value-free, and data does not change because they are being observed (Healy & Perry, 2000). That is, researchers view the world through a “one-way mirror” (Guba & Lincoln, 1994). The ontological assumptions can be characterised as naïve realism. Knowledge of “the way things are” is presented independent of time and context. The epistemological assumptions can be characterised as dualist and objectivist. However, this can be a criticism of this research paradigm as researchers distance themselves from the world they study, rather than acknowledging the role of the real world in order to better understand their research, as is the case in the other paradigms (Healy & Perry, 2000).

The post-positivist research paradigm emerged in response to the criticism directed at the positivist paradigm. The positivist view stresses the importance of “theory verification” where post-positivist focuses on “theory falsification” (Ponterotto, 2005). Post-positivists are said to adopt a “critical realist” ontology, in that they assume that there is an objective reality, but maintain that due to flawed human intellectual mechanism, this is only imperfectly and probabilistically apprehendable (Guba & Lincoln, 1994). The epistemological assumptions can be characterised as modified dualist and objectivist; researchers assume that it is only ever possible to approximate reality as it is imperfectly apprehensible (Healy & Perry, 2000). This paradigm accepts that researchers’ perceptions and feelings influence observations and findings, meaning that reality is seen through the eyes of the researcher and is, therefore, not necessarily the precise view of reality (Teddlie & Tashakkori, 2009). In conclusion, the complex, subjective nature of researching the utility of emerging technology such as Blockchain to support a dynamic use-case like Distributed Collaboration influenced the adoption of a critical realist approach.

Under the critical theory research paradigm, the researcher focuses on the social realities, aiming to critique and transform social, political, cultural, economic, ethnic, and gender values (Healy & Perry, 2000). The ontological assumptions can be characterised as historical realism, meaning that knowledge is grounded in social and historical routines. In contrast to the positivist research paradigm, knowledge is value-dependent (Guba &

Lincoln, 1994). The epistemological assumptions of critical theory can be characterised as transactional and subjectivist, meaning that researchers rely on conversations and reflections to develop their view of reality, often making subjective assumptions. Therefore, knowledge is value-dependent (Guba & Lincoln, 1994; Ponterotto, 2005).

Under the constructivist research paradigm, knowledge is established through the meanings attached to the phenomena studied; researchers interact with the subjects of study to obtain data; inquiry changes both researcher and subject; and knowledge is context and time-dependent (Krauss, 2005). The ontological assumptions can be characterised as relativism, which assumes that there are multiple, apprehendable realities which may even conflict one another. Reality is the product of the observer and can change as people become more informed (Guba & Lincoln, 1994; Ponterotto, 2005).The epistemological assumptions can be characterised as transactional and subjectivist; therefore, knowledge creation occurs from the interactions between the investigator and respondents (Guba & Lincoln, 1994).

1.5 Research Approach

Blockchain and cryptocurrencies naturally have a symbiotic relationship. The cryptocurrency market is constituted of a network of distributed participants, all with the shared objective of collaborating to reach consensus as to the price of the available assets. This led me to view the cryptocurrency market itself as a form of Distributed Collaboration. Therefore, I pursued an initial study to analyse perceptions of Blockchain technology through the lens of the cryptocurrency market. This study is presented in **Chapter 2** as a macro-level view of Blockchain and Distributed Collaboration (Figure 1.1). I then looked to examine how Distributed Collaboration could be enabled at a micro-level by adopting a Design Science Research approach.

I completed the first iteration Design Science Research (DSR) study in order to explore Distributed Collaboration and assess the potential for Blockchain as an enabling technology. The product of this research effort was published in the OpenSym Conference, 2017. My paper, ‘Exploring the Application of Blockchain Technology to Combat the Effects of Social Loafing in Cross-Functional Group Projects’, presented in **Chapter 3**, detailed both my understanding of Distributed Collaboration, the challenges faced by their members, as well as showcasing the first proof-of-concept, Blockchain-enabled system I had developed to capture users contributions to a group project.

As shown in Figure 1.1, upon completing this first iteration of DSR, the following three papers explore, in far greater detail, particular elements which had been introduced. First, I needed to develop a more comprehensive understanding of what I had initially referred to as ‘cross-functional groups’, this resulted in the execution of a systematic literature review focusing on ‘Distributed Collaboration’, this study is presented in **Chapter 4**.

Second, the challenges of free-riding, evaluation apprehension and production blocking which had been outlined required further exploration, in order to do so I held a series of exploratory interviews with industry participants operating in Distributed Collaboration, this study is presented in **Chapter 5**. While Blockchain has potential to combat these challenges, I determined that this was not an ideal application of the technology. I categorised this intra-organisational Distributed Collaboration as ‘Low Participation / Low Competition’ (Appendix 9.2). I then identified that Blockchain would better facilitate ‘High Participation / High Competition’, which became the focus of the following chapter.

Third, given the comprehensive understanding of Distributed Collaboration and the challenges faced in this type of work, I assessed how Blockchain could be implemented as an enabling technology. I further developed the Blockchain system, which is introduced in Chapter 2. I then rigorously evaluated its potential to capture individual contributions to a group. This process of designing, building, testing and, evaluating this system is presented in **Chapter 6**.

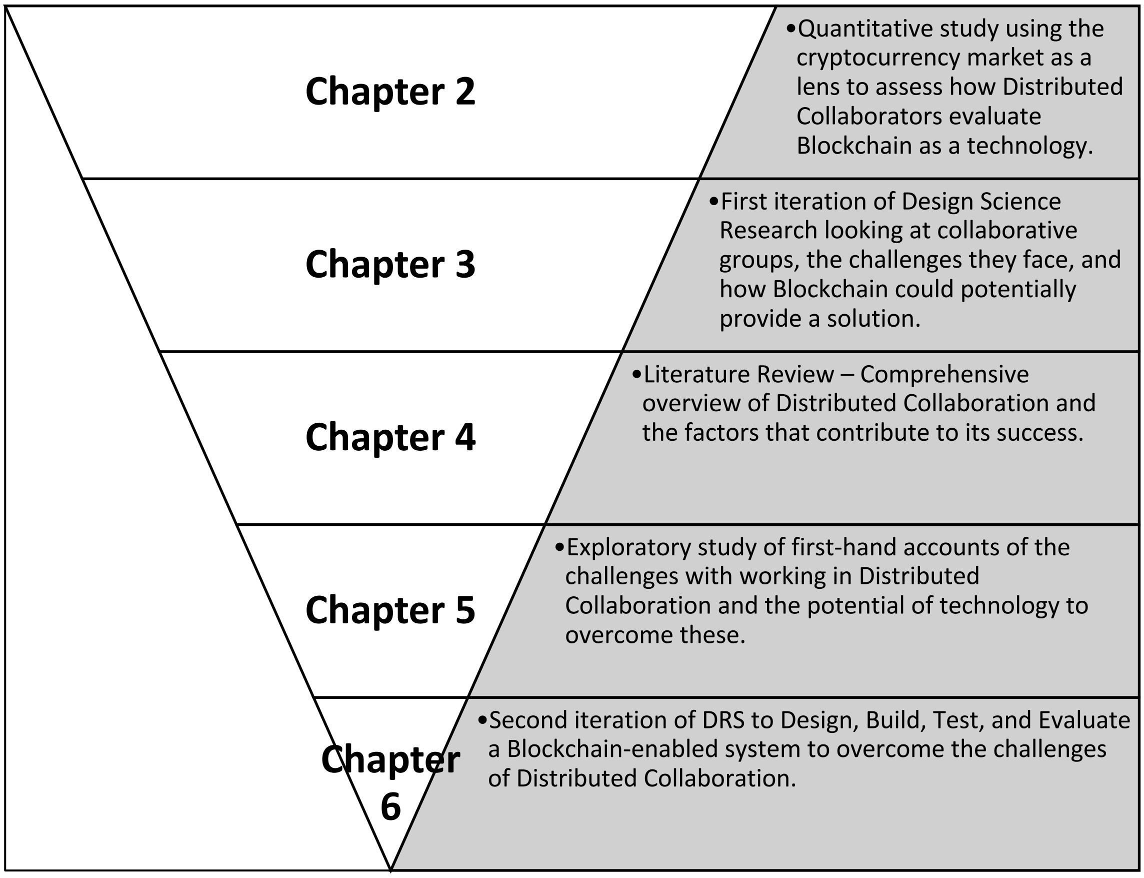


Figure 1.1 Overview of research objectives in each Chapter

1.6 Research Overview and Main Contributions

An overview of my research is illustrated in Figure 1.2 below.

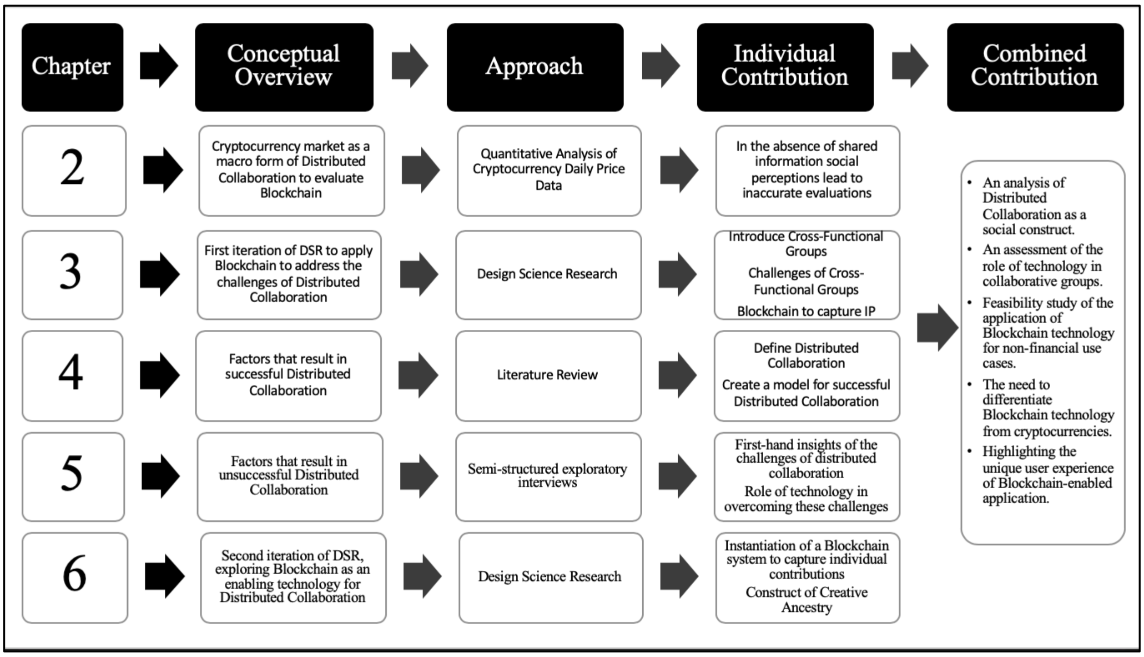


Figure 1.2 Research Contributions Overview

As detailed in Figure 1.2, due to the multidisciplinary nature of my research, and in keeping with the critical realism ontology adopted for this research, I chose to apply a selection of research approaches in order to produce a comprehensive body of work to explore Distributed Collaboration and the potential of Blockchain as an enabling technology. My research started by exploring the potential of Blockchain to enable Distributed Collaboration through the lens of the cryptocurrency market. I then focused on a Design Science Research approach to explore Distributed Collaboration and the potential of Blockchain as an enabling technology. DSR is an iterative process which I started in Chapter 3 and refined over the following three chapters. Each paper builds on the previous study and makes additional contributions to our understanding of Distributed Collaboration and the potential of Blockchain as an enabling technology as follows:

1. In **Chapter 2**, I analyse Distributed Collaboration on a macro-scale, through the lens of the cryptocurrency market. I view the market as a whole as a network of distributed participants, collaborating with the objective of evaluating cryptocurrencies and their underlying technology, Blockchain.
2. The paper presented in **Chapter 3** details the development of the first iteration of a proof-of-concept, Blockchain-enabled application which could capture individual contributions. This chapter represents an exploratory study into Blockchain for non-financial applications. This Chapter targets the problem of free-riding in, what I then referred to as *cross-functional group projects*. This study is now published in the OpenSym conference (O'Leary et al., 2017).
3. In my Literature Review presented in **Chapter 4**, I systematically explore the area of *cross-functional groups*. From this point, my research refers to this working arrangement as *Distributed Collaboration*, and a comprehensive definition is developed based on a number of popular synonyms found in the extant literature. Using a concept-centric approach as suggested by Webster and Watson (2002) I also illustrate a model for successful Distributed Collaboration.
4. In **Chapter 5**, I investigate the challenges which can disrupt Distributed Collaboration by conducting exploratory interviews with industry participants and analysing these interviews using Open, Axial, and Selective Coding methods. This chapter builds on the challenge of free-riding which was presented in Chapter 2 by discussing the other major difficulties of this type of work as well as gaining key insights from practitioners on the day-to-day reality of operating in Distributed Collaboration.

5. The potential of Blockchain as an enabling technology for Distributed Collaboration, is thoroughly investigated in **Chapter 6**, whereby the proof-of-concept system, which was initially developed for Chapter 3 is redesigned, redeveloped, and rigorously evaluated. The Design Science Research approach adopted for this chapter necessitates the development of two artefacts, first, the system instantiation, and second, the design construct of Creative Ancestry.

As a collection of research papers, this thesis contributes to the research domain by first, analysing Distributed Collaboration as a social construct. Second, this thesis assesses the role of technology in collaborative groups. Third, my research conducts a feasibility study of the application of Blockchain as a technology beyond financial use-cases, detailing not only *that* it can be implemented but also *how* to do so. Fourth, this research highlights the need to differentiate Blockchain technology from cryptocurrencies. Fifth, I have illustrated the unique user experience with a Blockchain-enabled application. A detailed discussion of these thesis-level contributions is presented in the conclusion Chapter of this thesis.

A summary of each of my research papers is shown in Table 1.2 below:

Table 1.2 Summary of Methods, Data and Findings of each Chapter

Chapter	Peer Review	Analysis Method	Key Data	Key Findings
2	Under Review with Information Society	Vector Autoregression and Polynomial Regression	731 daily observations of 3 major cryptocurrencies	• Ether is the best predictor of changing prices, not Bitcoin •These effects are stronger when prices are more extreme
3	Proceedings of the 13th International Symposium on Open Collaboration.	Design Science (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007).	Workshops	Blockchain technology has significant value for both innovation and recognition and reward Blockchain can address the problem of free-riding in cross-functional groups
4	Under Review with Communications of the Association for Information Systems	Concept-centric Matrix according to (Webster & Watson, 2002)	170 extant research papers	• Synthesised definition of Distributed Collaboration. • Model of successful Distributed Collaboration.
5	Submitted to Journal of Enterprise Information Management	Open, Axial, and Selective coding techniques (Strauss and Corbin, 1990; Urquhart, 2001)	Approximately 8 hours of qualitative interview data with a selection of manager and subordinates	• System features should be incorporated into a potential solution to overcome challenges. • Highlighting under-reported challenges of Distributed Collaboration

6	Submitted to Journal of Information Technology	Design Science (Peffers et al., 2007). and Structural Equation Modelling	Survey results from 121 participants who evaluate a system instantiation	• The design construct of Creative Ancestry to improve perceived fairness in Distributed Collaboration • The implementation of a Blockchain-enabled system to capture individual contributions

1.7 Chapter Summary and Conclusion

The process of conducting the research I present in this thesis has afforded me the opportunity to develop a deep understanding of Distributed Collaboration as an approach to work which is continuously implemented across all industries and disciplines, as well as Blockchain as an emerging and disruptive technology. Through pursuing a thesis by publication, I had the opportunity to tackle my research with a multidisciplinary approach. This allowed me to experience every element of my domain, analysing existing literature to build a foundational understanding, interviewing participants with first-hand experience of operating in this domain, designing and building a system instantiation, and rigorously analysing the cryptocurrency market.

The multiple iterations of peer review that each research paper has undergone has ultimately strengthened both the content and delivery of my work. One of the papers has been published, another has undergone two rounds of review for a special issue and is now under review with another top academic journal, while the remaining three papers are all under review in peer-reviewed journals.

I am confident that the content of this thesis is rigorous and comprehensive in its methods, definitive and accurate in its findings, and is presented in a manner which makes significant contributions. I hope you find my work to be insightful and enjoyable to review.

Chapter 2. “Information is the resolution of uncertainty”: The reliance on social perceptions to evaluate the price of cryptocurrencies

2.1 Abstract

The last number of years have seen the emergence and rapid growth of Blockchain technologies. Bitcoin has been widely credited for driving public confidence in Blockchain as a revolutionary operational technology, due to the financial investment Bitcoin has attracted as a cryptocurrency. Yet this relationship remains untested. Do changes in the price of Bitcoin actually predict changes in the prices of other cryptocurrencies? What do cryptocurrency prices tell us about public perceptions of Blockchain as a technology for further development? The objective of this study is to *examine how increased reliance on social cues impacts changes to the price of cryptocurrencies*. This research looks to show that in the absence of complete information and established methods for evaluating cryptocurrencies, investors rely on social perceptions to determine the price, this ultimately leads to uncertainty and large fluctuations in the market. Applying the dual lenses of herding and social amplification of risk we hypothesize how public perceptions cascade across Blockchain platforms/cryptocurrencies. Specifically, we investigate changing daily price data for Bitcoin (BTC), Litecoin (LTC), and Ether (ETH). Surprisingly, results show Ether is the best predictor of changing prices, not Bitcoin. This suggests perceptions of Blockchain as a platform may be driving prices of cryptocurrencies. We further show these effects are stronger when prices are more extreme, consistent with existing research on the social amplification of risk.

Keywords: Cryptocurrency, Blockchain, Herding Behaviour, Social Amplification of Risk.

2.2 Introduction

The last number of years has seen extraordinary growth in the cryptocurrency market, peaking in late 2017 before stabilizing in 2018. Bitcoin, the largest cryptocurrency, reported a rise in price of over 1300% in 2017, having reached a record high in December of $17,899.70 (coinmarketcap.com, 2019). Ether, the underlying cryptocurrency of the Ethereum network, outperformed Bitcoin in terms of percentage price increase in the same year, rising in price by more than 9,000% the same year, from a closing price of $8.17 on New Year's Day 2017 to $756.73 on New Year's Eve (coinmarketcap.com, 2019). Recent prices are more modest, with BTC trading at $10,210 and ETH at $281 at the time of writing (coinmarketcap.com, 2019). However, cryptocurrencies continue to attract significant attention, most recently with the announcement that Facebook is to launch its own cryptocurrency, Libra (Andriotis, Rudegeair, & Hoffman, 2019).

Naturally, there is a symbiotic relationship between perceptions of the potential of cryptocurrencies and public confidence in Blockchain, the underlying technology (Li & Wang, 2017). Research has shown that increased interest, measured through Google search trend, in cryptocurrencies and Blockchain are positively correlated (Sovbetov, 2018). This trend has been reflected in academic research, which has looked to establish the determinants of cryptocurrency price formation (Cheah & Fry, 2015; Georgoula, Pournarakis, Bilanakos, Sotiropoulos, & Giaglis, 2015; Kristoufek, 2013; Li & Wang, 2017), while also focusing on the potential of Blockchain technology (Beck, Czepluch, Lollike, & Malone, 2016; Beck, Müller-Bloch, & King, 2018; Hyvärinen et al., 2017).

These wild growth spurts raise questions regarding how these cryptocurrencies are valued. Certain studies suggest they are naturally prone to bubble behaviour (Cheah & Fry, 2015; Cheung, Roca, & Su, 2015; Fry & Cheah, 2016), comparable to Internet stocks of the 1990s rather than a true currency (Yermack, 2015). Other streams of research suggest a sustainable value, due to the practical benefits of Blockchain such as addressing the double-spend problem, lowering transaction costs, and improving fraud detection (Van Alstyne, 2014). Others recognise the dual nature of cryptocurrencies and includes the joint determination of technology and economic factors (Li & Wang, 2017). These diverse perceptions show that evaluating a cryptocurrency is undoubtedly different from evaluating traditional financial assets. Fiat currencies can be evaluated by examining the economic state of the issuing nation, the corresponding exchange rates, or the trade balance (Hopper, 1997). Similarly, a company's stock price can be evaluated by measuring factors such as customer satisfaction (Fornell, Mithas, Morgeson III, & Krishnan, 2006) and ownership structure (Thomsen & Pedersen, 2000). Cryptocurrencies do not allow investors the same capacity to ground and triangulate their perceptions with perceptions of established economic indicators which would be typically used to evaluate traditional organisations or economies. Thus, the value of a cryptocurrency is almost entirely determined by how investors perceive and pre-empt the evaluations of other investors.

The objective of this study is *to examine how increased reliance on social cues impacts changes to the price of cryptocurrencies*. This research looks to show that in the absence of complete information and established methods for evaluating cryptocurrencies, investors rely on social perceptions to determine the price, this ultimately leads to uncertainty and large fluctuations in the market.

In order to achieve this objective, we build on an emerging body of extant literature which has found volatility connectedness and herding behaviour in the cryptocurrency market, especially in periods of uncertainty (Bouri, Gupta, & Roubaud, 2018; da Gama Silva, Klotzle, Pinto, & Gomes, 2019; Stavroyiannis & Babalos, 2019; Vidal-Tomás, Ibáñez, &

Farinós, 2018; Yi, Xu, & Wang, 2018). This study contributes to this existing research which has identified herding in the market through the additional application of the Social Amplification of Risk Framework (SARF). SARF is a mechanism which explains how individuals rely on social observation in situations where the stakes are high and information is limited (Kasperson & Kasperson, 1996; Renn, Burns, Kasperson, Kasperson, & Slovic, 1992).

In the next section we will discuss the emergence of cryptocurrencies. This section describes how Bitcoin, Ether, and Litecoin were developed and the similarities and differences between each. Following this, we discuss how investors perceive and pre-empt the evaluations of other investors, culminating in the two hypotheses for this study. These hypotheses predict that movements in Bitcoin precede movements in the other cryptocurrencies and that this pattern increases when these movements are more extreme. Next, the methods and results for the study are presented, which suggest movements in the price of Ether (ETH) are actually more likely to precede movements in Bitcoin (BTC) and Litecoin (LTC). These findings are then discussed with regard to different investor populations and the role of investor perceptions of underlying Blockchain technologies.

2.3 The Emergence of Cryptocurrencies

Cryptocurrencies are built on Blockchain technology. The Blockchain records transactions in blocks of data which are verified by a network of peers in an immutable, cryptographically secure manner (Beck et al., 2018). The largest Blockchain-based cryptocurrency at the time of writing, and the technological foundation on which other cryptocurrencies are built is Bitcoin. Bitcoin was designed to allow individuals from anywhere in the world to send funds to one another in a truly peer-to-peer nature without needing a central intermediary (Nakamoto, 2008). The Bitcoin protocol was released during the global financial crisis when trust in the traditional, centralised banking system was low (Earle, 2009; Weber, 2014). Since its release Bitcoin has captured the attention of researchers from several different backgrounds, Holub and Johnson (2018) detailed a comprehensive literature review of 1206 research papers on Bitcoin, categorizing the research across Technology, Accounting, Economics, Finance, Tax, and Regulation.

Other cryptocurrencies were soon introduced. Litecoin was released in October 2011 by Charles Lee to improve on the technical details of Bitcoin (Sapuric et al., 2017). Several early competitors to Bitcoin in the cryptocurrency market were developed to address perceived shortcomings in the Bitcoin protocol, Litecoin was one of these early competitors. Specifically, Litecoin sought to address slow transaction times, the predetermined coin supply cap, and the reliance on powerful and specialised equipment to participate in the network (Sapuric et al., 2017; Sovbetov, 2018).

Ethereum was introduced to transcend purely financial uses and allow the currency to be spent for the storage of smart contracts and distributed applications (Ethereum, 2018). Ethereum does this by building an abstract foundational layer: a Blockchain with a built-in Turing-complete programming language, allowing anyone to write smart contracts and decentralised applications (Buterin, 2014). Ethereum utilises a cryptocurrency called *Ether*, which acts as the ‘fuel' to run the programming platform. Ether can be traded with other currencies, however, it is used for paying for things on the Ethereum network, such as creating smart contracts (Casino, Dasaklis, & Patsakis, 2018; Lindman, Tuunainen, & Rossi, 2017). This ability to support smart contracts has sparked significant interest among researchers and developers, who identify a number of use-cases that extend beyond basic financial transactions (Beck et al., 2018; Casino et al., 2018; Hyvärinen et al., 2017). This interest is not limited to start-ups and academics, many industry consortia have been established to examine the long-term potential, for example, IBM and Samsung recently collaborated to explore how Ethereum could support the growing Internet of Things networks (Beck et al., 2016). Other suggested applications are intellectual property, domain registration, crowdfunding, and prediction markets (Peters & Panayi, 2016; Swan, 2015; Tapscott & Tapscott, 2016).

Despite the obvious interest, the use of cryptocurrencies as a currency has been limited, with the majority of market participants seeming to treat cryptocurrencies as a longer-term investment opportunity. This was reinforced by research by Glaser, Zimmermann, Haferkorn, Weber, and Siering (2014), who found that new Bitcoin users increased the volume of transactions at the exchange but did not increase the volume of Bitcoin traded within the network. This suggests many people buying Bitcoin are not routinely using it to pay for goods and services.

2.4 Herding Behaviour in the Cryptocurrency Market

Cascading investor behaviour is common in financial markets, a phenomenon often referred to as *herding*, i.e. when some agents imitate the prior actions (buying or selling) of others (Avery & Zemsky, 1998). Herding behaviour has been researched extensively in existing literature, especially in the context of institutional investment (Cakan, Demirer, Gupta, & Marfatia, 2019; Deng, Hung, & Qiao, 2018; Rompotis, 2018). More recently, herding behaviour has been found to exist in the cryptocurrency market, especially in times of heightened uncertainty (Bouri et al., 2018; da Gama Silva et al., 2019; Stavroyiannis & Babalos, 2019; Vidal-Tomás et al., 2018; Yi et al., 2018).

Literature suggests multiple reasons why herding occurs in investment markets. First, many individuals have a tendency to disregard their own private information and trade as the crowd does for fear of reputational damage that could result from being the outlier

(Deng et al., 2018; Scharfstein & Stein, 1990). Even if a trader believes the consensus to be wrong, the dangers in acting against the crowd are often disproportionately larger than those from following them. Herding behaviour is common in stock markets, where money managers operate in an environment of intense competition. For example, in the lead up to the October 1987 bull market, professional money managers had largely reached a consensus that the prices were too high and were more likely to go down than up. However, they were slow to sell their holdings, fearing that the prices would continue to rise, highlighting them as the lone fools that missed out on the extended profits. They were also comforted by the fact that should the prices fall, they would not be the only ones to lose money, so everyone would suffer the same fate (Rompotis, 2018; Scharfstein & Stein, 1990). This reluctance to sell has been mirrored with the viral cryptocurrency trading strategy of 'HODL', a term which originated as a typo for 'hold' but has also been suggested as an acronym for 'hold on for dear life' (Dierksmeier, 2018; Quest, 2018).

Second, investors may trade together simply because they may be analysing the same indicators and as a result, they are trading off the same private information (Deng et al., 2018; Froot, Scharfstein, & Stein, 1992). Investors may also infer that others are better informed than themselves and thus assume they should trade in the same direction even if it is not clear why those trades are desirable (Bikhchandani, Hirshleifer, & Welch, 1992; Deng et al., 2018; Rompotis, 2018). This is also observable in the cryptocurrency market, not least because the sharing of information is legal as cryptocurrencies are not considered securities. This has even led to 'whale watching' websites and apps which make it easy to observe and follow the trading actions of large cryptocurrency holders, commonly referred to as 'whales' (Bouri et al., 2018).

Herding has also been used to explain bandwagon effects in technology adoption. If the manager of one firm adopts a particular technology this can often lead to other firms looking more favourably on this technology and adopting it themselves before conducting their own extensive research (Sun, 2013; Walden & Browne, 2009). Although Bitcoin remains the largest cryptocurrency in the market, the underlying Blockchain networks of each cryptocurrency are far from homogenous. Broadly speaking the market consists of (i) Bitcoin (arguably the first true cryptocurrency) (ii) newer alternatives to Bitcoin, or 'altcoins', such as Litecoin (iii) cryptocurrencies to 'fuel' multi-purpose Blockchain development platforms such as Ethereum which facilitate non-financial use-cases. Each of these currencies appears closely tied to the overarching success of the Blockchain paradigm. Yet each represents an alternative perception of where that eventual success lies. Bitcoin suggests the cryptocurrency market will continue to develop along similar lines, altcoins suggest the initial technology required refining, while Ethereum suggests the value of Blockchain extends beyond cryptocurrencies. Existing research has little insight to offer to prioritise these perceptions among the public. Thus, we work from the preliminary assumption that perceptions of value overlap equally in each direction, meaning herding will cascade from one currency to another indiscriminately. Thus, we present the first hypothesis:

H1: *Changes in the market price of one cryptocurrency will predict changes in the market price of other cryptocurrencies.*

2.5 Social Perceptions of Risk Around Cryptocurrencies

The source of value for Bitcoin is somewhat unorthodox, given it has no formal ties to any particular material asset or issuing body.

Viewed as a currency, Bitcoin’s lack of affiliation with any particular national economy means it is difficult to triangulate its worth with large-scale economic trends. Traditional currencies are not simply evaluated in isolation; rather they are compared with specific factors such as monetary and fiscal policy, the balance of payments, and other macroeconomic factors which contribute to determining exchange rates of fiat currencies (Hopper, 1997; Mussa, 1976).

Viewed as company stock, Bitcoin's lack of affiliation with a particular issuing body means it is difficult to triangulate its worth with specific consumer behaviours. Company stocks are typically judged on factors such as customer satisfaction (Fornell et al., 2006), ownership structure (Thomsen & Pedersen, 2000), and customer based brand-equity (Lassar, Mittal, & Sharma, 1995; Stocchi & Fuller, 2017). Even this idea of brand-equity is comparatively tangible in terms of market returns, e.g. 90% of the total price of $220 million paid by Cadbury-Schweppes for the ‘Hires’ and ‘Crush’ product lines they acquired from Procter and Gamble were credited to brand assets (Lassar et al., 1995).

This inability to triangulate the value of cryptocurrencies is compounded by the fact that Bitcoin does not yet operate as a widely accepted payment system across multiple markets, nor is there any underlying value to be derived from its consumption or production as is the case with commodities such as gold (Ciaian, Rajcaniova, & Kancs, 2016). Also, Bitcoin is not affected by an ownership structure as the creator of the cryptocurrency operated under the pseudonym ‘Satoshi Nakamoto’ (Nakamoto, 2008). Additionally, currency-related attributes such as monetary policy and money supply are predetermined by the network protocol of a cryptocurrency and the balance of payments is not relevant either as it is not representative of any particular economy (Kristoufek, 2013). This has led many to suggest cryptocurrencies such as Bitcoin should be considered as speculative assets, with no opportunity of repayment in the future, and whose value is determined only by ephemeral market sentiment (Corbet, Meegan, Larkin, Lucey, & Yarovaya, 2018; Yermack, 2015).

This naturally lends itself to wide fluctuations in price for cryptocurrencies; a tendency exacerbated by perceived vulnerabilities to hacking attempts and/or criminal misuse (Bouoiyour, Selmi, Tiwari, & Olayeni, 2016; Yermack, 2015). Thus, individuals are left to judge the value of cryptocurrencies based on social observations. Such circumstances are prone to a concept known as social amplification of risk (SARF), i.e. the idea that events associated with risks interact with psychological, social, institutional, and cultural processes in ways that heighten or attenuate perceptions of risks and shape risk behaviour (Renn et al., 1992). In other words, people tend to over or under-react to risk when it must be evaluated based on social observations (Kasperson et al., 1988). This means apparently minor risk events often result in massive public reactions, while larger risk events often seem largely ignored despite a seemingly obvious need for individuals to react. Kasperson et al. (1988) suggested amplification occurs in two stages: first in the transfer of information about the risk, and second, in the subsequent response mechanisms of society. They argue the absence of reliable information often results because direct personal experience is lacking, meaning individuals learn from other persons and the media, all the while debates among experts heighten public uncertainty, and erroneous information sources find ready access to the mass media.

This reliance on public perceptions to determine the price of cryptocurrencies has been supported by a number of studies which have found a correlation between increased search volume and social media activity and rising prices in cryptocurrencies. It, therefore, makes sense the relationship between the price of Bitcoin and search volume related to the cryptocurrency is bi-directional, meaning not only do search queries influence price, but the price also influences search queries (Kristoufek, 2013). Garcia, Tessone, Mavrodiev, and Perony (2014) looked at Bitcoin bubbles using digital behavioural traces of investors in their social media use, search queries, and user base. Their results showed positive feedback loops for social media use and the user base. Kristoufek (2015) found that interest in Bitcoin has an asymmetric effect during bubble formation and bubble bursting whereby, when a bubble is forming, public interest boosts prices higher, but during a burst, negative public perceptions pushes prices lower. Indeed, this is typical of many financial markets, where social discussion and peer-based propagation of good news stories are often key triggers for the entry of new investors (Kaustia & Knüpfer, 2012). Cryptocurrencies, as an emerging market, are naturally more vulnerable to information shocks (Girard & Biswas, 2007). This, combined with cryptocurrencies' inability to triangulate evaluations against those of nations or organisations, leads to our second hypothesis:

H2: *The relationship between the market price of one cryptocurrency and the price of another will be stronger when that market price is particularly high or low.*

2.6 Method

Daily price data for Bitcoin, Ether, and Litecoin were collected from Yahoo Finance ranging from January 1st, 2016 to December 31st, 2017, giving a total of 731 observations for each time series. The price data for all three cryptocurrencies is represented in terms of USD for the purpose of consistency.

We further gathered price data for three major fiat currencies to examine the extent to which changes in cryptocurrencies were a reflection of general market trends; Euro (EUR), Sterling (GBP), and Japanese Yen (JPY). As fiat currencies trade on a five-day market and cryptocurrencies trade on a seven-day market, we first analysed weekly price data for all six currencies over the same two-year time period to determine the presence of any relationships. Table 2.1 details a correlation matrix for each of the currencies. These results illustrate a strong positive correlation of greater than 0.9 between all three of the cryptocurrencies at the 0.01 level. No correlations were observed between any cryptocurrency and Sterling. However, a minor negative correlation is observed between JPY and BTC/ETH, and a strong positive correlation is observed between EUR and all three cryptocurrencies. In order to analyse these relationships further, it was necessary to coordinate the daily price data by inserting values for weekend dates. We did this by using the median of Friday and Monday scores as weekend approximates for fiat currencies.

A detailed overview of the data analysis process employed for this chapter is provided in Appendix 9.10, however, in brief, for our first hypothesis, we initially tested each time series for stationarity and cointegration (Table 2.2). If each series is stationary, we can use the Vector Autoregressive framework and Granger Causality to test the relationship between each time series pairing (Table 2.3). Additionally, we tested these relationships over time through Impulse-Response analysis, which shows the reaction of one variable to a unit shock in the other (Figure 2.1-2.6). The combination of these tests would illustrate if changes in the market price of one cryptocurrency will predict changes in the market price of other cryptocurrencies.

Polynomial regression analysis was then employed to test the validity of the second hypothesis which examines the relationship between the market price of one cryptocurrency and the price of another and if that relationship will be stronger when that market price is particularly high or low (Table 2.4 - 2.6 and Figure 2.6 - 2.9).

Table 2.1 Correlation Matrix representing the relationship between fiat and crypto currencies

	Mean price	High	Low	Stnd. Dev.	BTC	ETH	LTC	GBP	EUR	JPY
BTC	2407.20	16850.31	379.45	3516.87	1	.920**	.921**	-.011	.634**	-220*
ETH	121.72	789.39	0.94	178.51	.920***	1	.923**	-.034	.738**	-213*
LTC	28.38	307.69	3.04	53.32	.921***	.923***	1	.022	.605**	-.187
GBP	1.32	1.46	1.22	0.07	-.011	-.034	.022	1	.358**	-.036
EUR	1.12	1.20	1.05	0.04	.634**	.738**	.605**	.358**	1	.133
JPY	0.01	0.01	0.01	0.00	-.220*	-.213*	-.187	-.036	.133	1

* p<.05, ** p<.01,

Table 2.2 Stationarity and Unit-Root Tests

	KPSS p-value	ADF p-value
Bitcoin Price (daily)	0.01000000	0.9698128
Bitcoin log price	0.01000000	0.9139713
Bitcoin Difference	0.03761068	0.0100000
Bitcoin Log Difference *	0.10000000	0.0100000
Ether Price (daily)	0.01000000	0.9900000
Ether log price	0.01000000	0.7150292
Ether Difference	0.02335312	0.0100000
Ether Log Difference*	0.10000000	0.0100000
Litecoin Price (daily)	0.01000000	0.4088454
Litecoin log price	0.01000000	0.9112676
Litecoin Difference *	0.10000000	0.0100000
Litecoin Log Difference *	0.10000000	0.0100000
Euro Price (daily)	0.01000000	0.8516900
Euro log price	0.01000000	0.8406418
Euro Difference *	0.10000000	0.0100000
Euro Log Difference *	0.10000000	0.0100000
Japanese Yen Price (daily)	0.01000000	0.3702186
Japanese Yen log price *	0.10000000	0.0100000
Japanese Yen Difference *	0.10000000	0.0100000
Japanese Yen Log Difference *	0.10000000	0.0100000

“*” = Stationary

2.7 Findings

The results below will be presented as they relate to each hypothesis, therefore, we will first detail the results of the Granger Causality tests and impulse response functions and whether or not these support our first hypothesis. Following this, the results of the polynomial regression analysis will be presented and how these relate to the second hypothesis.

Table 2.3 illustrates the results of Granger Causality tests based on the VAR model. We employ Granger Causality to test the extent to which changes in the market price of each cryptocurrency predicts changes in price of the others. We also include EUR and JPY in the analysis to examine whether any observed effects may be secondary to changes in these currencies. We further calculated an impulse response functions (IRFs) for each combination where Granger Causality was observed to examine the impact of exogenous shocks across variables, in the presence of correlated noise (Lütkepohl, 2005). The results of these IRFs are plotted in Figures 6.1 - 6.6. This combination of Granger Causality and impulse response functions was utilised to account for the finite sample size of the data and the multidimensional nature of our analysis (Lütkepohl, 2005).

The results of the Granger Causality tests and impulse response functions show the price of Bitcoin does not predict changes in the market price of Ether, as the p-value fails to reject the null hypothesis of no causality. However, when we tested the converse of this relationship, the changes in the market price of ETH are found to be a significant predictor of the changes in the market price of BTC. IRFs in Figures 6.1 and 6.2 illustrate this trend further, showing that BTC has little or no impact on ETH as the impulse variable (Figure 2.1). In contrast, ETH shows a significant impact as an impulse variable on the price of BTC, lasting up to four days after the shock (Figure 2.2). When testing the relationship between Bitcoin and Litecoin, although the Granger tests suggest causality between the pairing, the IRF plot illustrated in Figure 2.3 shows this causality does not persist over time. We, therefore, partially accept Hypotheses 1, as it appears it is changes in the price of ETH that predict changes in other cryptocurrencies, BTC is not found to be a predictor for changes in the price of other cryptocurrencies.

Looking closer at the overall set of Granger Causality and IRF results, changes in the market price of both Bitcoin and Litecoin appear to have no statistically significant impact on the market price of Ether. However, changes in the price of ETH do show a significant change in the price of both BTC and LTC. Interestingly, this suggests movements in the price of Ether are actually more likely to precede movements in Bitcoin and Litecoin.

Table 2.3 Granger Causality Test Results for logarithmic difference series

Log Difference of Original Series					
Lag = 1	BTC	ETH	LTC	EUR	JPY
BTC	-	0.1022	0.00007057 ***	0.7181	0.9222
ETH	0.0000005679 ***	-	0.003966 ***	0.8658	0.6947
LTC	0.0003362 ***	0.9454	-	0.7495	0.817
EUR	0.5386	0.8914	0.3986	-	0.04938
JPY	0.8392	0.8772	0.9834	0.4711	-

* p<.05, ** p<.01, *** p<.001

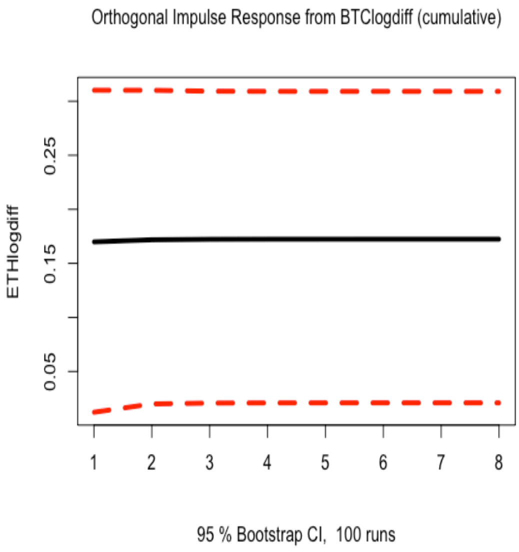


Figure 2.1 ETH Response to BTC Impulse

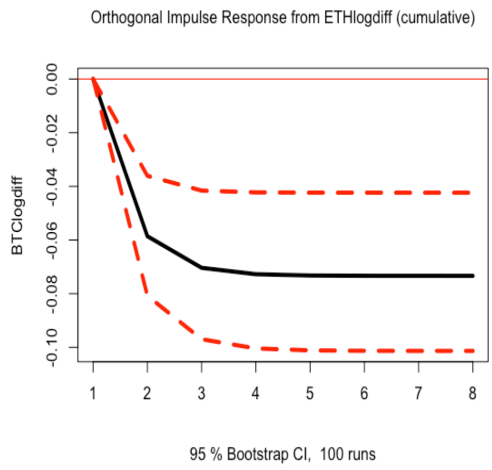


Figure 2.2 BTC Response to ETH Impulse

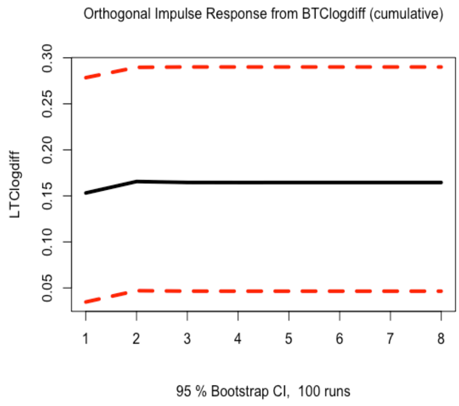


Figure 2.3 LTC Response to BTC Impulse

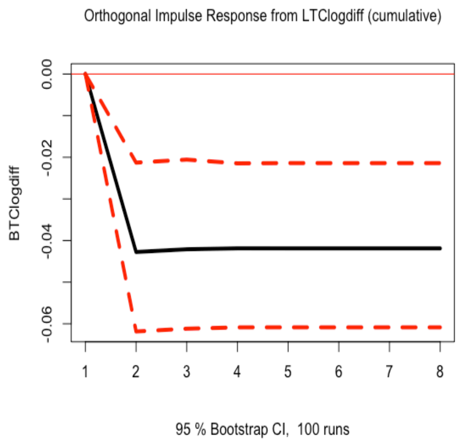


Figure 2.4 BTC Response to LTC Impulse

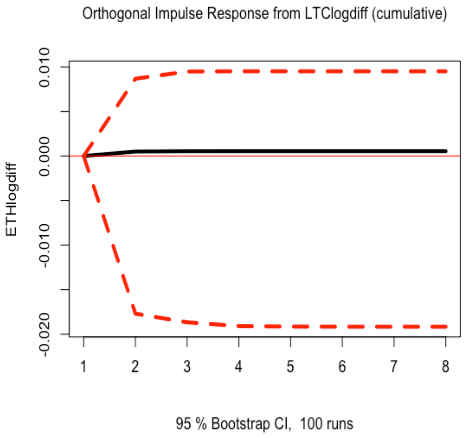


Figure 2.5 ETH Response to LTC Impulse

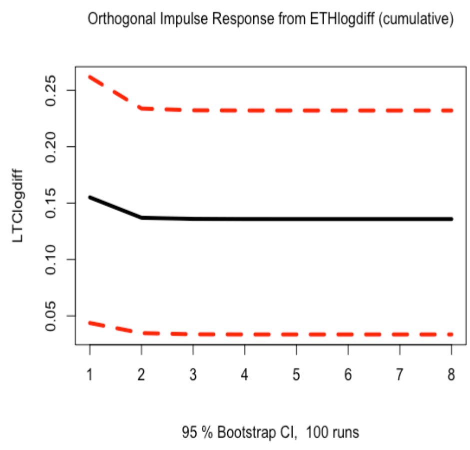


Figure 2.6 LTC Response to ETH Impulse

Next, we move to test Hypothesis 2, which predicts the relationship between the market price of one cryptocurrency and the price of another will be stronger when that market price is particularly high or low. Tables 6.4 – 6.6 provide the results of polynomial regression analysis of the relationship between cryptocurrencies. These polynomials allow us to identify whether the relationship between cryptocurrency prices is linear (the relationship is similar, regardless of whether prices are high or low), curvilinear (the relationship changes when prices are high or low), or s-shaped (the relationship changes when prices are high or low, when compared to when they are medium).

The results in Tables 6.4 – 6.6 suggest the predicted s-shaped relationships provide the most explanatory power between ETH and BTC, ETH and LTC, and between BTC and LTC (all of the relationships showing Granger Causality). For each of these relationships, the cubic model shows the highest R^2 and all terms are significant. Interestingly, while the shape of the relationship between ETH and BTC is as anticipated, the shape of other relationships differs. Notably, it appears that increases in the price of both ETH and BTC are most predictive of large, positive changes in LTC price when the prices of ETH and

BTC are medium. Increases in prices of ETH and BTC, when those prices are low or high, seem to predict either decreases or only marginal increases in LTC price.

Table 2.4 Polynomial Regression for logarithmic Ether as a predictor of Bitcoin

Ether as a predictor of Bitcoin			
ETH	0.553714 ***	-0.10284 **	0.35975 ***
ETH^2		0.087686 ***	- 0.097022***
ETH^3			0.019465***
ADJ R^2	0.862	0.9114	0.9197
Significance codes: ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’			

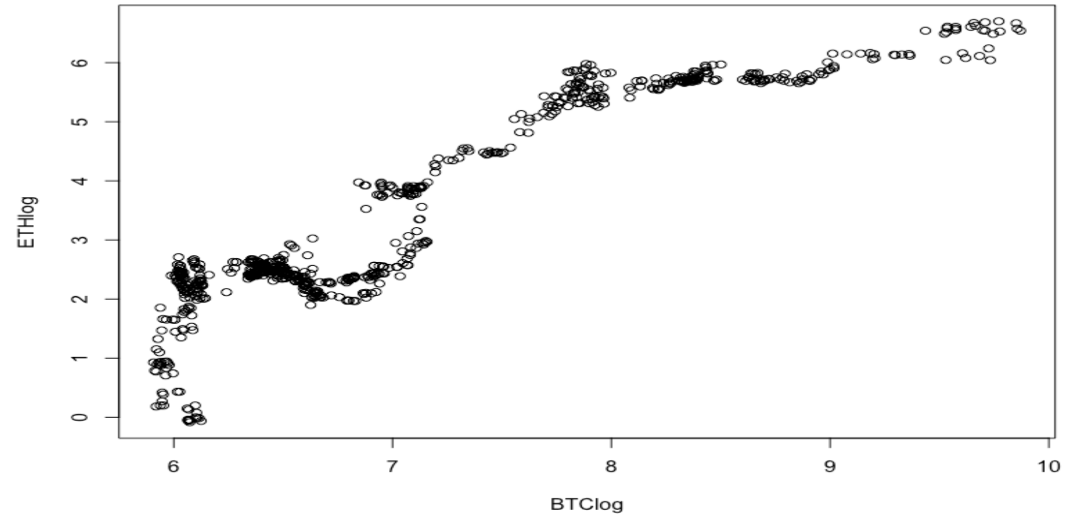


Figure 2.7 Scatter plot of ETH Logarithmic series (Y-axis) and BTC Logarithmic series (X-axis)

Table 2.5 Polynomial Regression for logarithmic Ether as a predictor of Litecoin

Ether as a predictor of Litecoin			
ETH	0.73037 ***	-0.32584 ***	-0.198210 ***
ETH^2		0.14106***	0.090101***
ETH^3			0.005371**
ADJ R^2	0.8942	0.9705	0.9708
Significance codes: ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’			

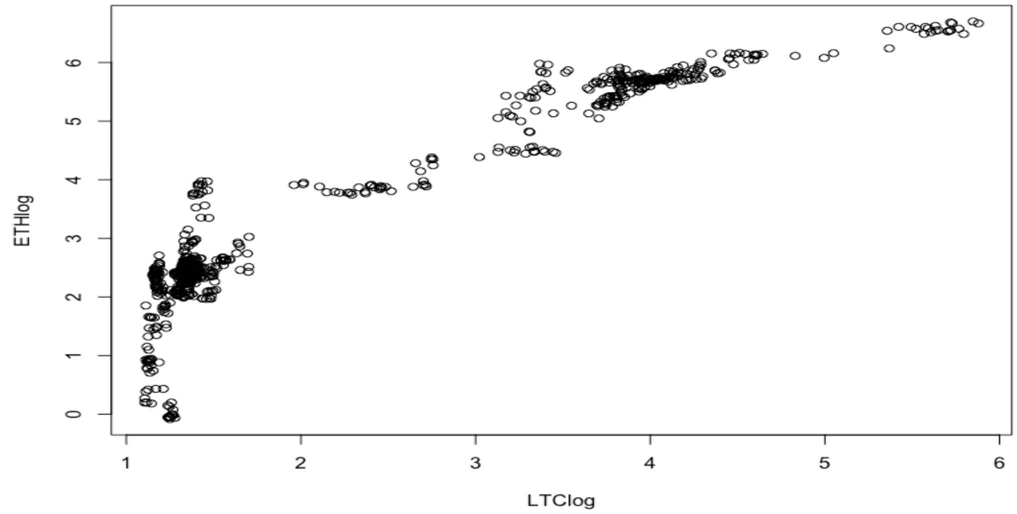


Figure 2.8 Scatter plot of ETH Logarithmic series (Y-axis) and LTC Logarithmic series (X-axis)

Table 2.6 Polynomial Regression for logarithmic Bitcoin as a predictor of Litecoin			
Bitcoin as a predictor of Litecoin			
BTC	1.24033 ***	0.70024 ***	-26.88521 ***
BTC^2		0.03573 **	3.65764 ***
BTC^3			-0.15647 ***
ADJ R^2	0.917	0.9177	0.9353
Significance codes: ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’			

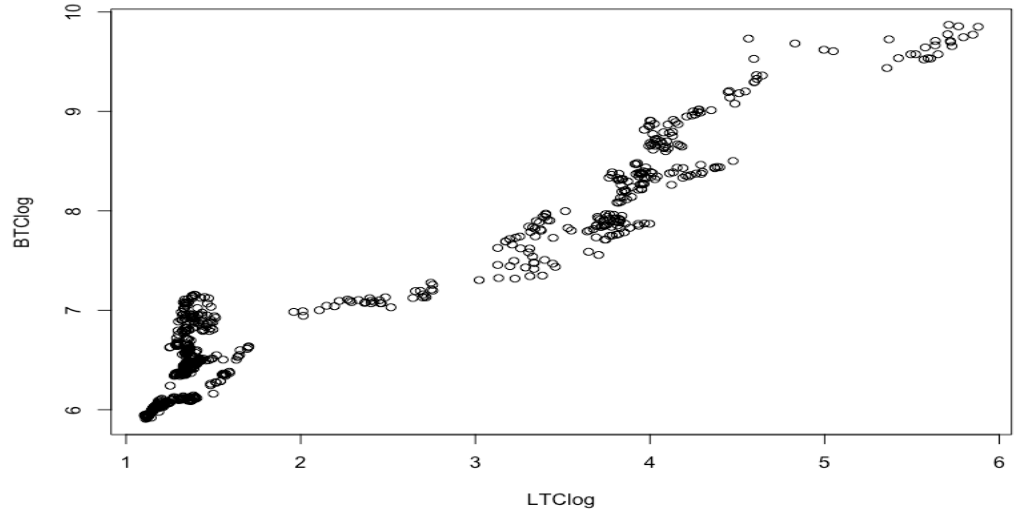


Figure 2.9 Scatter plot of BTC Logarithmic series (Y-axis) and LTC Logarithmic series (X-axis)

2.8 Discussion

The emergence and rapid growth of the cryptocurrency market has quickly sparked the attention of many researchers. Extant research can be broadly categorised as either examining cryptocurrencies as an alternative to traditional currency and the determinants of its price (Cheah & Fry, 2015; Georgoula et al., 2015; Kristoufek, 2013; Li & Wang, 2017), or research focused on the potential of the underlying Blockchain technology (Beck et al., 2016; Beck et al., 2018; Hyvärinen et al., 2017). Bitcoin is the market leader and often considered synonymous with Blockchain and other altcoins (Sovbetov, 2018). Hence, we applied the theory of herding behaviour and hypothesized that changes in the market price of any one cryptocurrency would predict changes in the market price of other cryptocurrencies (Bitcoin, Ether and Litecoin, in this case). Consistent with extant research (Bouri et al., 2018), we found herding behaviour to be a powerful mechanism in the cryptocurrency market. Specifically, our results found that it is Ether prices that seem to precede changes in the price of other cryptocurrencies. Equally interestingly, while changes in Ether are more predictive of changes in Bitcoin when prices are especially high or low, the relationship with Litecoin is different. Litecoin prices appear less likely to increase with Ether and Bitcoin prices when prices are especially high or low. These findings provide an interesting insight into how the cryptocurrency market facilitates a network of distributed participants to collaborate and determine the price of the assets being traded. The concept of Blockchain as an enabling technology for Distributed Collaboration will be explored in detail in the chapters to follow.

The first contribution of this research concerns the approach to evaluating cryptocurrencies. First, this research has shown that changes in cryptocurrency prices are not obviously preceded by changes in other fiat currencies. This observation is consistent with the findings of Corbet et al. (2018) who concluded that cryptocurrencies are isolated from market shocks and are decoupled from popular financial assets. This supports the basic underlying assumptions of this research that the value of cryptocurrencies is difficult to ground in specific economies and institutions. This is valuable as existing literature is somewhat divided on this matter. Some conclude the market is a speculative bubble similar to internet stocks in the 1990s (Bouoiyour & Selmi, 2015; Yermack, 2015), others focus on the practical side and believe Bitcoin has demonstrated that cryptocurrencies offer value as a currency (Van Alstyne, 2014). Other research has attributed the value of Bitcoin to its technical components, such as the difficulty of mining coins, the rate of unit production, and the cryptographic algorithm employed (Hayes, 2017). This is in stark contrast to traditional stocks which are determined by recognised factors such as customer satisfaction (Fornell et al., 2006), ownership structure (Thomsen & Pedersen, 2000), brand-equity (Lassar et al., 1995) or, macroeconomic factors in the case of fiat currencies (Hopper, 1997; Mussa, 1976).

Second, this research has highlighted that changes in the prices of cryptocurrencies have a non-linear effect on the prices of other cryptocurrencies. We predicted that social perceptions would lend themselves to over or under reactions. Therefore, the relationship between the market price of Bitcoin and the market price of other cryptocurrencies would be stronger if that market price was particularly high or low. This shows a tendency in the social valuation process for these cryptocurrencies to vary according to price-levels. This is consistent with existing literature, which demonstrates that people who rely on social cues to evaluate a situation often produce a disproportional reaction (Kasperson &

Kasperson, 1996; Kasperson et al., 1988), as well as literature which has found the cryptocurrency to be especially volatile in times of uncertainty (Bouri et al., 2018; Kristoufek, 2015; Yi et al., 2018).

Therefore, we conclude that in order to effectively evaluate the price of cryptocurrencies we need to reach a consensus as to what factors determines their price. This research clearly highlights that cryptocurrencies are fundamentally different from fiat currencies. However, with nothing but social perception as a guide to evaluate them, cryptocurrencies have been subject to severe price changes. As we have discussed, there are many forms of cryptocurrencies, including those which offer an alternative payment mechanism to fiat currencies, but also those which represent Blockchain development platforms. We believe that each cryptocurrency should be evaluated in isolation as their value propositions differ greatly.

The third contribution is the illustration that changes in the price of Ether are more likely to predict changes in the price of both Bitcoin and Litecoin. Two intuitive explanations are possible. The first is that prices of all cryptocurrencies are driven more by perceptions of Blockchain technology than the specific financial manifestation. Bitcoin and Litecoin both serve as a peer-to-peer version of electronic cash (Litecoin.org, 2018; Nakamoto, 2008), whereas Ether offers a ‘fuel’ to run the Ethereum smart contract development platform (Casino et al., 2018; Lindman et al., 2017). This means perceptions of Ether may be more meaningful, as they reveal more about the general perceived utility of Blockchain across a range of domains. This observation builds on our first contribution which suggests that there needs to be an established approach to evaluating cryptocurrencies, and each should be evaluated with respect to the objective of the underlying network. Answering this question requires further research to explore the perceptions of investors for different cryptocurrencies to determine how they are evaluating value and risk. The second explanation is that investors in Ether are perceived as better informed than Bitcoin and Litecoin investors, meaning Bitcoin and Litecoin investors are more likely to be influenced by Ether investors. This is consistent with much of the economic literature on herding, where knowledgeable investors are often considered disproportionally influential (Bikhchandani et al., 1992; Deng et al., 2018; Rompotis, 2018).

The fourth contribution is the peculiar patterns of changing prices in Litecoin. Our assumption was that Litecoin, as a less mature emerging currency, would largely follow the path of Bitcoin and Ether. Yet it appears the opposite is the case, as the more socially amplified the positive price of Bitcoin and Ether, the less interest there appears to be in Litecoin. However, this makes sense when Litecoin is considered a competing currency, rather than one that is complimentary. Litecoin was, after all, introduced to replace Bitcoin by addressing some of its technical flaws (Sapuric et al., 2017). Therefore, it is logical that investment in Bitcoin and investment in Litecoin should be adversarial, whereby falling prices in Bitcoin are more likely than rising prices to drive investors towards Litecoin. This leads to a more nuanced view of the market, where investors are moving between alternative cryptocurrencies, rather than simply hedging investment across parallel relatively homogenous options.

As for the limitations of this study, we accept that an analysis of the relationship between three cryptocurrencies may not be considered to be representative of the cryptocurrency market as a whole. We justify our selection for two primary reasons. First, the open protocol of leading cryptocurrencies such as Bitcoin has allowed ‘altcoins' to be developed with ease by simply adapting the source code to their own criteria (Sapuric et al., 2017). This, combined with widespread knowledge of increased profits in the cryptocurrency has, in turn, led to increased participation in the market (Kristoufek, 2013), which means the sheer number of cryptocurrencies is prohibitively large to analyse in detail. As of November 2018, the market consisted of a total of 2081 coins, compared to the 1335 coins which were listed as of December 31st, 2017 (coinmarketcap.com, 2019), the growth of new cryptocurrencies was also noted by da Gama Silva et al. (2019), they, therefore, focused on established cryptocurrencies with larger historical time series to analyse.

The second justification is that Bitcoin, Litecoin and Ether are nonetheless appropriate coins to analyse as they represent three different types of cryptocurrencies. First, Bitcoin is the leading cryptocurrency in the market and has been subject to significant research attention since its release (Holub & Johnson, 2018; Kristoufek, 2013). Second, Litecoin represents those so-called ‘altcoins' which were established by adopting the Bitcoin protocol to improve upon apparent weaknesses of the Bitcoin network by altering certain elements such as block generation time and coin supply (Sapuric et al., 2017). Third, Ether typifies a contrasting style of cryptocurrency whereby the coin itself is not developed as a means of financial exchange but rather a fuel to run smart contracts and facilitate the development of decentralised applications to serve use-cases within and beyond the financial domain (Beck et al., 2016; Beck et al., 2018). The same is true for the fiat currencies analysed. We used a limited set as an indicator and make no claims of exhaustivity. We also could not use USD in the analysis, as each of the costs was calculated relative to USD, meaning its inclusion in the analysis would have been impossible to interpret. We thus call for future research to examine other cryptocurrencies and fiat currencies. We believe this is necessary to create an accurate understanding of the relationship within and between these currencies.

Chapter 3. Exploring the Application of Blockchain Technology to Combat the Effects of Free-Riding in Cross-Functional Group Projects

3.1 Abstract

Today, many multinational organisations operate in a dispersed geographical environment. Teams consisting of members from around the globe can be assembled on an as-needed basis. However, this can prove to be a complex managerial task. Individuals, who believe that their efforts are not being effectively monitored by upper management, lose their motivation to fully contribute to the best of their abilities as they do not believe there is any correlation between the effort they exert and the reward they receive. With low levels of intrinsic motivation among employees, a lack of task visibility from upper management and limited social interaction among group members, many organisations struggle to combat the issue of free-riding in cross functional working groups. Blockchain technology, widely acknowledged as enabling openness, can facilitate the development of an immutable, transparent, secure, and verifiable application for capturing individuals Intellectual Property as they work. This would motivate employees to more openly contribute to group work, safe in the knowledge that their contribution will be recognised, enabling management to maintain a high level of task visibility over their employees work without requiring their physical presence.

3.2 Introduction

The objective of this research is to explore if Blockchain technology can be utilised to more effectively track employee’s contributions and efficiently record an individual’s contribution to group endeavours, potentially facilitating increased transparency, leading to improved productivity and rewards.

This research focuses on the issue of free-riding in cross functional dispersed teams and explores the potential of a Blockchain-based system to address this problem and garner an understanding as to the effectiveness of such a system to potentially increase individuals IP contributions, which are defined as ‘creations of the mind: inventions; literary and artistic works; and symbols, names and images used in commerce’ (World Intellectual Property Organization). Blockchain technology is potentially applicable in this setting as it acts as a distributed mechanism to capture data in an immutable, verifiable and independently auditable fashion (Swan, 2015).

The potential application of Blockchain technology for capturing IP contributions has been discussed in the literature in an inter-organisational setting. A report published by the UK Government’s Chief Scientific Advisor in 2016 advocated the potential that distributed ledger technology could have in the IP domain; “Enabling companies to register their Intellectual Property (IP) within a distributed ledger, rather than through traditional patent applications, may reduce the overall number of contract disputes” (UK Government Office for Science, 2016).

An analysis of the literature on organisational behaviour and forms of motivation reveals that many organisations experience the issue of being unable to effectively manage their employees to work productively, the problem being magnified when it comes to group projects due to ‘The Free-Rider Problem’ or ‘Social Loafing’ phenomenon. Low levels of task visibility and low levels of intrinsic motivation result in employees feeling that their work was undervalued and unimportant to the organisation (George, 1992). In the global environment in which we operate today, many organisations consist of teams containing group members from dispersed geographic locations. Although dispersed teams offer many advantages to an organisation, they lack the level of social comparison found in co-located groups which can contribute to increased levels of free-riding (Suleiman & Watson, 2008). Social comparison is defined as 'comparing our behaviours and opinions with those of others in order to establish the correct or socially approved way of thinking' (Vaughan & Hogg, 2014).

In order to complete this research we adopted a design science approach which is outlined in detail later in the paper. In brief, first we identified the problem of free-riding in distributed teams which will be outlined in the literature review. The literature review also details our analysis of Blockchain technology as a potential tool for combatting this problem. We then designed and developed a Blockchain-enabled proof-of-concept application to track individual contributions to a group project and demonstarted this to a number of organisations in order to evaulate it's potential and take suggestions for future applications of the system. Details of the application will also be outlined later in the paper.

3.3 Literature Review

Ryan and Deci (2000) paper on Intrinsic and Extrinsic motivation and 'Self-Determination Theory' described the ability to motivate somebody to perform tasks which are not inherently interesting or enjoyable as an essential strategy for successful teaching. Intrinsic motivation refers to when people perform an activity because they are interested in the activity itself and performing the activity gives them a sense of satisfaction. On the other hand, extrinsic motivation does not involve satisfaction coming from the activity itself but rather satisfaction from separable outcomes that come because of performing an activity such as rewards (Gagné & Deci, 2005). One form of extrinsic motivation under the umbrella of 'Organismic Integration Theory' is 'identification', this occurs where an individual partakes in an activity out of choice because they can see the benefit in doing so. Although they perform an activity to achieve 'separable outcomes' as described above, their behaviour is self-determined, for instance athletes who are involved in sport as they believe it contributes to their personal development (Pelletier et al., 1995). Organisations should focus their efforts on creating an environment which would enhance an individual's level of identification in a task by rewarding everyone on their contribution to achieving the organisational objectives. This would help counteract what is known as the dilution effect whereby members of groups feel their contribution is marginal towards the overall goal (Gagné & Deci, 2005).

Rational individuals have a desire to progress in their own careers. Behavioural economist, Dan Ariely, spoke to this point in his book entitled 'Predictably Irrational'. Rather than focusing on market norms where money is the primary motivator to work, Ariely suggests that social norms, i.e. showing recognition for the effort made by an individual can produce better output. He found that a lack of recognition for work completed is almost as bad as destroying one's work, however, the slightest amount of recognition, was enough to motivate people to work harder as they felt their work was worthwhile (Ariely, 2008). If there was a system in place in an organisation which would guarantee recognition for individual effort, each person would be able to identify with the importance of improving their productivity.

Regardless of an individual's level of identification, they may still be reluctant to participate in group activities as a result of the 'Free-Rider Problem'. The term 'free-rider' refers to a member of a group who obtains benefits from a group membership but does not bear a proportional share of the costs of providing the benefits (Albanese & Van Fleet, 1985). This issue is particularly relevant in the case of group activities because regardless of how motivated an individual may be to perform well, often they will not trust that other members of the group are making the same effort. This can result in individuals losing that level of identification in the task they are working, which undermines any strategy for motivating employees that may be in place within an organisation. Latané, Williams, and Harkins (1979) found that in group activities ‘lack of trust and the propensity to attribute laziness or ineptitude to others could have led people to work less hard themselves’. Furthermore, members of a group feel that the responsibility for the success of the group does not rest on their shoulders to the same extent as the success of an individual task would (Latané et al., 1979), a problem referred to as ‘diffusion of responsibility’ which is defined by Bandura, Barbaranelli, Caprara, and Pastorelli (1996) as ‘when everyone is responsible, no one really feels responsible’.

George (1992) explored the area of the ‘Free-Rider Problem’, or as she refers to it, ‘social loafing’ which she defines as being ‘the fact that individual contributions to a group product are often unidentifiable. When this is the case, motivation may be low since the perceived relationship between individual effort and sanctions or rewards is weak’. George (1992) put forward the following hypotheses to explain the factors that influence social loafing;

- *Task visibility* is negatively related to social loafing.
- An individual’s *intrinsic involvement* in work is negatively associated with social loafing.
- *Task visibility* will dominate intrinsic task involvement in terms of relative ability to predict social loafing in an ongoing organisation.
- *Intrinsic involvement* moderates the relationship between task visibility and social loafing such that the relationship is stronger when intrinsic involvement is low than when intrinsic involvement is high.

It is apparent from these hypotheses that the two main variables contributing to the factors that influence social loafing are task visibility and intrinsic involvement. George (1992) describes task visibility as; ‘the belief that a supervisor is aware of individual effort on a job’, and intrinsic involvement as; ‘beliefs that the work being done is meaningful and significant and that one’s own efforts are an important contribution to the employing organisation’. Therefore, an organisation should focus on increasing task visibility and individual’s intrinsic involvement to reduce social loafing and in turn improve productivity. Indeed, George (1992) purports that the reason individual productivity is not maximised is because employees do not believe their work has a direct contribution to the entire organisation, nor do they trust their employers to record their contributions.

Further research into this area has found that free-riding is particularly a problem in technology supported, dispersed and knowledge teams (Lin & Huang, 2009). One basic difference between global teams that work and those that don’t lies in the level of social distance—the degree of emotional connection among team members (Neeley, 2015).

In the case of traditional, co-located groups, Chidambaram and Tung (2005) cite social standards as key deterrents of free-riding; they argue that in a co-located environment, social pressure results in individuals being more productive as they can see their peers working around them, this acts as a form of motivation to other team members which is not present in a dispersed group.

Social pressure in groups is also highlighted by Suleiman and Watson (2008) as being integral to any effort to reduce free-riding tendencies. Their research found that self-feedback; feedback given on an individual basis, did not result in a reduction in the levels of free-riding in a group. However, when feedback was given to all members of the group and member's feedback was visible to all other members, this acted as a comparative tool and decreased level of free-riding.

The terms 'social loafing' and 'free-riding' have been synonymous with each other in previous literature (Hall & Buzwell, 2013). Social Loafing describes individuals who tend to perform at lower levels when part of a group than when they are expected to complete a task on their own (George, 1992). Free-Riding is a choice individuals sometimes make to avoid co-operating in the pursuit of rewards to be shared by the members of a group (Albanese & Van Fleet, 1985). The subtle difference between the two being that free-riding grows out of a rational calculation but social loafing can occur without conscious awareness (Wagner III, 1995). The terms have been considered analogous in this research as they both grow out of the choice to withhold co-operative effort from group endeavours (Wagner III, 1995). For consistency purposes throughout the remainder of this thesis, 'Free-Riding' will therefore be used to refer to instances where individuals withhold effort from a group endeavour.

To summarise, free-riding is a significant issue in distributed teams, with a myriad of factors impacting upon group dynamics, project success and the ability to manage and motivate individuals to contribute and innovate. Can Blockchain technology, with its focus on openness and transparency, potentially play a part in reducing free-riding and increasing individual's contribution?

We suggest, and are keen to investigate, if Blockchain technology can combat an employee's feeling that they are merely an anonymous tool in a large organisation through tracking individual contribution and recreating social presences in dispersed group settings. A Blockchain application which captures individual contribution to a group and ensures that individual intellectual property receives appropriate recognition may also potentially reduce perceptions of diffusion of responsibility, dehumanisation and attribution of blame as illustrated by Alnuaimi, Robert, and Maruping (2010).

As stated in the introduction, the objective of this research is to apply this concept to group projects and assess the potential the technology may have for recording individual contributions to a distributed team's towards improved performance.

3.4 Utilizing Blockchain for Capturing IP and Reducing Free Riding in Distributed Group Projects

This section reviews the state of the art in Blockchain technology and abstracts that; 1. the ability to store information on the Blockchain 2. The technologies record of being applied to capture IP and appropriate recognition 3. Blockchain's security and immutability characteristics and 4. The ability to leverage the technology to record verifiable contributions mean that it is a suitable technology to be applied for potentially improving the performance of geographically distributed teams.

3.4.1 Information Storage

Recording employees work can be facilitated by storing data on the Blockchain. This has already been successfully implemented by a few applications, most notably ProofOfExistence.com, a service which anonymously and securely stores an online distributed proof of existence for any document (Araoz, 2017). The service works in the following way: A user presents a document or file to the website. The file is never uploaded to the site but instead they create the cryptographic digest of the file and the user maintains the original copy 'off-chain' (Araoz, 2017). This adds security and privacy to the service because the original contents cannot be stolen from the service. The digest is then inserted into a transaction which is in turn mined into a block and is then registered forever on the Blockchain, regardless of whether the service is shut down. Should any conflict occur in the future over the ownership of the file, the user need only run the hash function over their off-chain copy of the file and the file will be verified if the digest produced is the same (Tapscott & Tapscott, 2016).

In fact, storing data and documents on the Blockchain is becoming an increasingly popular application for the technology. In October 2016 Dubai announced their objective to store all government documents on Blockchain by the year 2020, this is as part of Dubai's strategy to become a leader in the Blockchain industry. Estimates from the Dubai government suggest that this initiative has the potential to save 25.1 million hours of economic productivity as well as being environmentally friendly (Castillo, 2016).

3.4.2 Capturing IP and Recognition

An interesting example of where Blockchain technology has already been implemented to secure IP rights and ensure that appropriate recognition is given to the creators of IP is in the music industry. Tapscott and Tapscott (2016) credit Napster, the peer-to-peer music sharing platform, for casting a light on the music industry's distribution inefficiencies when the service was launched in 1999. This revolutionary innovation in the music industry caused musicians to rethink the role of record labels and opened their eyes to the unbalanced distribution of wealth. Today, musicians such as Imogen Heap are distributing their music via Blockchain based services such as 'Ujomusic', this platform uses smart contracts to ensure that artists get to decide who can interact with their work and how much each interaction is worth. All contributors to the purchased product are automatically paid directly into their wallets after each transaction (Heap & Tapscott, 2016). This research hopes to apply this logic to group work and ensure that each member of a group receives appropriate recognition for their work.

3.4.3 Security and Immutability

Blockchain uses Hashing and Secure Timestamping to conduct attestation services. Hashing is the process of compressing any document or file of any type into a string of alphanumeric characters which cannot be reverse computed into the original file (Tapscott & Tapscott, 2016). The hash function is 'second pre-image resistant', meaning that it is impossible for a transaction to be recorded on the Blockchain before it is executed. Also because of pre-image resistance of hash functions, it is impossible to recreate an identical hash in the future with a different file (Araoz, 2017). This directly relates to the issue of recognition discussed earlier in this paper as put forward by Ariely (2008); when employees believe that their work is not being recognised their production levels begin to decline. The hashing of transactions on the Blockchain can provide employees with a sense of security that all work they record on a Blockchain-enabled system will be securely recorded. In the event that any other party tried to claim ownership of their work, Blockchain has the ability to verify the true ownership of the record.

Blockchain timestamps all transactions as outlined in Nakamoto (2008), 'a timestamp server works by taking a hash of a block of items to be timestamped and widely publishing the hash. The timestamp proves that the data must have existed at the time, obviously, to get into the hash'. Combining this with Public Key Infrastructure (PKI), the Blockchain not only prevents a double spend but also confirms ownership of each transaction, and each transaction is immutable and irrevocable. Bitfury define immutability by saying 'the Blockchain could not be retroactively changed by the collusion of notaries' (Group, 2016). In summary, this means that Blockchain prevents us from claiming ownership of a transaction that is not our own, committing a transaction on behalf of another party or even preventing somebody's freedom to commit a transaction to the Blockchain. The

Blockchain provides a means of proving ownership and preserving records without censorship (Tapscott & Tapscott, 2016).

3.4.4 Recording Verifiable Contributions

Organisations today are constantly striving to keep their employees motivated, particularly when individuals can identify with the benefits of working hard on a task (Ryan & Deci, 2000). If they feel intrinsically involved in the task, or if they feel that management maintains a high level of visibility over their work (George, 1992) they will be more likely to be productive. However, this can be undermined if individuals feel that their efforts are not being effectively recorded, especially in the context of group endeavours (Latané et al., 1979).

This research hopes to illustrate that Blockchain technology can facilitate an application that would resolve these issues by creating a trustless, secure mechanism for recording any content produced by any individual. The technology is immutable meaning that no third party could prevent an individual from having their efforts recorded. Transactions are irrevocable so nobody could claim ownership of work they did not perform. Transactions are timestamped, allowing everyone to see when the work was completed. Finally, transactions are verifiable through hashing so that should conflict of ownership ever arise, it can be easily resolved.

3.5 Statement of the Research Problem

The focus of this research study is to explore the possible utility of a Blockchain-enabled application to combat the problems of free-riding and increase individual contributions in cross functional, geographically dispersed group projects. In order to conduct this research, the following research questions will be answered;

- Does utilizing Blockchain technology in cross functional geographically dispersed group projects both increase individual contributions and reduce the potential for free-riding?
- What are the factors which determine the success of utilizing Blockchain technology to reduce free-riding and increase IP capture in cross functional geographically dispersed group projects?

3.6 Research Methodology: A Design Science Approach

Given the nature of the research, and the necessity to design an artefact to answer the research questions outlined, design science is a suitable methodology to investigate this problem. ‘The design science paradigm seeks to extend the boundaries of human and organisational capabilities by creating new and innovative artefacts’ (Hevner, March, Park, & Ram, 2004). Design Science Research (DSR) generates prescriptive design knowledge in the act of creating and evaluating some new IT artefact(s) (Gregor & Hevner, 2013; Hevner et al., 2004; March & Smith, 1995). This research builds on, and informs, the types of descriptive/explanatory knowledge generated by traditional (non-design) approaches (Gregor & Jones, 2007; Hevner, 2007).

The purpose of conducting IS Research is to create and evaluate IT artefacts which will solve problems faced by an organisation. The specific types of contributions vary, though the most fundamental types of theorising tend to take the form of design constructs, design methods, design models, and design instantiations (Hevner & Chatterjee, 2010; Hevner et al., 2004). Other types of contributions may include design principles/rules (Gregor & Hevner, 2013; Gregor & Jones, 2007) and embedded explanatory/predictive theory (Conboy, Gleasure, & Cullina, 2015; Kuechler & Vaishnavi, 2012). Design is both a process and a product. The products of design are the constructs, models, methods, and instantiations as outlined above whereas the processes of design are building and evaluating (Hevner et al., 2004).

Table 3.1 below employs the Six Activities outlined in Peffers et al. (2007) Design Science Methodology and a brief overview of each as they pertain to the stated research problem. This model was chosen because his study involved analysing all prior research into Design Science Frameworks and building on this groundwork to create a generalizable methodology.

Table 3.1 Design Science Approach

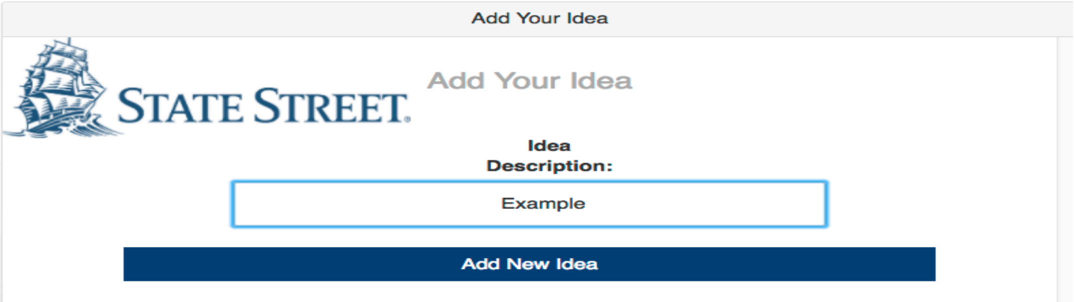
Activity	Applicability
Problem Identification and Motivation	Due to low levels of task visibility and intrinsic task involvement, many organisations experience high levels of 'free-riding' among their employees which reduces levels of productivity in individual and group work (George, 1992). This problem becomes more pronounced in cross functional groups because of low levels of social interaction between group members (Chidambaram & Tung, 2005). Also, work that individuals do complete is under threat of being stolen, international IP theft adds up to over $7 trillion globally (UK Government Office for Science, 2016).
Define the objectives for a solution	To assess the ability of a Blockchain-enabled system in improving overall group productivity by capturing individual productivity during cross functional group projects. Blockchain will create a secure and frictionless solution, aiming to improve productivity by increasing management's visibility over everyone's efforts, improve individual's level of identification with their work and create a degree of social interaction between members of dispersed groups.
Design and Development	*Development of a prototype instantiation:* If the initial exploratory investigatory research reveals the utility of a solution a prototype will be built. This solution will be developed using Blockchain technology and will aim to demonstrate how the immutability, transparency, verifiability and timestamping features of Blockchain can be utilised to create a successful product.
Demonstration	Once an artefact of an acceptable standard (preferably a prototype system) has been produced it will be demonstrated during workshop sessions in organisations operating in a variety of industries. The workshops will be conducted for managers and project team members to gain an insight into the requirements of each type of user. In an ideal scenario, the

	prototype would be implemented for a trial period in each organisation to fully assess its potential, however, a simulated situation will suffice if necessary.
Evaluation	*Evaluation of the System Prototype:* Before any workshops, a full unit test will be carried out on the system to ensure that every method works correctly. During the workshops, the system will be evaluated in terms of general feedback as well as metrics gathered. User feedback will be important to gain insight into the user's general interaction with the system, and any suggested improvements they may have, this will then be used to direct future iterations of the system. The workshops will look to suggest improvements to the aesthetics of the system but also whether a Blockchain-enabled system produced any significant benefits or drawbacks compared to a traditional system. Also, the system's reporting capabilities will be assessed by the managers taking part in the workshops. The metrics gathered during workshops will include, time taken to record each task, time required for each transaction to be subsequently mined to the Blockchain, the level of user engagement will be recorded by the quantity of tasks submitted to the system.
Communication	The results of this piece of IS Research will be documented and communicated in the form of an Empirical Research Paper which will then be submitted to a number of peer-reviewed outlets.

3.7 Blockchain Innovation Tool: proof-of-concept

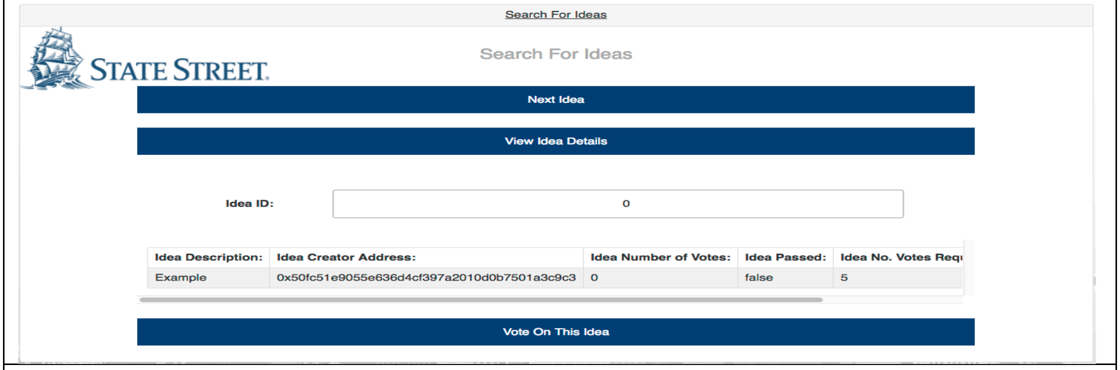
Table 3.2 Blockchain Innovation Tool

Figure 3.1 User adds and idea



Idea Description: Example

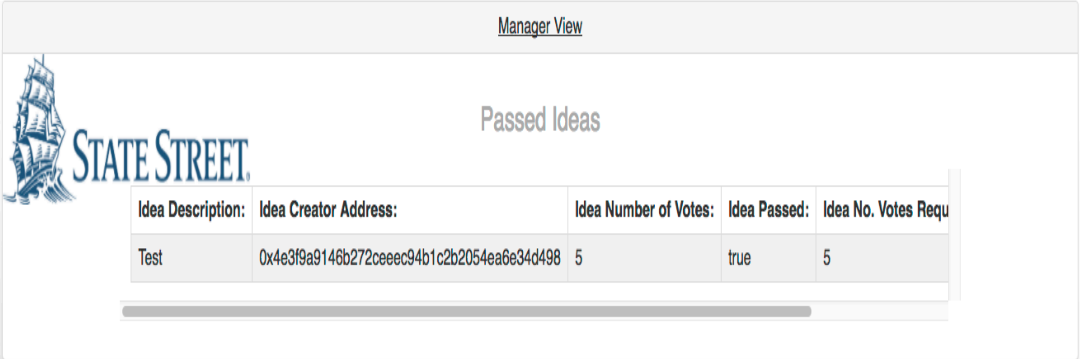
Figure 3.2 Users browse and vote on ideas



Idea ID: 0

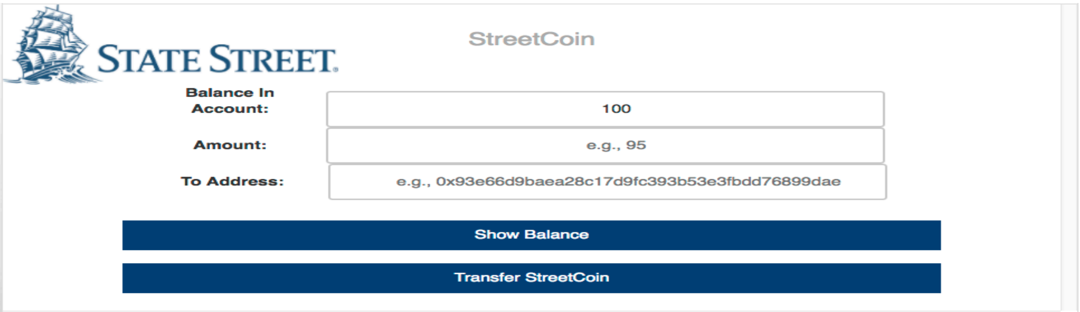
Idea Description:	Idea Creator Address:	Idea Number of Votes:	Idea Passed:	Idea No. Votes Requ
Example	0x50fc51e9055e636d4cf397a2010d0b7501a3c9c3	0	false	5

Figure 3.3 Managers get a report of passsed ideas



Idea Description:	Idea Creator Address:	Idea Number of Votes:	Idea Passed:	Idea No. Votes Requ
Test	0x4e3f9a9146b272ceeec94b1c2b2054ea6e34d498	5	true	5

Figure 3.4 Contributors rewarded for successful ideas



Balance In Account: 100

Amount: e.g., 95

To Address: e.g., 0x93e66d9baea28c17d9fc393b53e3fbdd76899dae

This proof-of-concept application has been developed considering the suggestions and recommendations of managers and distributed group members in State Street corporation. After conducting exploratory interviews with these parties, we decided the develop the application to tackle a specific use-case, namely intra-organisational groups and the innovation process.

The system was built on the Ethereum Blockchain network which allowed us to utilise smart contracts to implement a voting mechanism and an internal cryptocurrency.

The different activities and the associated Blockchain Innovation Tool GUI are outlined in Table 3.2. First, members of a group can login to the system to post an idea they may have (Figure 3.1); this idea will be immutably stored on the Blockchain for all group members to see, towards increasing task visibility and intrinsic involvement of group members.

Next (Figure 3.2), individuals will have the ability to browse through all ideas which have been posted to the system and vote for ideas which they consider having potential. This feature combats the issues which contribute to free-riding, for example, social comparison is increased in groups as each member can see the ideas being put forward by their peers. Although Blockchain will not be able to create the level of social interaction found in a face-to-face setting, the technology will be able to increase levels of individual task monitoring so that each member will observe a similar level of social comparison that would be found in a co-located group. Feedback is provided to all members, by all members, thus harnessing the wisdom of the crowd, and this is broadcasted to everyone as the current vote count will be captured by the smart contract and displayed to all users.

The smart contract is designed and programmed so that each idea requires a certain number of votes before it is deemed valid. Once this quota is reached the idea will be flagged as ‘passed’ and presented to management (Figure 3.3), giving them a high-level report of popular ideas amongst their group. This increases transparency for management and by giving each member a say, the system can reduce the ‘dilution effect’ in group-based innovation.

Finally, the system also utilises smart contract technology to improve recognition and reward (Figure 3.4), once an idea is passed by the voting system, the smart contract will automatically reward the individual who contributed the idea with a predefined amount of internal coins. Potentially, these coins may have intra-organisational value, for example being redeemable for lunch in the cafeteria etc.

3.8 Conclusions

This research contributes to both theory and practice. From a theoretical stand point, this research illustrates that Blockchain technology has significant value beyond a transactional setting, revealing that it can be applied as part of an organisation’s (1) innovation and (2) recognition and reward process. Furthermore, it illustrates that Blockchain technology, through the transparency which it enables can address the problem of free-riding in dispersed, cross functional group terms.

Furthermore, from a practitioner perspective, the Blockchain-enabled POC (Proof-of-Concept) would, if operationalised, allow individuals to record their contributions in a frictionless manner as they operate. An immutable, verifiable and transparent application for capturing individuals IP could potentially improve individual’s contributions, particularly in group environments by combatting free-riding.

Finally, Design Science Research is inherently iterative, progress is made through repeated iterations whereby the scope of the design problem is refined and with each iteration, the artefact becomes more relevant and valuable (Hevner et al., 2004). The purpose of this Chapter has been to complete a first iteration of design science research to combat challenges faced by cross functional groups through the application of Blockchain technology. This chapter has been successful in suggesting that Blockchain does indeed have potential to facilitate cross functional groups. Over the course of the subsequent chapters in this thesis the scope and utility of the system instantiation presented in here will be refined and iterated. First, in Chapter 4, we will present a systematic Literature Review to develop our understanding of this use-case. Following this, in Chapter 5, we will empirically explore the challenges faced by these groups in greater detail. Finally, having refined our understanding of the design problem we are looking to tackle, Chapter 6 will present a second iteration of the design and development of this system instantiation artefact.

Chapter 4. Reviewing the Contributing Factors and Benefits of Distributed Collaboration

4.1 Abstract

Distributed Collaboration has become increasingly common across many domains, ranging from software development, to information processing, to the creative arts, to entertainment. However, researchers have applied a myriad of terms to define these operations. We first addressed this issue by developing a definition of Distributed Collaboration which is representative of all its forms. Existing research has identified a number of factors that contribute to the success of Distributed Collaborations. Yet these factors are typically discussed in modular theoretical terms, meaning researchers and practitioners often struggle to identify and synthesise literature spanning multiple domains and perspectives. This research performs a systematic literature review to bring together core findings into one amalgamated model. This model categorises the contributing factors for Distributed Collaboration along two axes (i) whether they are social or material (ii) whether they are endemic or relational. The relationships between factors is also explicitly discussed. The model further links these contributing factors to different collaborative outcomes, specifically mutual learning, relationship building, communication, task completion speed, access to skilled personnel, and cost savings.

Keywords: Distributed Collaboration; Contributing factors; Model; Success; Literature Review.

4.2 Introduction

The growth of digital technologies has facilitated an uptake in Distributed Collaborations (Asatiani & Penttinen, 2019; Cheng, Fu, & Druckenmiller, 2016; Liu, Hull, & Hung, 2017; Tapscott & Williams, 2008). Examples of Distributed Collaboration are discussed under several synonyms and can be found in a variety of industries, for example, virtual teams (Kanawattanachai & Yoo, 2007; Nordbäck & Espinosa, 2019), online communities (Hauser, Hautz, Hutter, & Füller, 2017; Park, Im, Storey, & Baskerville, 2019), and dispersed teams (Magni, Ahuja, & Maruping, 2018). These forms of online social production have become an increasingly viable and popular way of creating high quality knowledge goods (Faraj, Jarvenpaa, & Majchrzak, 2011; Grigore, Rosenkranz, & Sutanto, 2015).

However, not all historic attempts at adopting Distributed Collaboration have proven successful, despite significant capital investment (Worthen, 2008), motivating researchers to find the root cause of this failure to gain mass adoption (Butler, Bateman, Gray, & Diamant, 2014; Zhang, Hahn, & De, 2013), even operational research on Distributed Collaboration means it is unlikely these failures can be attributed only to unforeseen factors. Instead, it appears that research is inadequately supporting practice because the range of theoretical models are either too complex or too individually disconnected and incomplete.

The objective of this review paper is, therefore, to address these issues by *developing a more comprehensive understanding of the contributing factors and benefits of this type of working arrangement*. First, consolidating different definitions of Distributed Collaboration into one synthesised definition. Second, by building an amalgamated model of the factors that predict success in Distributed Collaboration. Third, by detailing how these factors compliment and moderate one another. The following section details how we produced our definition of Distributed Collaboration. We then perform a systematic literature review that uses the concept-centric matrix approach of Webster and Watson (2002) to find recurring success outcomes and contributing factors for Distributed Collaboration. We then examine the interactions between these factors. Finally, we discuss the implications for theory and practice.

4.3 Defining Distributed Collaboration

Traditionally collaborative groups operated in a co-located environment, as this offered better communication and coordination between team members (Gupta et al., 2009). However, advancements in ICT led to the emergence and growth of distributed groups, which sacrificed face-to-face communication in favour of access to global expertise (Gupta et al., 2009; Vlaar, van Fenema, & Tiwari, 2008; Watson-Manheim, Chudoba, & Crowston, 2012). This attracted a lot of attention from researchers, who framed these new dynamics in a variety of ways (see Table 4.1).

Table 4.1 Definitions of Distributed Collaboration synonyms

Virtual teams	Groups of geographically and/or organisationally distributed participants who collaborate towards a shared goal using a combination of information and communication technologies (ICT) to accomplish a task.	(Bjørn & Ngwenyama, 2009)
Online communities	A collection of people who communicate and interact openly with each other in a computer-supported virtual space to seek some shared purposes.	(Phang, Kankanhalli, & Sabherwal, 2009; Ren et al., 2012)
Dispersed teams	Collective of individuals who are distributed across different geographic locations and rely primarily on ICTs to communicate and collaborate with each other to achieve joint outcomes for which they are responsible.	(Magni et al., 2018)
Online discussion communities	Groups of people with shared interests who communicate over the internet through a common platform.	(Butler et al., 2014)
Distributed teams	Groups of people who interact through interdependent tasks guided by a common purpose, and who work across space, time, and organisational boundaries primarily through electronic means.	(Majchrzak, Malhotra, & John, 2005)
Virtual communities	Online social networks that allow people with common interests, goals, or practices to interact and share information and knowledge.	(Bock, Ahuja, Suh, & Yap, 2015; Porter, Devaraj, & Sun, 2013)

We use ‘Distributed Collaboration’ as an umbrella term to encapsulate each of these forms of collaborative groups. We acknowledge there are differences among the above definitions. However, there are three common elements that are present in each: (1) the distribution of members (2) the use of ICT to communicate (3) a shared goal. Thus, we define Distributed Collaboration as *the pursuit of a shared objective by groups that include non-proximate members, whose participation is facilitated by ICT.*

4.4 A Systematic Literature Review

We began by conducting a keyword search of articles published in Senior Scholars Basket of 8 IS journals from January 2000 - June 2019, an approach commonly adopted to gather the discipline’s most respected research (Bernroider, Pilkington, & Córdoba, 2015; Dean, Lowry, & Humpherys, 2011). The obvious issue with the keyword-centric approach is the ‘cold-start problem’ of identifying applicable keywords (Levy & Ellis, 2006). This was particularly challenging for this study, as there are multiple terms used to describe Distributed Collaboration. We thus created a keyword matrix that would help uncover and keep track of emerging terms. We began with searches for *Distributed* and *Collaboration*. Based on initial results, we created a list of synonyms for each of these terms, and then searched all pairings between these alternative terms. The synonyms used for *Distributed* were *Dispersed*, *Global*, *Virtual*, and *Online* and the synonyms for *Collaboration* were *Team*, *Work*, *Group*, and *Community* (see Table 4.2).

We searched for papers articles published in Senior Scholars Basket of 8 IS journals using the Web of Science, the AIS Electronic Library, and Google Scholar. This resulted in an initial set of 290 papers. The set of papers was subsequently limited to peer-reviewed articles, and all duplicates removed, resulting in a total set of 153 papers. Table 4.2 provides more details concerning the numbers retrieved for each keyword pair. Building on this, we performed ‘backward searching’, which refers to reviewing literature referenced in the articles yielded in the keyword search (Levy & Ellis, 2006; Webster & Watson, 2002). This yielded a further 20 papers to be included in the review process.

The next round of refinement discarded articles that did not fit with the definition of Distributed Collaboration adopted, e.g. because there was no obvious shared objective, or teams were operating in shared premises. This resulted in the removal of 3 articles, meaning a final set of 170 papers were included for theory amalgamation. Initial analysis focused on the identification of contributing factors and outcomes, which were organised in an evolving concept matrix (Webster and Watson, 2002). The use of a concept matrix enhances the sense-making task of a successful literature review by bringing a logical structure to how we discuss a topic's central ideas (Webster & Watson, 2002). Continued iterations gradually found the contributing factors could be grouped according to whether they were endemic or relational, and whether they were social or material. This created an overarching theoretical framework in which to position individual constructs, described in the following section.

Table 4.2 Keyword Search Results

Keyword	Database	Initial Results
Distributed + Collaboration OR Team OR Work OR Group OR Community	AIS Electronic Library	3
	Google Scholar	13
	Web of Science	19
Global + Collaboration OR Team OR Work OR Group OR Community	AIS Electronic Library	0
	Google Scholar	4
	Web of Science	11
Dispersed + Collaboration OR Team OR Work OR Group OR Community	AIS Electronic Library	3
	Google Scholar	1
	Web of Science	1
Virtual + Collaboration OR Team OR Work OR Group OR Community	AIS Electronic Library	21
	Google Scholar	37
	Web of Science	55
Online + Collaboration OR Team OR Work OR Group OR Community	AIS Electronic Library	18
	Google Scholar	53
	Web of Science	51
Initial Results:		290
Results (Minus Duplicates)		153
Papers Removed for Irrelevance		3
Additional Papers from Backward Searching		20
Total		170

4.5 A Model of Distributed Collaboration Attributes and Collaboration Benefits

Figure 4.1 illustrates the final set of constructs, grouped according to the emerging theoretical framework. Social factors concern the attitudes, perceptions, and knowledge possessed by the team members, while material factors describe the perceived qualities of objects in the system. Endemic factors exist across a range of collaborative configurations, while relational factors vary according to which people and tools are interacting.

The factors are presented in Figure 4.1 as being related to one another. The purpose of this is to illustrate that no factor, or group of factors, results in successful Distributed Collaboration, rather all factors should be managed in unison to ensure success. The manner in which factors compliment and moderate one another will be discussed at length in section 4.6.

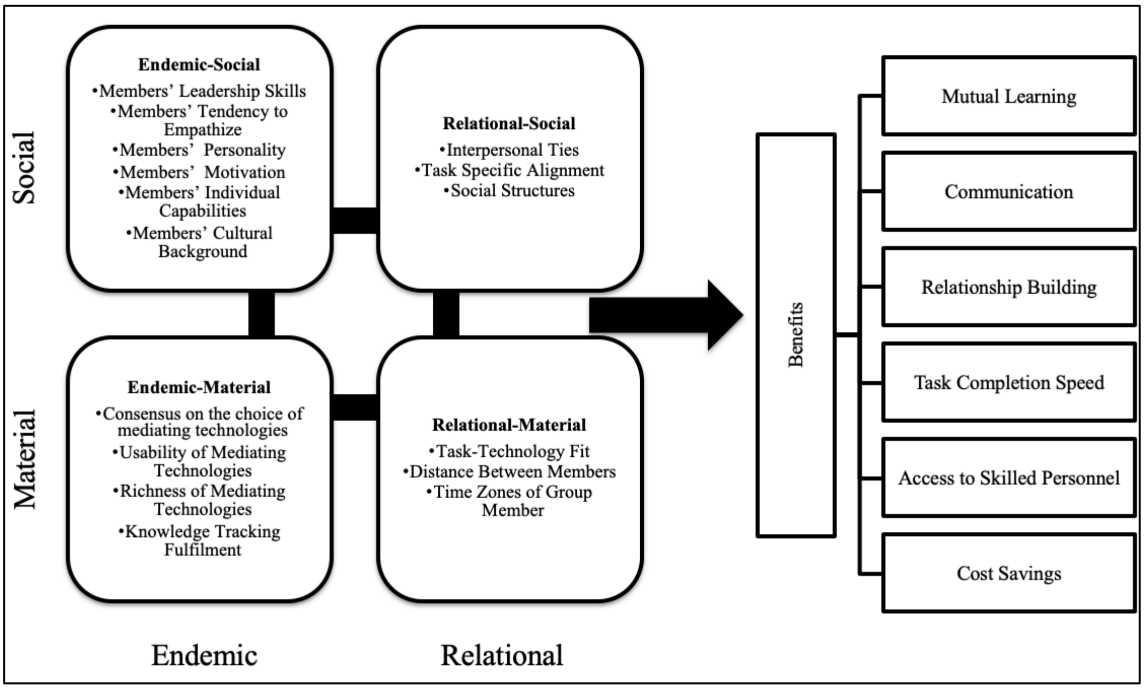


Figure 4.1 A Model for Distributed Collaboration

4.5.1 Collaboration Benefits

The first benefit of Distributed Collaboration is *communication*. Online social technologies afford low-cost and easy to access communication media (Hauser et al., 2017). However, the benefits are not simply about the quantity of communication, the quality may also benefit. Communication in these environments is often predominately text-based, which carriers particular learning advantages as it allows the user to read, reflect, write and revise their thoughts before they post their contributions (Minas, Potter, Dennis, Bartelt, & Bae, 2014). Communication can be mediated either synchronously, for example a chat room, or asynchronously such as a discussion board (Massey, Montoya-Weiss,

& Hung, 2003; Piccoli & Ives, 2003; Spagnoletti, Resca, & Lee, 2015). Nuanced benefits result from each type of distributed communication. Groups which use synchronous text-based communication generally share more unique information as the text-based communication helps the contributors overcome the selective information search bias which is common in face-to-face groups (Minas et al., 2014). Benefits found from asynchronous communication include members being less subject to ‘pressure to closure’ which prevents members from dedicating time to explore alternative solutions when problem solving (Colazo & Fang, 2010). Good communication can also enhance other benefits such as mutual learning and relationships (Hauser et al., 2017; Yang, Tong, & Teo, 2015) which will be discussed next.

Table 4.3 Collaboration Benefits

Benefit	Definition	Sources
Communication	The synchronous and asynchronous transfer of information between collaborators.	(Bartelt & Dennis, 2014; Sarker, Ahuja, Sarker, & Kirkeby, 2011)
Mutual learning	The transfer of useful knowledge and skills between collaborators.	(Gupta et al., 2009; Oshri, Van Fenema, & Kotlarsky, 2008; Ridings, Gefen, & Arinze, 2006; Robert Jr, Dennis, & Ahuja, 2008)
Relationship Building	The development of reusable and reciprocal relationships between collaborators.	(Bateman, Gray, & Butler, 2011; Kraut, Wang, Butler, Joyce, & Burke, 2010; Paul & McDaniel Jr, 2004; Robert Jr et al., 2008)
Task completion speed	The speed with which a given task can be completed.	(Colazo & Fang, 2010; Massey et al., 2003; Sarker & Sahay, 2004)
Access to Skilled Personnel	The ability to include specialised or highly skilled collaborators as needed.	(Fuller, Hardin, & Davison, 2006; Ransbotham & Kane, 2011; Wang & Haggerty, 2011)
Cost Savings	The reduction of costs when transferring or maintaining resources	(Asatiani & Penttinen, 2019; Breu & Hemingway, 2004; Gómez, Salazar, & Vargas, 2017)

The second benefit of Distributed Collaboration is *mutual learning*. Mutual learning is often considered the major attraction for members or organisations to participate in Distributed Collaboration (Kotlarsky & Oshri, 2005; Ridings et al., 2006; Wang, Noe, & Wang, 2014). Mutual learning differs from communication, as the focus is not merely on exchanging information; rather it is about changing group members' perspectives through the sharing, transfer, recombination, and reuse of knowledge among parties (Jarvenpaa & Majchrzak, 2010). Distributed Collaborations are most successful when members not only share their unique knowledge and integrate that knowledge across the group as a whole; they also generate new ideas and understanding as they contrast and compare perspectives and interpretations (Robert Jr et al., 2008). The value of mutual learning has been reflected by the adoption of open innovation models by many large multinational firms, such as Procter and Gamble, Fiat and IBM (Gómez et al., 2017). This is largely due to the prevailing perception that adopting strategies such as open innovation and virtual teams provides knowledge transfer opportunities at low marginal costs (Griffith, Sawyer, & Neale, 2003).

The third benefit of Distributed Collaboration is *relationship building*. Those who participate in Distributed Collaboration may often benefit by finding people for emotional support, instrumental aid, companionship, a sense of belonging and encouragement, (Huang, Chengalur-Smith, & Pinsonneault, 2019; Ridings et al., 2006). They may also enjoy a new platform for entertainment or to discuss social and political issues (Bateman et al., 2011; Kraut et al., 2010). These relationships are particularly apparent in online health communities, where relationship-building provides strong emotional support for individuals who may be struggling with the personal and social demands of illness (Mein Goh, Gao, & Agarwal, 2016). There is further evidence that the stronger the relationship, the more likely members are to trust the information being shared as they work towards some common purpose (Barrett, Oborn, & Orlikowski, 2016).

The fourth benefit of Distributed Collaboration is *task completion speed*. Mutual learning and relationship building are primarily social benefits. However, Distributed Collaboration also produces tangible, easily measurable outputs. Distributed Collaboration means groups can collaborate on a task at any time, either working simultaneously or separately – this is particularly attractive when the group is geographically dispersed, spanning multiple time zones (Kanawattanachai & Yoo, 2002; O'Leary & Cummings, 2007; Yang et al., 2015). Not only is this a beneficial arrangement for group members, it also provides increased flexibility, which is desirable for customers. Groups can now offer round-the-clock service to customers and rapid response to global market demands as members in different time zones allow themselves to easily adapt to changing environmental conditions (Kankanhalli, Tan, & Wei, 2006; Massey et al., 2003; Yang et al., 2015).

The fifth benefit of Distributed Collaboration is *access to skilled personnel*. These benefits are typically associated with the expanded geographic scope of distributed groups, providing access to skilled contributors 24 hours a day (Gupta et al., 2009). Compared with co-located groups, which are geographically limited in the group members to choose from, distributed groups have greater capacity to choose members with the ideal skill sets for the specific task at hand (Beranek, Broder, Reinig, Romano Jr, & Sump, 2005). Distributed Collaboration can, therefore, deliver significant strategic flexibility by efficiently forming groups of the best available talent for the duration of a specific task and then disbanding upon completion (Piccoli & Ives, 2003). This is particularly advantageous from an R&D perspective as partnerships can be developed to access specialised know-how on demand (Gómez et al., 2017). Despite these obvious benefits, it can also be a difficult task to manage a large dynamic group (Goh & Wasko, 2012). However, Ransbotham and Kane (2011) suggested that even the membership turnover experienced in Distributed Collaboration can prove to be favourable as it allows new information and abilities to enter the group, without losing the content generated by those who depart.

The sixth benefit of Distributed Collaboration is *cost savings*. The opportunities described already explain that Distributed Collaboration can achieve more with similar commitment of resources. This also means Distributed Collaboration creates opportunities to achieve similar results with fewer resources. Operating in Distributed Collaborations is associated with significant cost savings, as it is seen as a user-friendly, low-tech, and low-cost means of managing dynamic requirements – one which can expand and contract in size and scale (Bauer, Franke, & Tuertscher, 2016; Ferguson & Soekijad, 2016; Hauser et al., 2017).

Breu and Hemingway (2004) advise that by moving work to the worker rather than vice versa, organisations can achieve significant cost savings. Others have pointed out that Distributed Collaboration allows people and organisations to share information more systematically, meaning a reduction in R&D expenditure through duplication and rework (Gómez et al., 2017).

4.5.2 Endemic-Social Contributing factors

We use the term *endemic-social* to describe attributes of collaborating members that are not limited to specific relationships; rather they are recurring traits of those collaborators (Table 4.4). The first *endemic-social* contributing factor is *members' leadership skills*. In the case of Distributed Collaboration, leadership is vital for defining the goal or vision for the group project, attracting and retaining members to the group, communicating effectively, and promoting active participation in the group (Oh, Moon, Hahn, & Kim, 2016; Pauleen, 2003). Traditional collaborations and Distributed Collaborations differ in that the role of leadership is considered a collective effort in a distributed environment (Johnson, Safadi, & Faraj, 2015; Nordbäck & Espinosa, 2019). Leadership in Distributed Collaboration may be formal or informal, as long as some team collaborators are recognised by their peers as being influential in the actions the group takes to achieve their shared objective(s) (Johnson et al., 2015; Nicholson, Sarker, Sarker, & Valacich, 2007; Nordbäck & Espinosa, 2019; Pauleen, 2003). Many scholars have argued leadership is more challenging in Distributed Collaborations, due to the continuous dynamic reconfigurations taking place (Faraj, Kudaravalli, & Wasko, 2015; Nicholson et al., 2007).

The second *endemic-social* contributing factor is *members' tendency to empathise*. Empathy plays an important role in the success of Distributed Collaboration. Empathy is displayed through social sensitivity in co-located groups and is related to group performance, the lack of visual cues in Distributed Collaboration makes this difficult to replicate (Barlow & Dennis, 2016).

The third *endemic-social* contributing factor is the *members' personalities*. Personalities are important when determining the ability of individuals to establish individual roles and resolve conflict (Potter & Balthazard, 2002). Certain combinations of personalities are more likely to be effective collaborators (Brown, Poole, & Rodgers, 2004).

The fourth *endemic-social* contributing factor is the *motivation of collaborating members*. Distributed Collaboration is dependent on members handing over knowledge to benefit the group as a whole and this requires they see sufficient value to do so (Wasko & Faraj, 2005). Extrinsic factors which motivate members include reputation, career advancement, while intrinsic factors may include ideology and a sense of collective reciprocation (Roberts, Hann, & Slaughter, 2006; Von Krogh, Haefliger, Spaeth, & Wallin, 2012; Zhang et al., 2013).

Table 4.4 Endemic-social contributing factors for successful Distributed Collaboration

Contributing factor	Definition	Sources
Members' Leadership Skills	The recognition of specific collaborators as positive influencers in the pursuit of some shared objective(s).	(Faraj et al., 2015; Johnson et al., 2015; Kayworth & Leidner, 2002; Nicholson et al., 2007; Oh et al., 2016; Zigurs, 2003)
Members' Tendency to Empathise	The sensitivity with which collaborators interact with one another.	(Bateman et al., 2011; Fan & Lederman, 2018; Grigore et al., 2015; Johnson, Faraj, & Kudaravalli, 2014)
Members' Personality	The values and interaction styles of collaborators.	(Brown et al., 2004; Cummings & Dennis, 2018; Nicholson et al., 2007; Potter & Balthazard, 2002)
Members' Motivation	The intrinsic and extrinsic reasons why individuals are engaging with the collaboration.	(Ridings et al., 2006; Roberts et al., 2006; Von Krogh et al., 2012; Wasko & Faraj, 2005; Zhao, Zhang, & Bai, 2018)
Members' Individual Capabilities	The knowledge and skill possessed by individual collaborators.	(Barlow & Dennis, 2016; Fuller et al., 2006; Kayworth & Leidner, 2002; Wang & Haggerty, 2011)
Members' Cultural Backgrounds	The different national and local cultures of individual collaborators.	(Porter et al., 2013; Posey, Lowry, Roberts, & Ellis, 2010; Sarker & Sarker, 2009; Shin, Ishman, & Sanders, 2007; Vlaar et al., 2008)

The fifth *endemic-social* contributing factor is *members' individual capabilities*. Considering that Distributed Collaboration is facilitated by ICT, technical proficiency can act as a significant barrier to collaboration (Barlow & Dennis, 2016; Fuller et al., 2006). The capabilities of group members influence perceptions of competency among group members (Paul & McDaniel Jr, 2004). Digital collaboration-specific competences can refer to (1) virtual self-efficacy, i.e. an individual's belief in their abilities, (2) virtual media skill, i.e. an individual's skill levels in using communicative technologies, and (3) virtual social skill, i.e. an individual's ability to build social relationships in a virtual setting (Wang & Haggerty, 2011). Many groups assist members by providing some degree of training or support depending on the group structure (Pauleen & Yoong, 2001). This is important, as the varying skill-sets and knowledge of ‘technophobes’ may be lost due to the technical demands of Distributed Collaboration (Paul, Samarah, Seetharaman, & Mykytyn Jr, 2004). Instead, collaborations may be dominated by an over-representation of members with a positive predisposition to technology (Asatiani & Penttinen, 2019; Wang & Haggerty, 2011).

The sixth and final *endemic-social* contributing factor is the *members’ cultural backgrounds*. Intercultural differences present a continuous challenge in Distributed Collaboration (Sarker & Sarker, 2009).

4.5.3 Endemic-Material Contributing factors

We use the term *endemic-material* to describe tangible attributes (Table 4.5) of the specific infrastructure that support the collaboration. The first *endemic-material* contributing factor is the *consensus on the choice of mediating technologies*. The choice of technology provides the consistent link between the group members (Gómez et al., 2017; Pauleen & Yoong, 2001). Thus, the choice of technology plays a crucial role in capturing assertions, thoughts, and experiences between members (Altschuller & Benbunan-Fich, 2013). The choice of mediating technology may have to factor in cost-benefit comparisons between various options, e.g. typing is simple to implement but takes more time and effort than speaking, phone calls reduce travel need but are not as natural as face-to-face meetings (Bos, Olson, & Nan, 2009).

The second *endemic-material* contributing factor is the *usability of mediating technologies*. Increasing usability is considered a critical design goal when forming Distributed Collaborations (Butler et al., 2014; Kankanhalli et al., 2006; Sarker & Sarker, 2009). Technologies must provide virtual spaces that do not get in the way of interactions if they are to produce the types of sociable environments needed for meaningful collaboration

(Phang et al., 2009), these capabilities include thread-posting, real-time chat, private messaging, polling tools, communal calendars/scheduling, and social network applications (Bock et al., 2015).

Table 4.5 Endemic-material contributing factors for successful Distributed Collaboration

Contributing factor	Definition	Sources
Consensus on the choice of mediating technologies	The extent to which mediating technologies are accepted by collaborators.	(Gómez et al., 2017; Gupta et al., 2009; Ma & Agarwal, 2007; Pauleen & Yoong, 2001)
Usability of Mediating Technologies	The extent to which mediating technologies are effortless to use by collaborators.	(Lindberg, Berente, Gaskin, & Lyytinen, 2016; Phang et al., 2009; Spagnoletti et al., 2015)
Richness of Mediating Technologies	The extent to which mediating technologies afford parallel communication and rapid feedback.	(Cummings & Dennis, 2018; Daft & Lengel, 1986; Dennis, Fuller, & Valacich, 2008; Watson-Manheim & Bélanger, 2007)
Knowledge Tracking Fulfilment	The extent to which mediating technologies allow collaborators to track knowledge activities.	(Altschuller & Benbunan-Fich, 2013; Phang et al., 2009)

The third *endemic-material* contributing factor is the *richness of mediating technologies*. Media richness describes the ability of a communication channel to capture different types of information and feedback rapidly and in parallel, so reducing ambiguity and uncertainty between parties (Daft & Lengel, 1986). Media richness is socially constructed, meaning that different individuals will have different perceptions of richness, ultimately media richness and how group members communicate is dependent on how the individuals interact with the technology (Dennis et al., 2008).

The fourth and final *endemic-material* contributing factor is *knowledge tracking fulfilment*. This describes the extent to which members believe their need to track knowledge activities can be fulfilled by the technology used by the group (Phang et al., 2009).

4.5.4 Relational-Social Contributing factors

Relational-social contributing factors describe qualities that exist within the relationships between collaborators. The description of these factors in existing literature was more complicated than other contributing factors. Hence, they are modelled in this study as hierarchical constructs, each comprised of multiple constituent factors (see Table 4.6). The first *relational-social* contributing factor is *interpersonal ties*. This contributing factor is comprised of four sub-concepts, namely *trust among specific group members*, *interpersonal relationships among specific group members*, *communication among specific group members, and prior work history between collaborating members*.

Interpersonal relationships among specific group members are essential to allow 'synergistic knowledge' to be developed through group interactions (Griffith et al., 2003). These relationships may existing within and across different organisations (Liu et al., 2017). *Trust among specific group members* may be divided into cognitive and affective trust (Fan & Lederman, 2018; Kanawattanachai & Yoo, 2002) whereby cognitive trust involves a cognitive assessment of other members competence, reliability and dependability, while affective trust deals with emotional bounds, caring and reciprocity (Altschuller & Benbunan-Fich, 2013; Fan & Lederman, 2018). Both of these dimensions are important. However, Distributed Collaboration means members are dispersed and projects may be short term, hence cognitive trust often takes precedence (Altschuller & Benbunan-Fich, 2013; Liu et al., 2017). *Communication among specific group members* is important as those who communicate more will be seen more positively within the group (Bock et al., 2015; Pauleen, 2003; Sarker & Sahay, 2004). Existing literature has cited *prior work history* as a consideration for distributed collaborative groups (Piccoli & Ives, 2003; Robert Jr et al., 2008). Distributed Collaborations often face a logistical hurdle which would be less common in co-located groups in that members are likely to have no history of working with one another (Gu, Konana, Rajagopalan, & Chen, 2007; Kanawattanachai & Yoo, 2002).

Table 4.6 Relational-social contributing factors for successful Distributed Collaboration

Contributing factor	Attributes	Sources
Interpersonal Ties	Relationships Among Specific Group Members	(Goh & Wasko, 2012; Kraut et al., 2010; Liu et al., 2017; Paul & McDaniel Jr, 2004; Pauleen, 2003; Pauleen & Yoong, 2001)
	Trust Among Specific Group Members	(Altschuller & Benbunan-Fich, 2013; Cheng et al., 2016; Fan & Lederman, 2018; Kanawattanachai & Yoo, 2002; Ridings, Gefen, & Arinze, 2002; Robert, Denis, & Hung, 2009)
	Communication Among Specific Group Members	(Dennis et al., 2008; Kotlarsky & Oshri, 2005; Ridings et al., 2006; Sarker et al., 2011; Zhang et al., 2013)
	Past/Future Work with Other Members	(Altschuller & Benbunan-Fich, 2013; Cummings & Dennis, 2018; Espinosa, Slaughter, Kraut, & Herbsleb, 2007; Robert et al., 2009; Wu, Gerlach, & Young, 2007)
Social Structures	Communication standards adopted in Group	(Gu et al., 2007; Jarvenpaa, Shaw, & Staples, 2004; Moser, Ganley, & Groenewegen, 2013; Potter & Balthazard, 2002; Sarker & Sahay, 2004)
	Social Network Within Group	(Cummings & Dennis, 2018; Garg, Smith, & Telang, 2011; Kane & Ransbotham, 2016; Robert Jr et al., 2008; Sarker et al., 2011; Wasko & Faraj, 2005)
	Governance Structure of Group	(Bauer et al., 2016; Crowston, Li, Wei, Eseryel, & Howison, 2007; Faraj et al., 2011; Grigore et al., 2015; Hauser et al., 2017)
	Social Norms	(Bjørn & Ngwenyama, 2009; Butler & Wang, 2012; Park et al., 2019; Ridings & Wasko, 2010; Sarker & Sahay, 2004; Watson-Manheim et al., 2012)
	Subgroups	(Bock et al., 2015; Bos et al., 2009; Gu, Konana, Raghunathan, & Chen, 2014; O'Leary & Cummings, 2007; Windeler, Maruping, Robert, & Riemenschneider, 2015)
Task-Specific Alignment	Shared Goals/ Understanding Among	(Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000; Ray, Kim, & Morris, 2014; Robert Jr et al., 2008; Sarker et al., 2011; Wasko & Faraj, 2005; Windeler et al., 2015)

	Specific Group Members	
	Coordination Among Specific Group Members	(Beranek et al., 2005; Kanawattanachai & Yoo, 2007; Lindberg et al., 2016; Moser et al., 2013; Robert Jr et al., 2008; Yang et al., 2015)
	Mutual learning Among Specific Group Members	(Faraj et al., 2011; Kane & Ransbotham, 2016; Kotlarsky & Oshri, 2005; Ma & Agarwal, 2007; Oh et al., 2016; Posey et al., 2010; Ransbotham & Kane, 2011; Ridings et al., 2006; Staples & Webster, 2008; Wasko & Faraj, 2005)

The second *relational-social* contributing factor is the *social structures* of the group, this is comprised of five sub-concepts, *communication standards adopted in group*, *the social network within the group*, *the governance structure*, *social norms*, and *subgroups*.

Communication standards, sometimes referred to as genre rules, are defined as the instantiation of the social structures for how a communication tool is used by a set of users (Bartelt & Dennis, 2014; Watson-Manheim & Bélanger, 2007). Communicative genres are distinctive types of communicative action, characterised by socially recognised communicative purpose and common aspects of form (Moser et al., 2013). They are typically adopted intuitively by users as they communicate with one another, further emphasising the self-structured nature of Distributed Collaboration (Bartelt & Dennis, 2014).

Establishing a *social network within the group* increases social presence, which is the perception that social counterparts in virtual exchanges are real (Altschuller & Benbunan-Fich, 2013; Srivastava & Chandra, 2018). This in turn creates social comparison, which should be managed to promote positive actions from group members (Bhagwatwar, Massey, & Dennis, 2017). Social capital theory, specifically structural capital can be applied to Distributed Collaboration when discussing the power of social networks on the group (Robert Jr et al., 2008). Structural capital reflects the overall pattern of interactions among group members (Cummings & Dennis, 2018; Wasko & Faraj, 2005).

One of the distinguishing factors of Distributed Collaboration over a traditional, hierarchical group within an organisation is its *governance structure*. The application of communication technology means these groups are typically governed by self-organisation, keeping a detailed trace of the interactions between members in real time (Bauer et al., 2016; Crowston et al., 2007; Grigore et al., 2015). These Distributed Collaborations are established and maintained by its members as a platform to share common interests and information relating to that topic without any organisational input (Hauser et al., 2017; Porter et al., 2013). Distributed collaborative groups implement their own content boundaries, which are an individual perceptions of what materials and discussions are part of the community and what are not (Butler & Wang, 2012). The lack of formal structure in Distributed Collaboration has been shown to free collaborators from the pressure of social convention and hierarchy, fostering levels of innovation which are not found in traditional organisational structures (Faraj et al., 2011).

Social Norms are the informal rules and standards of a group that emerge out of social interactions and influence group members' social behaviour without the force of laws (Huang et al., 2019). Social norms develop over time within a group with repeated interactions, contributions and exchanges (Bjørn & Ngwenyama, 2009).

Subgroups or cliques are a subset of a network in which actors are more closely and intensely tied to one another than they are to the other members of the entire network (Bock et al., 2015).

The third *relational-social* contributing factor is *task-specific alignment*. This social contributing factor is also achieved through the combination of elements which are discussed in a number of prior studies, specifically *shared goals/understanding among group members*, a *coordination among specific group members*, and *mutual learning between members*.

Distributed Collaborations require a *shared understanding* of what they are trying to achieve in order to operate towards a common goal. The importance of shared goals and understanding in Distributed Collaboration draws on cognitive capital, i.e. the extent to which members share a common understanding about their teamwork and/or task (Mathieu et al., 2000). Park et al. (2019) showed that shared understanding leads to 'affective contagion' i.e. a process in which a person or group influences the affect or behaviour of another person or group through the conscious or unconscious induction of affect states and behavioural attitudes. In an effort to develop a shared understanding there are also obstacles which should be avoided, first, it is important to avoid confirmation bias, which is the tendency to search for or interpret information in a way that confirms one's preconceptions (Minas et al., 2014). Second, developing a shared understanding within the group is not always achieved, many groups experience conflict among team members which must be resolved (Oshri et al., 2008; Windeler et al., 2015).

Coordination among group members occurs when members develop an understanding of the activities of others, coordination is defined as the management of dependencies among task activities, when the task activities of multiple individuals need to interrelate in a synchronised fashion, the corresponding interdependencies need to be well managed (Espinosa et al., 2007). This role of coordination of group members in a Distributed Collaboration is well regarded in the extant literature (Lindberg et al., 2016; Moser et al., 2013; Yang et al., 2015) and an understanding of 'who knows what' can improve the performance of the group (Oshri et al., 2008).

Mutual learning, i.e. the sharing, transfer, recombination, and reuse of knowledge among parties (Jarvenpaa & Majchrzak, 2010) is a central activity of Distributed Collaboration. However, it can be extremely difficult to encourage users to participate (Ren et al., 2012). Distributed Collaboration follows a power law distribution whereby a few top contributors provide most of the resources, for example, over 65% of Gnutella network users downloaded free music without ever contributing themselves (Gu et al., 2007). Equality of participation is considered an important factor of group performance as there in a need to integrate knowledge from as many group members as possible, if some members do not contribute, the group loses this potential knowledge (Barlow & Dennis, 2016).

4.5.5 Relational-Material Contributing factors

We use the term *relational-material* to describe tangible factors which determine how group members interact with one another (Table 4.7). The first *relational-material* requisite is *task-technology fit*. Task-technology fit refers to the fit between the task requirements and the capabilities of the IT to facilitate communication (Asatiani & Penttinen, 2019). IT coordinates the features of the communication medium with the situation and social context of the group (Barlow & Dennis, 2016; Jarvenpaa et al., 2004) and has been discussed as a contributor to collaborative success in the extant literature (Barlow & Dennis, 2016; Beranek et al., 2005; Figl & Saunders, 2011).

The second *relational-material* contributing factor is *distance between group members*. When operating in Distributed Collaboration, groups must overcome geographical distance which is traditionally considered antithetical to successful coordination (Lindberg et al., 2016). Of course distance can also be harnessed to the groups advantage as the virtual space is not subject to geographical limitations so members can access the platform anywhere, anyhow, and anytime (Spagnoletti et al., 2015).

The third *relational-material* contributing factor is the *time zones occupied by group members*. Extant research has highlighted time as 'one of the most elusive concepts related to work' (Sarker & Sahay, 2004). For distributed collaborative groups, as distance and group size increases, groups are likely to experience difficulties with members working in different time zones (Kayworth & Leidner, 2002; Massey et al., 2003). This is referred to as temporal dispersion (Colazo & Fang, 2010; O'Leary & Cummings, 2007) and is considered an 'internal boundary' for distributed groups (Espinosa, Cummings, Wilson, & Pearce, 2003).

Table 4.7 Relational-material contributing factors for successful Distributed Collaboration

Contributing factor	Definition	Sources
Task-Technology Fit	The appropriateness of the mediating technology adopted given the context of the group's operations.	(Asatiani & Penttinen, 2019; Bartelt & Dennis, 2014; Faraj et al., 2011; Figl & Saunders, 2011)
Distance Between Members	The geographic dispersion of group members.	(Colazo & Fang, 2010; Espinosa et al., 2003; O'Leary & Cummings, 2007; Sarker & Sahay, 2004)
Time Zones of Group Members	The time zones occupied by collaborating participants of the group.	(Colazo & Fang, 2010; Espinosa et al., 2003; Massey et al., 2003; O'Leary & Cummings, 2007; Sarker, Ahuja, & Sarker, 2018; Sarker & Sahay, 2004)

4.6 Complimentary and Moderating Factors

To this point this literature review has detailed the benefits which organisations or groups can reap from effective Distributed Collaboration as well as modelling the factors which must be managed in order to produce such rewards. However, through the process of reviewing existing literature, it became obvious that many factors did not operate in isolation and instead were complimented by others. Through retrospectively reviewing these complimentary factors after producing our model illustrated in Figure 4.1, it was no surprise that social factors, both endemic and relational were found to be complimented or moderated by a number of other listed factors. The following sections will detail how the factors listed in our research model have a complimentary or moderating influence on the endemic-social or relational-social factors.

4.6.1 Endemic-Social

Leadership is particularly challenging due to the multidisciplinary and geographically distance between members in Distributed Collaboration (Eseryel & Eseryel, 2013). Choosing a leader is influenced by *mutual learning*, *personality* and *members tendency to empathise* as factors that are often associated with a good leader include level of participation (Faraj et al., 2015), strong leadership *personality* traits (Nicholson et al., 2007), or simply being considerate of others' feelings (Eseryel & Eseryel, 2013).

Empathy has a positive effect on the level of participation, thus improving *mutual learning* (Huang et al., 2019; Johnson et al., 2014; Leimeister, Ebner, & Krcmar, 2005). Showing empathy also *motivates* other members and encourages unselfish behaviours (Grigore et al., 2015). As already mentioned, empathy can also compensate for an absence of formal *leadership*, whereby members assume the role of a mentor, developing their peers by listening and showing support (Wakefield, Leidner, & Garrison, 2008).

The role of *individual personalities* can be moderated by *social networks* within a group as Distributed Collaborations arguably make it more difficult to express one's *personality*, due to the decrease in continuous exposure. This means certain personality traits, such as charisma, can become less effective in Distributed Collaboration if the member is not also proficient in the necessary *technical skills* to allow them to express it (Windeler et al., 2015). Although much of the extant research focuses on the effect of an individual's personality on their role in Distributed Collaboration, the converse of this relationship has also been shown to be true, mutual learning and participation in Distributed Collaboration can negatively influence individuals' personalities, e.g. if the pressures of working in a distributed group interfere with an individual's work-life balance (Sarker, Sarker, & Jana, 2010).

Increased *motivation* has been shown to compliment *mutual learning* as having a sense of belonging in a group increases information exchange and cooperation in the group (Cummings & Dennis, 2018). Members with greater commitment to the group will stay with it longer and contribute more (Kraut et al., 2010; Yan, Leidner, & Benbya, 2018). Levels of commitment play a key role in regulating members behaviour such as reading posts, posting replies and moderating discussions (Bateman et al., 2011). A large portion of group members in open environments typically start as 'lurkers' who must be motivated to become more actively involved by showing them the potential value from active participation (Ridings et al., 2006).

The mix of national and local *cultures* often has a strong influence on *communication*, *shared understanding*, and *leadership* in the group as members require greater communication skills to avoid misunderstandings or cultural biases (David, Chand, Newell, & Resende-Santos, 2008; Kayworth & Leidner, 2002; Pauleen & Yoong, 2001; Vlaar et al., 2008). Group members from different cultures may interact with their peers in contrasting ways. For example, Nordbäck & Espinosa (2019) showed that members from high power-distance cultures are more likely to accept unequal distribution of power, making them less equipped and less likely to assume leadership roles. On the other hand, team members from low power-distance cultures are more likely to favour less centralised leadership approaches. Similarly, the mix of cultures in a group can influence the development of interpersonal relationships and knowledge sharing necessary for mutual learning as different cultures may have different attitudes to self-disclosure (Posey et al., 2010) and members from a culture of individualism will tend to have loose interpersonal ties vs. collectivists which will tend to be cohesive and well-integrated (Paul et al., 2004; Posey et al., 2010; Shin et al., 2007).

4.6.2 Endemic-Material

The decision *on the choice of mediating technologies* will directly influence the level of *communication* between members, for example there could be secondary compatibility issues, e.g. some communication tools, such as Google+ and Facebook, are not available in China, but U.S. members may not be accustomed to using WeChat (Cheng et al., 2016).

Second, the *usability of mediating technologies* will impact *mutual learning* as it is important for the technology to support the sharing of digital content in multiple formats in order for participants to collaborate properly (Spagnoletti et al., 2015). For example, platforms such as GitHub provide a comprehensive suite of communication and collaboration features which support users in effectively coordinating their work (Lindberg et al., 2016).

The third *endemic-material* contributing factor is the *richness of mediating technologies*, which again, can either compliment or negatively impact *communication* between members and play a significant role in the ultimate success or failure of Distributed Collaboration, as less rich media slows and inhibits complex communication between collaborating members (Kayworth & Leidner, 2002).

The fourth and final *endemic-material* contributing factor is *knowledge tracking fulfilment*. Distributed Collaboration systems can enable knowledge tracking fulfilment by maintaining a digital record of member contributions and contributors, so improving *relationships* within the group as increased public awareness encourages members to build relationships (Altschuller & Benbunan-Fich, 2013). Knowledge tracking fulfilment can also act as a *motivation* tool as it plays an important role in reputation-building and group acknowledgement (Wasko & Faraj, 2005; Wasko, Faraj, & Teigland, 2004).

4.6.3 Relational-Social

Following our model presented in Figure 4.1, the first *relational-social* contributing factor is *interpersonal ties*. This contributing factor is comprised of four sub-concepts, namely *trust among specific group members*, *interpersonal relationships among specific group members*, *communication among specific group members, and prior work history between collaborating members*.

First*, interpersonal relationships among specific group members,* form the basis for the development of *trust and communication* (Cummings & Dennis, 2018; Paul & McDaniel Jr, 2004; Pauleen, 2003; Windeler et al., 2015).

Second, *trust between members* can be difficult to develop, given the lack of established *relationships* or *prior work history* between members in Distributed Collaboration, they must often rely on 'swift trust', a presumptive form of trust that allows individuals to begin collaborating as quickly as possible (Robert et al., 2009). Once trust is established, *mutual learning* follows as individuals are more likely to share information and make contributions, it also means they are more likely to accept the information and contribution of others (Robert Jr et al., 2008; Zhang & Watts, 2008).

Communication among specific group members is predicated on the condition the group *trusts* the communicator, as otherwise high levels of communication are simply seen as wasteful 'babbling' (Sarker et al., 2011). Communication between members can be improved based on the *usability of technology* as individual communications can be differentiated according to their 'rehearsability', i.e. the extent to which users can reread and edit communications before sending them (Dennis et al., 2008). This not only allows individuals to avoid making mistakes or offending people, it also alleviates some of the social pressures of synchronous or face-to-face communication (Ray et al., 2014).

Having no *prior history working together* does not mean trust cannot be developed but, as discussed already, it does necessitate the development of swift trust (Robert et al., 2009). Having a satisfactory prior collaborative experience has been shown to encourage continued participation and, therefore, improve *mutual learning* (Wu et al., 2007). This can influence members impressions of one another, not only do members rarely have a history of working together, they also rarely meet in person during the course of a collaboration which would assist in establishing a *relationship* (Cummings & Dennis, 2018). The lack of familiarity between group members means they struggle to develop relationships and routine over time (Barlow & Dennis, 2016), making it difficult for group members to develop a *shared understanding* (Windeler et al., 2015), decreasing *communication* between members and thus, increasing the likelihood of conflict in the group (Oshri et al., 2008).

Communication standards naturally has a direct influence on the *communication* between group members, effective communication is essential in Distributed Collaboration, and by establishing genre rules, a group can increase the ease of use, reduce communication cost, and improve both efficiency and effectiveness of communication (Espinosa et al., 2007). Previous studies have recommended that Distributed Collaborations even make explicit agreements for how quickly emails should be responded to in order to dramatically improve overall communication (Bos et al., 2009). The explicit implementation of communication standards such as this would help overcome *trust* issues between members as research has shown that in the case of communication responsiveness, a group member with high trust in their peer will attribute slow responsiveness to an external factor. However, if trust is not established, they will interpret the delay in response as noncooperative behaviour (Jarvenpaa et al., 2004). Establishing communication standards can also overcome *cultural* differences, as previous research has highlighted the difference in communication culture between different nationalities (Sarker & Sahay, 2004).

Social networks in the group rely on the *richness of the mediating technology,* as well as *distance between members* as distance has an effect on communication, and the social influence of the exchange is subject to the richness of the communication media (media richness theory) (Dennis et al., 2008). Rich media are better suited to ambiguous tasks, whereas lean media are better for information processing (Asatiani & Penttinen, 2019). An interesting outcome from a strong social presence in a group is social proof, which is an effect *motivation* tool whereby members engage in an activity as they believe that other in the group are also participating in that activity (Posey et al., 2010). Groups with decentralised networks do not have a history of a small number of members dominating discussions, therefore, higher structural capital increases the likelihood that more members will contribute, share, and use information from all members (*mutual learning*) (Robert Jr et al., 2008). Although members of Distributed Collaboration may not have prior work experience, it is interesting to note the prevalence of homophily. Homophily refers to the propensity to seek interactions with those who have similar beliefs (Gu et al., 2014) and how members of Distributed Collaboration have a tendency to discover the same information because of their shared interests (Garg et al., 2011).

Governance structure has a unique impact on *leadership,* unlike traditional organisations, in keeping with the free structure or Distributed Collaboration, leaders emerge informally either by natural selection or those who are actually doing the work in the group determine who should take certain responsibilities (Eseryel & Eseryel, 2013). By establishing some degree of control within the group, feedback is provided to members which increases the probability of reaching the *shared goals* of the group (Dennis, Robert Jr, Curtis, Kowalczyk, & Hasty, 2012), and increases the perceptions of fairness among members (Magni et al., 2018). Governance structures are maintained by the presence of moderators who play a crucial role in sustaining the group (Phang et al., 2009), as well as having *trust* and good *relationships* between group members (Pauleen, 2003).

Social norms emerge on a voluntary basis and moderate the interactions of contributors and ensure quality of contributions, thereby improving *mutual learning* (Butler & Wang, 2012; Gu et al., 2007; Ridings & Wasko, 2010). When norms are established in a group it helps develop a *shared understanding* and *motivate* participation (Sarker & Sarker, 2009; Zhao et al., 2018), this is considered a form of *relational-social* capital (Robert Jr et al., 2008). However, for a number a reasons, distributed collaborative groups find it difficult to establish social norms, for example, as has been discussed in detail already, *cultural* difference between members can cause conflict in a group which inhibits to development of norms (Sarker & Sahay, 2004; Wakefield et al., 2008). Also, the lack of *past work experience*, established *relationships* or even the *social cues* present in face-to-face interactions present a challenge (Barlow & Dennis, 2016; Robert et al., 2009). Failing to establish social norms can lead to a lack of cohesion in the group, or worse, the belief that they have established a *shared understanding* while remaining oblivious to the presence of misunderstandings (Watson-Manheim et al., 2012).

Distributed Collaboration facilitates the formation of *subgroups*, firstly, through the *choice of mediating technology* and its technical infrastructure as emails and communication tools can support both collective and subgroup communication (Magni et al., 2018;

Thomas & Bostrom, 2010). Second, Distributed Collaborations create homophily, as they are formed in order to collaborate on a *shared topic or goal* (Park, Konana, Gu, Kumar, & Raghunathan, 2013), therefore, members find that they identify with particular subgroups (Robert et al., 2009) which may increase their *motivation* and thus improve *mutual learning* through increased participation (Bos et al., 2009). The formation of subgroups should, however, be cautiously monitored as it has been cited as restricting the development of *trust* (Windeler et al., 2015) and increasing the likelihood of conflict, i.e., a lack of *shared understanding* (O'Leary & Cummings, 2007).

Shared understanding itself is particularly important for Distributed Collaborations to develop as they are geographically dispersed and may not have the same opportunities to *communicate* with one another (Sarker et al., 2011; Vlaar et al., 2008). Therefore, along with forming strong *interpersonal ties*, the group requires a *shared understanding* and sense of belonging, mutual responsibility and a sense of obligation toward one another (Ray et al., 2014; Vlaar et al., 2008). This cognitive capital facilitates efficient *communication* and *coordination of members* in a Distributed Collaboration (Robert Jr et al., 2008; Wasko & Faraj, 2005). As discussed above, Distributed Collaboration is a fluid object where members can come and go as they please, creating potential for confirmation bias in the group (Faraj et al., 2011; Yan et al., 2018). However, the strength of Distributed Collaboration lies in the variety of expertise and *individual capabilities* within a group (Lindberg et al., 2016; Zhao et al., 2018). We view conflict as the absence of shared understanding, Hauser et al. (2017) describe this as an interaction relationship between two or more parties that pursue mutually exclusive or incompatible goals. The likelihood of conflict increases with *geographic distance* and dispersion of members (Windeler et al., 2015).

Creating and maintaining this *awareness* reduces the effort needed to coordinate tasks and resources, once developed through *communication* and working as a group, this familiarity helps group members anticipate the actions of others (Beranek et al., 2005; Nordbäck & Espinosa, 2019). When Distributed Collaborations have a shared understanding, they begin to develop shared mental models which are important for effective information exchange and integration (*mutual learning*) and enable high performing groups to coordinate themselves without the need for over *communication* (Beranek et al., 2005; Robert Jr et al., 2008; Yang et al., 2015). This requires particular attention in distributed rather than co-located collaborations, as the latter has the advantage of 'bumping into one another' which would remind them of tasks that need to be delivered upon etc. (Bos et al., 2009). Instead, Distributed Collaborations rely on Transactive memory systems (TMS) which refer to the combination of individual memory systems and communications between individuals (Oshri et al., 2008). In particular TMS discussed the awareness of knowledge specialisation among group members (Kanawattanachai & Yoo, 2007). TMS is vital for Distributed Collaborations as members may not have close *personal relationships* but come together to facilitate *mutual learning* (Kotlarsky & Oshri, 2005).

Social exchange theory has also been applied in prior literature when studying *mutual learning* in distributed groups (Posey et al., 2010; Ridings et al., 2006). Social exchange theory is applied in this context as a subjective cost-benefit perspective, comparing intangible costs such as contributing to the group, to intangible benefits such as the respect you will receive (Posey et al., 2010). Existing literature shows us that members require *trust* (Staples & Webster, 2008) and the belief that their reputation will be enhanced (Wasko & Faraj, 2005) to *motivate* them to contribute themselves (Posey et al., 2010).

Members of Distributed Collaboration operate on a somewhat voluntary basis, meaning that members, and as a result their contributions, are far more volatile (Oh et al., 2016). The literature has shown that Distributed Collaborations have high membership volatility (Faraj et al., 2011), member retention and *motivation* to participate proves to be a constant struggle and is crucial for the survival and success of the group (Ransbotham & Kane, 2011). However, other studies suggest that the volatile nature of membership can be a positive factor as it increases group size and, therefore, information quality (Kane & Ransbotham, 2016). Distributed Collaborations naturally have more difficulty in encouraging mutual learning due to the lack of face to face *communication* (Griffith et al., 2003; Ma & Agarwal, 2007) Distributed Collaborations invest heavily in *media-rich* communication tools to support mutual learning across their sites, however, breakdowns and other challenges are still evident (Kotlarsky & Oshri, 2005).

Of course, not all knowledge which should be shared between members is explicit, it is also important for tacit knowledge to be exchanged (Wang et al., 2014), although this can be difficult in a distributed setting with limited interpersonal *communication* (Gupta et al., 2009). Therefore, members rely on repeated interactions, contextualising their questions and validating answers (Johnson et al., 2015). Knowledge creation theory indicates that in order to encourage mutual learning, there must be high levels of social interaction between individuals, because knowledge is created by individuals, groups should look to create 'communities of interaction' to improve mutual learning (Yan et al., 2018).

4.6.4 Relational-Material

Task-technology fit also has a close relationship with the *coordination of team members* as it is important to align individual with tasks, technology and group structure to achieve optimal performance (Wang & Haggerty, 2011). Task-technology fit should be given as much consideration as the technology itself to ensure the investment in collaborative tools is not wasted, increased availability of communicative technology means that *communication can* take place, but does not mean that it *will* take place (David et al., 2008). Technology can alleviate *cultural, temporal and geographic* issues, however, if the fit between task and technology is not optimal these issues could be amplified (Asatiani & Penttinen, 2019).

The challenge presented by having group members dispersed across a variety of sites is how best to distribute work, responsibilities and *leadership* across the sites and then re-integrate them into the group as a whole (David et al., 2008). The result of greater *distance* between group members is that the intensity of *communications* is reduced, in particular when members face problems with media that cannot substitute face-to-face communication (Kotlarsky & Oshri, 2005).

The additional factor of different *time zones* to coordinate increase the complexity of *communication*, especially synchronous communication becomes difficult to arrange (Cheng et al., 2016; Kankanhalli et al., 2006), individuals experience unproductive waits for responses which can lead to inefficiencies, rework and ultimately working outside regular hours (Sarker et al., 2018). For example, David et al. (2008) detail an observation of their study on GLOBALIS, meetings took place at 08:00 AM (EST), which meant it was 13:00 in Ireland, 19:00 in India, 07:00 in Texas and 06:00 in Utah. The result of this is that people on the east coast of America started their day with a meeting, Irish workers had their day interrupted with a meeting and members in Texas, Utah or India had to work outside their normal hours to participate in meetings. Schedules such as this have also been the cause of *conflict* in distributed collaborative groups, giving rise to complaints that meetings are scheduled during times that are more convenient for one group, or that certain groups are given better assignments (Magni et al., 2018). The temporal benefits such as 24-hour service which are detailed in the benefits section of this paper, come at the cost of *coordination* issues such as this when an all-group meeting is required (Kankanhalli et al., 2006).

4.7 Discussion and Conclusions

The objective of this study was to conduct a comprehensive overview of the current literature on Distributed Collaboration, and in doing so, develop a more complete understanding of the contributing factors and benefits of this type of working arrangement. The first step in this process was to define Distributed Collaboration as *the pursuit of a shared objective by groups that include non-proximate members, whose participation is facilitated by ICT*. This definition was developed by synthesising several other synonyms including virtual teams, online communities, dispersed teams, online discussion communities, virtual communities, and distributed teams, which are used in extant research. This development alone contributes both to researchers and practitioners. As we have discussed, Distributed Collaboration has been applied to a plethora of industries and applications, however, each instance seems to operate under a new title. Defining Distributed Collaboration provides clarity for both practitioners who are looking to adopt this approach to work as well as researchers who study how it operates.

A systematic approach to searching academic databases was taken by first developing a keyword search matric to overcome the challenge of searching for comprehensive literature in a multidisciplinary field. Once the literature was gathered and duplicates removed we began our review of the material and developed a concept-centric matrix to capture the contributing factor factors to be managed for successful collaboration, as well as the benefits which resulted from these groups (Webster & Watson, 2002). The contents of this concept-centric matrix are illustrated in our core research model (Figure 4.1).

This study contributes to the existing body of research by providing a core model for Distributed Collaboration which can be adopted and built upon in future research. This model enhances knowledge on successful Distributed Collaboration and creates a lens to enable organisations to understand how to realise the benefits of Distributed Collaboration. While existing research has focused on specific factors and the role they play in Distributed Collaboration, for example trust (Jarvenpaa et al., 2004; Ridings et al., 2002), leadership (Eseryel & Eseryel, 2013; Johnson et al., 2015; Kayworth & Leidner, 2002), and communication (Bartelt & Dennis, 2014; Sarker et al., 2011), our analysis of existing literature did not reveal a comprehensive model for successful Distributed Collaboration.

This model makes a number of significant contributions, both to theory and practice. First, we distinguish both contributing factors and benefits as being either ‘social’ or ‘material’. This is an important distinction to make considering our definition of Distributed Collaboration highlights the reliance on ICT to facilitate this type of working arrangement. Therefore, our model stresses that both technology and structural factors (‘material’) as well as factors pertaining to the members within the group and how they interact with one another (‘social’) must be examined.

The second axis of our model divides the contributing factors as being either endemic or relational. Again, referring back to our definition of Distributed Collaboration, groups consist of geographically dispersed members working towards a common goal or shared interest. Therefore, dispersed workers will carry their own personal attributes, which we label as being social-endemic. All factors relating to how members perform within the group as a whole are then categorised as social-relational. Similarly, we found that material factors can also subcategorised as either endemic or relational; endemic being those which relate to the specific technology implementation and relational being the structural factors in place which dictate the composition of the group.

Second, in addition to illustrating a comprehensive model of the contributing factors for successful Distributed Collaboration and categorising each of these factors, we have also detailed the interactions between these factors and how they can complement or regulate one another. This is particularly important from a practitioner's perspective as it provides valuable insights into how to efficiently integrate all the elements of the model.

Third, this research has drawn attention to factors which have received varied levels of research. Factors such as trust (Jarvenpaa et al., 2004; Ridings et al., 2002), leadership (Eseryel & Eseryel, 2013; Johnson et al., 2015; Kayworth & Leidner, 2002) and communication (Bartelt & Dennis, 2014; Sarker et al., 2011) have been the focus of many research papers. However, other factors such as empathy and knowledge tracking fulfilment have not been explored to the same extent. This research not only explicitly outlines the importance of these infrequent factors but also outlines the role they play in the overall success of Distributed Collaboration. Highlighting the importance of knowledge tracking fulfilment is especially important given the developments in communication technology. Future research should look to explore the role of knowledge tracking fulfilment in the context of emerging technologies which facilitate this ability, for example the ability of Blockchain technology to capture data in a secure, immutable, and publicly verifiable manner (Beck et al., 2018).

As regards directions for future research in this domain, we believe this study has highlighted a number of potential avenues for researchers to explore. First, this study has presented a synthesised definition of Distributed Collaboration which encapsulates a plethora of terms which have been applied to describe similar forms of collaborative groups in previous research. We believe it would be beneficial for future research to explore the dynamics of Distributed Collaboration further in an effort to categorise what distinguishes different flavours of this type of working arrangement. Second, the primary contribution of this study is the core research model presented in Figure 4.1 which illustrates the contributing factors which must be managed to effectively produce the benefits of Distributed Collaboration. Future researchers could adopt this model and evaluate its accuracy against an established Distributed Collaboration use-case. Finally, as mentioned in the body of this paper, we decided to limit the scope of our literature search to papers published between 2000 and 2019 in order to maintain a degree of relevance to advancements in modern communicative technologies. Although we are satisfied that this study represents the current state of Distributed Collaboration, we also must acknowledge the pace of development of communicative technologies. For instance with the growth of virtual and augmented reality and its application in collaboration (Venkatesh & Windeler, 2012). Future research should, therefore, iterate this study to capture the contribution of these technologies to Distributed Collaboration.

Chapter 5. Exploring the Challenges Associated with Distributed Collaboration

5.1 Abstract

Collaboration has evolved from co-located to distributed settings. A wealth of research has examined how Distributed Collaboration is affected by the challenges of free-riding, production blocking, and evaluation apprehension. Research also suggests that the application of technology can help overcome these issues. This study applies this extant literature to inform a set of propositions to detail how the implementation of a system could overcome these challenges. A series of exploratory interviews with industry participants are conducted to gain insights into their experiences with these challenges while operating in Distributed Collaboration. This data is analysed using Open, Axial, and Selective coding techniques. Findings detail first-hand, rich accounts of the challenges faced when operating in Distributed Collaboration. Results from data analysis contribute to the emergence of new insights and hypotheses on how to overcome these challenges. The findings highlight how collaborations differ based on the team function, project objective or individuals' approach to work. This study illustrates that a sufficient balance of people, processes, and technology is necessary to overcome the challenges faced in Distributed Collaboration. Much of the existing research on the challenges of Distributed Collaboration derive their results from short simulations. This study contributes rich insights gathered from participants with first-hand experience operating in Distributed Collaboration, thereby contributing to both theory and practice.

Keywords: Distributed Collaboration; Free-Riding; Evaluation Apprehension; Production Blocking.

5.2 Introduction

Traditional forms of collaboration were focused on teams in a co-located environment. However, the emergence and growth of digital technologies has given rise to the growth of Distributed Collaborations i.e. the pursuit of a shared objective by groups that include non-proximate members, whose participation is facilitated by ICT (Asatiani & Penttinen, 2019; Cheng et al., 2016; Liu et al., 2017; Tapscott & Williams, 2008). Examples of Distributed Collaboration are discussed under several synonyms and appear in a variety of industries, for example, virtual teams (Kanawattanachai & Yoo, 2007; Nordbäck & Espinosa, 2019), online communities (Hauser et al., 2017; Park et al., 2019), and dispersed teams (Magni et al., 2018). Working under these conditions allows individuals with a range of backgrounds and expertise from various geographic locations to bring new perspectives to bear on complex problems in a variety of domains (Faraj et al., 2011; Grigore et al., 2015).

Much of the extant literature dedicated to researching different forms of Distributed Collaboration has focused on the myriad of success factors which must be managed in this type of working arrangement such as trust (Jarvenpaa, Knoll, & Leidner, 1998; Porter et al., 2013; Ridings et al., 2002), leadership, (Carte, Chidambaram, & Becker, 2006; Kayworth & Leidner, 2002; Nordbäck & Espinosa, 2019) and communication (Garg et al., 2011; Jarvenpaa & Leidner, 1999; Sarker et al., 2011). There is also a wealth of research which examines the challenges facing collaborative teams. These include production blocking, which is when individuals cannot express their ideas in a collaborative group because someone else is talking; evaluation apprehension, which is when individuals withhold their ideas out of concern that others may not approve them; and free-riding, which refers to a member of a group who obtains benefits from a group membership but does not bear a proportional share of the costs of providing the benefits (Albanese & Van Fleet, 1985; Briggs & Reinig, 2010; Diehl & Stroebe, 1987; Gallupe et al., 1992; McGrath, 2015).

The objective of this study is, therefore, *to investigate the operational challenges of Distributed Collaboration, as well as gaining insights from industry participants on how a technology-enabled solution could overcome these challenges.* In order to develop a better understanding of how these issues affect members of Distributed Collaboration, we conducted semi-structured interviews with individuals working in a large multinational organisation, hereafter referred to by the pseudonym 'DE Computers'. Findings make two primary contributions; first, the analysis of data gathered in interviews draws attention to the importance of harmonizing the combination of people, processes, and technology to overcome the challenges faced in Distributed Collaboration. Second, this research adds new insights and depth regarding the day-to-day reality of operating in Distributed Collaboration. This perspective is not covered in detail in extant research.

The remainder of this study will be structured as follows; first, a theoretical grounding will be established by examining the evolution of collaboration from traditional, co-located settings to geographically distributed environments. The challenges mentioned above of production blocking, evaluation apprehension, and free-riding will also be discussed in detail as well as the potential of technology to provide a solution. Second, the methodological approach will be detailed, including the background of those interviewed and how the interview data was analysed. Third, the findings of the study will be presented as a synthesis of the research. Finally, we will discuss the implications of this research for theory and practice, as well as the limitations.

5.3 Theoretical Grounding

5.3.1 The Evolution from traditional to Distributed Collaboration

Traditionally collaborative working groups operated in a co-located environment as the physical distance was seen as detrimental to collaboration between people and organisations (Eppinger & Chitkara, 2006; Gupta et al., 2009). Geographic proximity was considered advantageous as it offered better communication and coordination between team members as they worked (Sapsed, Gann, Marshall, & Salter, 2005). Also, certain regions were established industrial districts or had an environment to foster innovation (Amara, Landry, & Ouimet, 2005).

Knowledge itself is recognised as a corporate asset that can provide a company with a competitive advantage (Bordia, Irmer, & Abusah, 2006); therefore, promoting knowledge sharing is essential for success. Traditional, co-located teams used meetings as an opportunity for team members from different departments to collaborate and generate and share their ideas (Paulus & Yang, 2000). Knowledge management is a crucial activity for organisations to facilitate the sharing of explicit as well as tacit knowledge (Wang et al., 2014). The real benefit of knowledge sharing between group members comes when members from various backgrounds begin to share ideas, taking advantage of cognitive diversity and sharing unique expertise (Paulus, 2000; Paulus & Yang, 2000), thus it is important to facilitate the generation and sharing of ideas to create synergies between individuals in a group.

Bordia et al. (2006) applied social exchange theory to analyse knowledge sharing as an economic exchange whereby group members conduct a cost-benefit analysis before sharing knowledge. Members consider the effort involved in sharing as a cost and the rewards received as a benefit. Wang et al. (2014) suggested that practices that induce accountability are necessary to promote knowledge sharing in a team.

The concept of *brainstorming* was initially developed by (Osborn, 1953) as a mechanism for increasing the amount of ideas shared between members of a group, and has since been cited by numerous studies as the origin of group idea generation and knowledge sharing exercises (Briggs & Reinig, 2010; Dennis & Valacich, 1993; Gallupe et al., 1992; McGrath, 2015; Paulus, 2000). Osborn (1953) detailed four rules to govern idea generation sessions: do not criticise, encourage quantity, combine and improve suggestions, and say all ideas no matter how wild.

However, researchers found that the combined performance of individuals brainstorming and then aggregating their ideas afterwards was more productive than interactive brainstorming groups. In fact, these *nominal groups* produced nearly twice as many different ideas than interactive groups (Camacho & Paulus, 1995; Gupta et al., 2009; Sutton & Hargadon, 1996). In particular, the marginal productivity of members of brainstorming groups declines with increasing group size (Gallupe et al., 1992).

The reason for this underperformance in brainstorming groups is that the four rules outlined by Osborn (1953) are often ignored. Many studies find that brainstorming groups suffered from members feeling the weight of evaluation (evaluation apprehension), members struggling to contribute ideas (production blocking) and reduced motivation to contribute, leaving others to complete the task (free-riding) (Briggs & Reinig, 2010; Diehl & Stroebe, 1987; McGrath, 2015).

Advancements in ICT lead to the emergence and growth of Distributed Collaborations (Asatiani & Penttinen, 2019; Cheng et al., 2016; Liu et al., 2017; Tapscott & Williams, 2008). These teams are not restricted by geography and instead have access to global expertise (Chiu, Liang, & Turban, 2014; Eppinger & Chitkara, 2006; Ye & Kankanhalli, 2015). This has created a new ‘flat world' of participation, where old collaborative hierarchies give way to more open and inclusive collaborations involving large numbers of distributed collaborators. Organisations must embrace these collaborations within evolving and boundary-spanning technological ecosystems (Friedman, 2005). These new Distributed Collaborations act as a form of ‘nominal group' whereby members work alone, and their contributions are aggregated. These groups are consistently found to be more productive than traditional brainstorming groups (Gupta et al., 2009; McMahon, Ruggeri, Kämmer, & Katsikopoulos, 2016; Sutton & Hargadon, 1996).

Due to the dispersed nature of these groups and their reliance on technology to communicate, Distributed Collaboration utilises *electronic brainstorming.* Electronic brainstorming is considered an enhanced form of brainstorming whereby members contribute ideas through a computer rather than in an open, face-to-face forum (Dennis & Valacich, 1993). Knowledge sharing exercises such as this are often considered the major attraction for individuals or organisations to participate in Distributed Collaboration (Griffith et al., 2003; Jarvenpaa & Majchrzak, 2010; Kotlarsky & Oshri, 2005; Ridings et al., 2006). Distributed Collaborations are most successful when participants not only share their unique knowledge and integrate that knowledge across the team as a whole; they also generate new ideas and understanding as they contrast and compare perspectives and interpretations, developing synergies (Robert Jr et al., 2008). Electronic brainstorming develops synergies as there are more participants, providing a diverse set of skills and expertise (Dennis & Valacich, 1993) and members can combine and build upon one another’s ideas (Kohn, Paulus, & Choi, 2011).

Electronic brainstorming was seen as a solution to the inhibitors of traditional brainstorming. Production blocking was reduced as all ideas can be expressed simultaneously. Increased anonymity reduced evaluation apprehension. Improved accountability combats free-riding (Briggs & Reinig, 2010; Nijstad, Stroebe, & Lodewijkx, 2003; Paulus, 2000; Paulus & Yang, 2000). Groups that use electronic brainstorming were found to be more productive than co-located groups and nominal groups (Dennis & Valacich, 1993; Gallupe et al., 1992; Sutton & Hargadon, 1996).

5.3.2 Production Blocking in Collaborative Groups

Production blocking is defined as "group members who are prohibited from verbalizing their ideas may forget or suppress them because they seem less relevant or less original at a later time." (Diehl & Stroebe, 1987). Many studies have suggested that production blocking has reduced productivity in collaborative groups (Camacho & Paulus, 1995; Dennis & Valacich, 1993; Diehl & Stroebe, 1987).

Diehl and Stroebe (1987) examined production blocking in detail, outlining that it occurs when only one speaker is allowed at a time. It has been suggested that production blocking results in reduced output because the delay caused by blocking prevents individuals from developing their original thought and other ideas as they are rehearsing one thought until they express it to the group. Delays in the idea generation process result in cognitive interference, which results in productivity loss (Diehl & Stroebe, 1987; Nijstad et al., 2003; Paulus, 2000). The obvious proposed solution to this problem is to utilise a mechanism that facilitates simultaneous contributions (Briggs & Reinig, 2010).

Proposition 1: *Production Blocking will result in the suboptimal performance of Distributed Collaboration.*

5.3.3 Evaluation Apprehension in Collaborative Groups

Evaluation apprehension refers to the fear of negative evaluations from other group members preventing subjects who are working in groups from presenting their more original ideas (Collaros & Anderson, 1969). Despite the benefits of group idea generation, working in a group could deter an individual from contributing for fear of embarrassment, hostile evaluation, the pressure to conform as well as other social forces (Collaros & Anderson, 1969; McGrath, 2015; Paulus, 2000). The original rules outlined for brainstorming as detailed above attempted to combat the effects of evaluation apprehension by discouraging criticism of contributions (Dennis & Valacich, 1993). Diehl and Stroebe (1987) investigated the impact of evaluation apprehension on group productivity by telling members that either external judges or their peers would evaluate their ideas. Their results showed that by generating evaluation apprehension in a group, concerns about the quality of ideas increase among members, which resulted in a decrease in the number of ideas produced as individuals began to self-censor.

When examining knowledge sharing from a social exchange theory perspective, Bordia et al. (2006) listed evaluation apprehension as a cost, which leads to underperformance in knowledge sharing groups. Their research also suggested that the effects of evaluation apprehension are increased when participants do not have control over who gets access to their contributions. Individual status within a group also has an effect on the levels of evaluation apprehension experienced, with low-status members being less likely to contribute in the presence of high ranking members (Camacho & Paulus, 1995; Collaros & Anderson, 1969; McGrath, 2015). The effects of this are found to be reduced as members ascend the ranks within an organisation (Bordia et al., 2006).

Allowing participants to write their contributions down (Paulus & Yang, 2000) and increasing levels of anonymity (Briggs & Reinig, 2010; Dennis & Valacich, 1993) are frequent suggestions for alleviating the effects of evaluation apprehension. Connolly, Jessup, and Valacich (1990) suggested that increasing the level of anonymity "should encourage full participation of junior and shy group members, and expression of unpopular, novel or heretical opinions". However, through increasing anonymity, groups must maintain recognition and reward to ensure participants will continue to contribute (Bordia et al., 2006; Wang et al., 2014).

Proposition 2: *Evaluation Apprehension will result in the suboptimal performance of Distributed Collaboration.*

5.3.4 Free-Riding in Collaborative Groups

The term 'free-rider' refers to a member of a group who obtains benefits from a group membership but does not bear a proportional share of the costs of providing the benefits (Albanese & Van Fleet, 1985). Free-riding occurs when team members decrease their efforts and expect others to pick up the slack (Suleiman & Watson, 2008). This can be due to a belief that one's contribution is dispensable and does not contribute to the success of the group (Dennis & Valacich, 1993; George, 1992; Kudrowitz & Wallace, 2013; Paulus, 2000). Furthermore, members of a group feel that the responsibility for the success of the group does not rest on their shoulders to the same extent as the success of an individual task would (Latané et al., 1979). This problem is known as *diffusion of responsibility* which is defined as 'when everyone is responsible, no one really feels responsible' (Bandura et al., 1996). This has been referenced as an essential factor to manage in ensuring the success of these self-directed teams whereby team members can be inclined to put self-interests ahead of the shared interest of the group (Carte et al., 2006; Han et al., 2012; Spagnoletti et al., 2015). Diffusion of responsibility occurs more in the presence of perceived experts (Camacho & Paulus, 1995; Diehl & Stroebe, 1987; Paulus, 2000).

Free-riding is particularly relevant in the case of Distributed Collaboration due to the temporary nature of most teams. Members will be more likely to behave in an untrustworthy manner and take more from the team than they give in return (Lin & Huang, 2009; Sarker et al., 2011). The lack of face-to-face interaction can cause free-riding in Distributed Collaboration due to reduced accountability (Boughzala, De Vreede, & Limayem, 2012). 'Lack of trust and the propensity to attribute laziness or ineptitude to others could have led people to work less hard themselves'(Latané et al., 1979). On the other hand, groups in which all members pull their weight are able to maintain high trust between members (Piccoli & Ives, 2003).

Distributed Collaborations that work and those that do not differ in the level of social distance. Social distance is the degree of emotional connection among team members (Robert Jr et al., 2008). In the case of traditional, co-located groups, Chidambaram and Tung (2005) cite social standards as key deterrents of free-riding. They argue that in a co-located environment, social pressure results in individuals being more productive as they can see their peers working around them. This acts as a form of motivation to other team members who are not present in Distributed Collaboration. In fact, performance did not differ between co-located and distributed collaborative groups and the only impact of co-location was the social pressure to appear productive.

Although this form of electronic idea generation and knowledge sharing reduced what were seen as barriers to contribution, it also heightened concerns over levels of recognition and reward (Suleiman & Watson, 2008; Wasko & Faraj, 2005). With mass contributions from members who were not working in a co-located environment and were not personally familiar with one another, the task of assigning credit to contributors became increasingly tricky (Beranek et al., 2005; Chidambaram & Tung, 2005). Research has found that feedback given on an individual basis, did not result in a reduction in the levels of free-riding in a group. However, when feedback was given to all members of the group and member's feedback was visible to all other members, this acted as a comparative tool and decreased the level of free-riding (Suleiman & Watson, 2008). The proposed solution to free-riding in groups is increasing accountability and the ability to identify individual contributions (Diehl & Stroebe, 1987; Wang et al., 2014).

George (1992) explored the area of the 'Free-Rider Problem', or 'social loafing'; this study revealed that the two main variables that influence free-riding are *task visibility* and *intrinsic involvement*. George (1992) describes task visibility as; 'the belief that a supervisor is aware of individual effort on a job', and intrinsic involvement as; 'beliefs that the work being done is meaningful and significant and that one's own efforts are an important contribution to the employing organisation'. Therefore, an organisation should focus on increasing task visibility and an individual's intrinsic involvement to reduce free-riding and in turn, improve productivity.

Proposition 3: *Free-Riding will result in the suboptimal performance of Distributed Collaboration.*

5.3.5 Applying Technology in Collaborative Groups

Electronic brainstorming (Dennis & Valacich, 1993; Gallupe et al., 1992; Nijstad et al., 2003), or 'brainwriting' (Paulus & Yang, 2000) are commonly proposed solutions to production blocking as members of the group can write their ideas down rather than wait to individually voice their suggestions. Writing ideas rather than verbalizing them has been found to combat production blocking and eliminate productivity loss (Nijstad et al., 2003;

Paulus & Yang, 2000). “Working under conditions that allowed them to verbalise their ideas as they occurred, subjects produced approximately twice as many ideas as they did when working under conditions in which subjects had to wait their turn” (Diehl & Stroebe, 1987).

Gallupe et al. (1992) found that traditional brainstorming groups were less productive as group size increased. However, electronic brainstorming groups were not hampered by this as their members can work simultaneously by typing ideas into a computer. Inputting ideas in a system prevents any one individual from dominating the discussion, so production blocking remains at a constant low, regardless of group size. They also suggest that the implementation of a system could further reduce production blocking in distributed groups. Gallupe et al. (1992) propose that adopting electronic brainstorming could prove to be especially useful when people are working on different schedules on account of their time zones and workloads. Therefore, suggesting that this is especially applicable for Distributed Collaboration.

As for the role of technology in mitigating the negative effect of evaluation apprehension in group idea generation, evaluation apprehension in traditional brainstorming groups increases with increasing group size as each additional member acted as an extra critic. However, apart from groups of two members, in electronic brainstorming groups, the level of evaluation apprehension remains constant with increasing group size (Briggs & Reinig, 2010). This is the result of increased anonymity in technology-supported groups, which are an effective method of reducing evaluation apprehension. However, the anonymity of users should be introduced with caution. First, because reducing the effect of evaluation apprehension could encourage bad or irrelevant ideas to be contributed (Briggs

& Reinig, 2010). Second, recognition must be maintained in order to avoid free-riding (Bordia et al., 2006; Dennis & Valacich, 1993).

Electronic brainstorming combats free-riding by increasing individual accountability in their performance (Paulus, 2000). Free-riding occurs in the absence of management practices such as rewards and evaluations; however, knowledge management systems that induce accountability are found to increase contributions from group members (Wang et al., 2014). The temptation to free-ride is shown to increase with increasing group size in traditional co-located teams as the identifiability of individual contributions decreases (Gallupe et al., 1992; Gressgård, 2012; Kudrowitz & Wallace, 2013). However, electronic brainstorming techniques can improve the ability to identify individual contributions and therefore reduce free-riding (Paulus & Yang, 2000).

Proposition 4: *The implementation of a system could improve the performance of Distributed Collaboration.*

5.4 Methodology

A series of exploratory interviews were conducted to investigate the operational challenges of Distributed Collaboration, and to gain insights from industry participants on how a technology-enabled solution could overcome these challenges. Each interview included focused questions relating to the interviewee's team as well as open-ended questions, which ensured that a complete understanding of the interviewees experience working in Distributed Collaboration was captured. These questions are provided in Appendix 9.7.

As previously stated, Distributed Collaboration encapsulates a wide variety of activities ranging from online communities and virtual teams to intra-organisational teams of globally distributed members. For several reasons including, ease and speed of collection, consistency of interviewee background, and culture, eight exploratory interviews were carried out within a single organisation, each interview lasting approximately 1 hour. The organisation, ‘DE Computers’, has a large multinational presence with globally distributed groups. A combination of managers and their subordinates were interviewed to gain insights into the challenges of both the management and participation in Distributed Collaboration. Interviewees worked in a cross-section of areas within DE Computers including (1) the field delivery support team, (2) the IT service delivery team, (3) general accounting team, and (4) the mobile development team. Diversifying the background of interviewees avoided producing results that would be specific to one department or team within DE Computers. Instead, the results produced are representative of Distributed Collaboration in general. Details of the interviewees are listed in Table 5.1.

Table 5.1 Interviewee Backgrounds

Role (*Pseudonym*)	**Team**
Senior Manager *(Manager A)*	Field Delivery Support
Senior Manager *(Manager B)*	IT Service Delivery
Manager (Manager C)	General Accounting
Manager (Manager D)	Mobile Development
Financial Analyst *(Employee A)*	Field Delivery Support
Senior Financial Analyst *(Employee B)*	Global Business Services
IT Finance Business Consultant *(Employee C)*	IT Service Delivery
IT Project Manager *(Employee D)*	Global Infrastructure & Services

The data were analysed using open, axial, and selective coding techniques (Strauss & Corbin, 1990; Urquhart, 2001) to refine the propositions into a set of hypothesis. This approach necessitates the researchers to be immersed in the data (Glaser & Strauss, 1967) and to draw on existing theoretical knowledge (Strauss & Corbin, 1990; Urquhart, 2001). It thus encourages the researcher to be flexible and creative while imposing systematic coding procedures (Strauss & Corbin, 1990).

Open coding requires a brainstorming approach to analysis because, in the beginning, analysts want to open up the data to all potentials and possibilities contained within the data. Comments were first assigned labels based on the context of the comment, for instance, Employee A said *Long Projects don't produce tangible outputs at first, but a lot of grunt work is put in.* This was labelled as *Evaluating Contributions* (Table 5.3).

Next, axial coding was performed to relate categories with one another. Comments were further categorized based on the relationships between the context of these comments. For example, Employee A's comment above was one of a number of comments which related to employee's desire to maintain *autonomy* over how they did their job.

Finally, we analysed the relationship among these second-order categories (selective coding), it was logically determined that the overriding relationship between each of the categories highlights that the implementation of a system alone will not overcome the problems faced in Distributed Collaboration, rather it requires the effective balance of people, processes, and technology. Employee A's comment above related specifically to the *People* aspect of this. Furthermore, comments relating to Technology are detailed in Table 5.2, and those relating to Processes are outlined in Table 5.4. The relationship between these top-level categories of comments are illustrated in Figure 5.1.

Table 5.2 Insights from interviews related to Technology in Distributed Collaboration

Context	**Comment**	**Concept**
Current Tools	Email communication can be hard to interpret. *(Employee C)*	Communication Media
	WebEx calls are used to see facial expressions and these can be very positive. *(Employee C)*	
System Requirements	[The system] Should have better real-time information on the performance of offshore teams rather than having to chase them for updates. *(Manager C)*	Proposed Solution
	Simplicity and good user experience are essential. *(Manager B)*	
	Better reporting and status updates. *(Manager B)*	
	[The system] Should also capture when you helped out with smaller, ad-hoc tasks. *(Employee C)*	
	Normal day to day tasks is enough without introducing another HR system. *(Employee C)*	
Perceived Benefits	It would be great if it was transparent across the organisation and showed how employees in other teams were treated. *(Employee A)*	
	Possibly an anonymous method of allowing people to get their ideas out there without having to stand up and speak in front of a group would help. *(Manager B)*	

Table 5.3 Insights from interviews related to People in Distributed Collaboration

Context	**Comment**	**Concept**
Interpersonal Relationships	[It is difficult to establish personal relationships in Distributed Collaboration], especially when new members join the team in different locations that you haven’t met before. *(Manager C)*	Distributed Members
	[Distributed members] may not benefit from having a personal relationship with their manager. *(Employee A)*	
Individuals Approach to work	[Distributed members] may have other priorities going on in their local areas that you are not aware of. *(Manager C)*	
	[Distributed members] may not feel like they are determining what the goal is, but they do feel as though they are contributing toward executing it. *(Manager A)*	
Implementing a system	You must be aware of cultural differences within the team. *(Manager C)*	
Individuals Approach to work	Some prefer to leave work until the last minute, others prefer to get it finished straight away. *(Employee A)*	Individual’s Job Autonomy
	We operate on core hours of 10:00-16:00 and flexi-time after that. 9 to 5 doesn’t exist anymore. *(Employee A)*	
	[Individual goals are created] by setting the goal for the organisation and deriving individual goals from this. In bi-weekly one-to-one meetings, [individuals] prepare a four-quadrant chart showing; what they achieved last week; what they aim to do next week; goals for the quarter; any questions. *(Manager A)*	
Evaluating contributions	[Managers] encourage people to try something new as long as they can justify their attempts. *(Manager C)*	
	Long projects do not produce tangible outputs at the start, but a lot of grunt work is put in. When the emphasis is put on hours spent in the office, some people tend to stay late early in the week, being unproductive just so they can leave early on Friday. *(Employee A)*	
	We are also encouraged to help to do smaller, ad-hoc tasks like training and roles which are not directly involved in the project. *(Employee C)*	
Implementing a system	You don’t want to lose your independence and have to justify your role. *(Employee A)*	

Table 5.4 Insights from interviews related to Processes in Distributed Collaboration

Context	**Comment**	**Concept**
Team Composition	Teams are largely made up of members from different departments across multiple countries. *(Manager B)*	Team/Project Structure
	(In relation to team size) Bigger teams are harder to stand out in. Bigger teams have poorer communication. In larger team's managers do not have the time to spend on one-to-one meetings so progress is not discussed on a regular basis, so if goals are not reached management doesn't really understand. *(Employee A)*	
Team Function	*(In relation to managing a shared service team)* The team is given a list of activities to perform. We know how long each activity takes and how much it will cost. Every quarter the performance is reviewed to ensure it aligns with the SLA. *(Manager A)*	
	(In relation to the team's capacity to innovate) Innovation in Finance is always going to have strict boundaries. A business team has more room for expansion and development. *(Manager A)*	
	(In relation to adopting a more data-driven approach to tracking contributions) It depends on team size and function, in smaller team's communication is key, in large teams or when the role is transaction then a data-driven approach is better. *(Manager C)*	
	(In relation to implementing a system to track individual contributions) It depends on the type of organisation and team function. We must be careful not to micro-manage people, however, with a shared service team, it could be very good. *(Manager A)*	
Individual's willingness to contribute	There may be reluctance as managers may shoot down an idea. People tend to lack confidence; people are often reluctant to stand up and speak their mind. Managers need to create an environment to allow this. *(Manager B)*	Social Structure
	Having a strong personal relationship with my manager helps, I know that any overtime I do is being recognised but I can see how this would be difficult for distributed members of my team. *(Employee A)*	
Current approaches to tracking contributions	Teams try to arrange annual meetups where possible. *(Employee C)*	
	[Managers and individuals] have bi-weekly one-to-one progress meetings and a global team call on alternate weeks. *(Manager A)*	

	Involves chasing people to make sure files have been updated. Very subjective as it deals with how individuals interact with their team. *(Manager C)*	
	[Rewards are allocated] based on a mixture of hitting targets and relationship with management. *(Employee C)*	
	It relies on people to speak up about the state of their project. *(Manager C)*	
	Background work is not captured. *(Manager C)*	
	During global team calls meeting minutes are taken to record who has signed up for tasks. *(Employee A)*	
	Freedom of this system is better as it is open to creativity. *(Employee C)*	
Implementing a system	Micromanaging can demotivate people. *(Manager A)*	
	Should support the existing trust and relationships between managers and the team. *(Manager C)*	
	The team has to buy into the system. *(Manager C)*	
	Communication up front to inform members why the system is being used to make sure they don't feel targeted. *(Manager C)*	
	It would create a level playing field, especially in teams where managers are based in one location and the members at that office have the advantage of a personal relationship. *(Employee A)*	

5.5 Research Synthesis

Figure 5.1 groups the concepts which emerged from the analysis of interview data presented in Tables 5.2-5.4 as they relate to People, Processes, and Technology. This figure illustrates that People, Processes, and Technology must be coordinated effectively to ensure the success of the Distributed Collaboration.

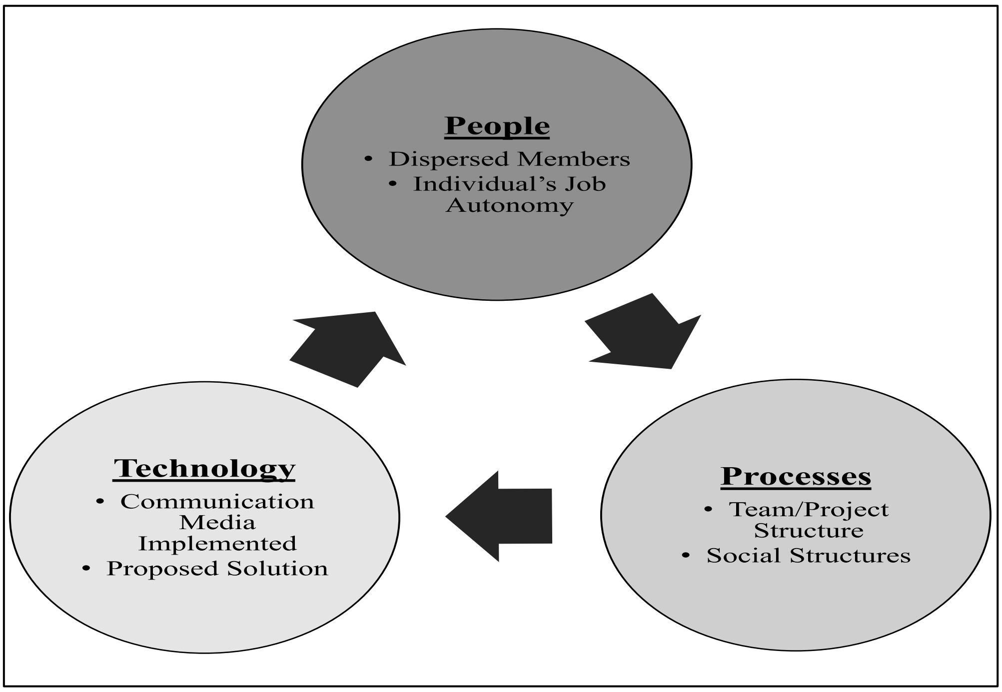


Figure 5.1 Balancing People, Processes, and Technology in Distributed Collaboration

Next, the propositions outlined in the theoretical grounding of this paper are discussed. Insights gathered from the semi-structured interviews resulted in these propositions being refined into a set of hypotheses.

5.5.1 The impact of production blocking on the performance of Distributed Collaboration

Data gathered from interviews with participants of Distributed Collaboration produced several findings that relate to the impact of production blocking on the performance of these groups. First interviewees noted that differences in team composition have a significant impact on performance. Larger teams were said to experience poor communication, making it difficult for individuals to stand out and resulting in less time for meetings between managers and team members. *Manager A* was responsible for a large group which consisted of co-located and distributed members. In order to maximise efficiency in bi-weekly one-to-one meetings with team members, they adopted a structured approach to tracking progress. For these meetings "[individuals] prepare a four-quadrant chart showing; what they achieved last week; what they aim to do next week; goals for the quarter; any questions." As group size increases, managers have less time to spend with each individual. Therefore, they must adopt structured management approaches such as this. Although this is an effective way to track progress, it does not allow for free form discussion between team members and their managers. Therefore, new ideas cannot be shared and deliberated. This observation is consistent with the findings of Diehl and Stroebe (1987), who illustrated that communication decreases with increasing group size.

Also, Distributed Collaboration teams are obligated to accept the different ways in which team members may approach their work. Interviewees highlighted that they must accept that distributed members may have to deal with 'local priorities' which they were not aware of, resulting in delays in their shared project. Another factor to consider is when team members will choose to work. This will often influence the productivity of other team members, especially when working on a collaborative project. *Employee A* described the different approaches people take to work; "Some prefer to leave work until the last minute, others prefer to get it finished straight away". *Employee A* also described variances in individual's availability "We operate on core hours of 10:00-16:00 and flexitime after that. Nine-to-Five does not exist anymore". These factors can lead to a break in the momentum of a project, which can be likened to cognitive interference, an established factor in production blocking (Nijstad et al., 2003; Paulus, 2000; Wang, Rosé, & Chang, 2011).

Analysing the data gathered from interviews with participants of Distributed Collaboration using Open, Axial, and Selective coding techniques revealed that changes in team composition and differences in how individuals approach their work can negatively influence performance in Distributed Collaboration, thus providing empirical support for

Proposition 1; production blocking will result in the suboptimal performance of Distributed Collaboration. Proposition 1 can, therefore, be refined to specify the following two hypotheses:

H1: *The influence of production blocking on the performance of Distributed Collaboration is affected by Team Composition.*

H2: *The influence of production blocking on the performance of Distributed Collaboration is affected by individual member's Approach to Work.*

5.5.2 The impact of evaluation apprehension on the performance of Distributed Collaboration

Data gathered from interviews with participants of Distributed Collaboration produced several findings that relate to the impact of evaluation apprehension on the performance of these groups. Interviews revealed that the social structures in place within a team have a distinct impact on the levels of evaluation apprehension in the group. Interviewees described that in their current approach, individuals were expected to volunteer to take on project tasks. This may be a deterrent for individual members; *Manager B* discussed this issue, explaining that "people are often reluctant to stand up and speak their mind." *Manager C* admitted that there might be a reluctance to contribute as case managers "shoot down an idea". Additionally, *Manager B* felt that it was the responsibility of management to "create an environment" to encourage contributions from all members. These observations support the notion that productivity is affected when individuals are being judged, especially when judges are of a higher status than them (Camacho & Paulus, 1995; Collaros & Anderson, 1969; McGrath, 2015).

Second, our findings show that evaluation apprehension is also affected by team composition, specifically the function of the team. Evaluation apprehension refers to the fear of negative evaluations from other group members preventing subjects who are working in groups from presenting their more original ideas (Collaros & Anderson, 1969). Interviewees indicated that ideas would be evaluated differently depending on the function of their team. For example, as described by *Manager A*, the regulation involved in finance means a team operating in this field would be far less likely to contribute innovative ideas because members are aware that they have little chance of being adopted. Also, when team members have been hired to execute a Service Level Agreement (SLA), their roles are monitored in detail. *Manager A* explained that "The team is given a list of activities to perform. We know how long each activity takes and how much it will cost"; therefore, they are less likely to contribute new ideas as it is not part of their role.

We found that team members can experience evaluation apprehension as a result of the social structure within a group, and also due to the function of their team. This can result in reduced performance, thus providing empirical support for Proposition 2 and enabling it to be refined into the following two hypotheses:

H3: *The influence of evaluation apprehension on the performance of Distributed Collaboration is affected by Social Structures.*

H4: *The influence of evaluation apprehension on the performance of Distributed Collaboration is affected by Team Function.*

5.5.3 The impact of free-riding on the performance of Distributed Collaboration

Data gathered from interviews with participants of Distributed Collaboration produced findings that relate to the impact of free-riding on the performance of these groups. When analysing the data gathered from interviews, it was apparent that the interviewees placed much value in the amount of autonomy they had over their jobs. High levels of job autonomy highlighted the importance of trust in preventing free-riding (Latané et al., 1979). Individuals are assigned quarterly goals that are tracked in bi-weekly one-to-one meetings with their managers. Individuals present a graphic which details the quarterly goal, progress made last week, the objective for the coming week, and any outstanding questions. Outside of this, they are free to work as they please, some may choose to work consistently, others leave work build up. Team members are encouraged to work on ad-hoc tasks and training initiatives. Also, managers understand that in long projects, there may not be tangible outputs at first but, as *Employee A* puts it, “a lot of grunt work” was being executed. Many stated that they would not want to lose this independence if a system was implemented in their team.

Job autonomy was found to be moderated by team function. Management was comfortable with adopting a holistic approach to monitoring contributions and giving individuals ownership over how they operated for most roles. However, when team members have been hired to execute a Service Level Agreement (SLA), their roles are monitored in a more metric-driven approach, involving high levels of task visibility.

The second observation made in relation to the presence of free-riding was the effect of the team's social structure. A number of interviewees acknowledge that they were fortunate for being co-located with their manager. As a result, they benefited from a strong personal relationship. They were assured that if they had to work overtime or a project involved much background-work, their efforts would be acknowledged. However, they empathised with distributed members who did not have this advantage. All managers interviewed indicated that the allocation of rewards was quite subjective.

To overcome the differences between co-location and dispersion, all teams interviewed utilised many communication tools. An email was cited as being difficult to interpret, especially when culturally specific references were used in the text. Video conferencing tools were also prevalent throughout DE Computers, and all interviewees rated it highly as it allowed for more fruitful communication.

Analysing the data gathered from interviews, it became apparent that individual job autonomy and social structures within the team rely on trust and communication between team members. Without this, free-riding will lead to suboptimal performance; this provides empirical support for Proposition 3 and enables further refinement into four hypotheses:

H5: *The influence of free-riding on the performance of Distributed Collaboration is affected by an Individual Member's Job Autonomy.*

H6: *Individual Member's Job Autonomy is moderated by the Project Function.*

H7: *The influence of free-riding on the performance of Distributed Collaboration is affected by Team's Social Structure.*

H8: *Team's Social Structure is moderated by Communication Media.*

5.5.4 The impact of system implementation on the performance of Distributed Collaboration

First, the implementation of a system to track individual contributions in Distributed Collaboration could overcome the challenges created by team composition. Managers and team members alike alluded to the fact that as teams grew in size, it became increasingly difficult to maintain effective communication regarding the progress made by individuals. For example, *Employee A* outlined that "In larger team's managers do not have the time to spend on one-to-one meetings, so progress is not discussed on a regular basis, if goals are not reached management does not really understand". This was primarily caused by the fact that *Manager C* described the current approach to tracking contributions as “manual” and “involves chasing people for updates”. They, therefore, called for a potential solution to involve “better real-time information rather than having to chase them for updates”.

Second, our analysis of qualitative data shows that the implementation of a system to track contributions could overcome the influence of social structures within a Distributed Collaboration. For example, when discussing the reluctance of shy team members to contribute to the group, *Manager B* suggested that “Possibly an anonymous method of allowing people to get their ideas out there without having to stand up and speak in front of a group would help”. This comment is consistent with previous research on the benefits of anonymity in electronic brainstorming (Briggs & Reinig, 2010). *Employee A* also noted that they were confident to make suggestions and were assured that they would receive appropriate recognition for their work. This confidence was because they had a strong personal relationship with their manager as they worked alongside one another. However, they empathised with their distributed team members and noted that implementing a system "would create a level playing field, especially in teams where managers are based in one location, and the members at that office have the advantage of a personal relationship".

Third, interviewees specified that the implementation of a system could increase transparency across a Distributed Collaboration group which would bring several benefits. According to *Employee C*, accountability would increase as there would be better reporting and status updates for tracking projects. Also, a system could "capture when you helped out with smaller, ad-hoc tasks". *Employee A* suggested that "It would be great if it was transparent across the organisation and showed how employees in other teams were treated". This level of transparency would be consistent with Chidambaram and Tung (2005), they argue that in a co-located environment, social pressure results in individuals being more productive as they can see their peers working around them. This acts as a form of motivation to other team members which is not present in a Distributed Collaboration group. Additionally, the use of group-level feedback to act as a comparative tool and decrease levels of free-riding (Suleiman & Watson, 2008).

Finally, a common point that was discussed throughout the interviews was that participants stressed the importance of integrating a system as seamlessly as possible into their existing work schedule. It was apparent throughout that the introduction of technology itself would not help Distributed Collaboration and would most likely be destructive. Team members and managers alike agreed that a good user experience was essential. As *Employee C* put it, "Normal day to day tasks is enough without introducing another HR system". Participants were sceptical about the micromanagement which often comes with technology. Although their current approach was labelled as subjective, they appreciated the freedom it afforded them. The critical factors for success for system implementation, which emerged involved the people and the processes within the team, not the technology. *Manager C* mentioned that "Communication upfront to inform members why the system is being used to make sure they don't feel targeted". Also, the "Team have to buy in to the system". Any system "Should support the existing trust and relationships between managers and the team". *Employee A* added that "You don't want to lose your independence and have to justify your role".

Analysis of the data gathered revealed that participants supported the proposition that the implementation of a system could improve the performance of Distributed Collaboration. Thus, providing empirical support for Proposition 4 and concluding the implementation of a system to track individual contributions could improve the performance of Distributed Collaboration. Proposition 4 can, therefore, be refined to specify the following four hypotheses:

H9: *The implementation of a system to track individual contributions in Distributed Collaboration could impact overall team performance by combatting the effects of changing team composition.*

H10: *The implementation of a system to track individual contributions in Distributed Collaboration could impact overall team performance by supporting social structures within the group.*

H11: *The implementation of a system to track individual contributions in Distributed Collaboration could impact overall team performance by increasing transparency throughout the team.*

H12: *The impact on overall team performance resulting from the implementation of a system to track contributions is moderated by the effect it has on the people and processes established in the team.*

5.6 Discussion and Conclusions

Growth and increased adoption of digital technologies have increased the breadth of collaboration from traditional, co-located, to large, globally Distributed Collaborations (Asatiani & Penttinen, 2019; Cheng et al., 2016; Liu et al., 2017; Tapscott & Williams, 2008). This growth has increased the potential geographic distance between team members and expanded the range of expertise and talent available for teams to utilise and collaborate on a shared goal (Faraj & Sproull, 2000; Surowiecki, 2004).

While there is a wealth of extant research available which discusses the factors to success (Carte et al., 2006; Jarvenpaa et al., 1998; Jarvenpaa & Leidner, 1999; Kayworth & Leidner, 2002; Ridings et al., 2002; Sarker et al., 2011), as well as the challenges faced by these collaborative groups (Albanese & Van Fleet, 1985; Diehl & Stroebe, 1987; Gallupe et al., 1992), the objective of this study is *to investigate the operational challenges of Distributed Collaboration, and also to gain insights from industry participants on how a technology-enabled solution could overcome these challenges* A review of the relevant existing literature was conducted to understand the evolution from co-located to Distributed Collaboration and the challenges involved. This subsequently informed a set of propositions to structure the research.

5.6.1 Implications for practice

Regarding implications for practice, by conducting semi-structured interviews with industry participants, this research was able to capture rich, nuanced findings which would not have been possible with a structured interview approach, or even quantitative data gathering techniques. This provides valuable, practical insights as much of the extant research on the challenges of free-riding, production blocking, and evaluation apprehension base their findings on experiments which involved relatively short periods of idea generation or collaboration between participants (Diehl & Stroebe, 1987; Gallupe et al., 1992; Suleiman & Watson, 2008). Participants interviewed for this study recalled their day-to-day experiences of the reality of operating in Distributed Collaboration.

First, the fact that many projects which they work on involve large amounts of "grunt work" in which no tangible results are produced. However, this is a necessary step in order to pave the way for the completion of the overall project. This observation stresses the importance of team and project function, which we have discussed as moderating factors in our hypothesis. Extant literature which used workshops and simulations to produce results-focused on idea generation exercises (Diehl & Stroebe, 1987; Gallupe et al., 1992; Suleiman & Watson, 2008). However, the reality of Distributed Collaboration is much different and not all roles have the same tangible outputs. Therefore, different roles require specialised evaluation techniques to account for these intangible contributions.

Second, interviewees discussed the fact that when operating in Distributed Collaboration, the group project will not be their only concern and often their time will be consumed by "local priorities". These ad-hoc tasks require their attention and halt their progress. This is yet another reality that must be accepted and resolved in Distributed Collaboration. Local priorities are another element which would not have been captured in much of the prior research. Distributed members may be allocated to many different projects at one time. Without the benefit of face-to-face interactions and social presence that would be available in a co-located environment, these local priorities which must be attended to are often forgotten about by distributed colleagues. Practitioners should be more cognizant of this reality when operating with distributed colleagues.

Third, managers and team members alike drew attention to the fact that not all teams should be treated equally. Teams should be managed in accordance with their function and objective. For instance, certain groups should be evaluated using a holistic approach. Whereas other groups, primarily contracted groups of distributed workers, require a more detailed, data-driven model in order to ensure targets and objectives are reached. This was a valuable insight that again, like the importance of “grunt work” and “local priorities”, highlights the reality of Distributed Collaboration in operation rather than a simulation. Practitioners should have a clear evaluation strategy in place when assessing distributed members, which should consider the team function and adopt an appropriate method of evaluation to suit.

Finally, this research has also detailed the features which should be included in a solution to manage Distributed Collaboration. Similar to Briggs and Reinig (2010) we believe an optimal solution to overcome all three challenges would be a tool which could reveal the number of contributions made by individuals without revealing their identities. The system could allow users to rate ideas and then reveal who contributed the highest-ranked ideas. Such a solution would allow simultaneous contributions to overcome production blocking, incorporate an element of anonymity to overcome evaluation apprehension, as well as identifiability to dissuade free-riding.

5.6.2 Implications for theory

This research raises several potential questions that would be of interest to future research efforts. First, as touched on in the introduction to this study, Distributed Collaboration can take many forms, this study has examined the experience of participants operating in firm-hosted Distributed Collaboration. The next obvious challenge would be to research the experiences of those operating in non-firm hosted collaborations. Considering the potential background of individuals in these groups is likely to be more diverse, and the likelihood of members having prior relationships with one another is slim, the results may provide further insights regarding the operations of Distributed Collaboration.

Second, considering part of the objective of this study was *gaining insights from industry participants on how a technology-enabled solution could overcome these challenges*, another avenue for future research would be to explore potential technologies that would be appropriate to build such a solution. Findings have shown the importance of team members having autonomy over their jobs, which requires trust between management and team members. Increased anonymity was suggested as a possible approach to increasing shy members willingness to contribute. Participants in management roles noted that they would like to see improved real-time reporting on the performance of their teams. Team members suggested that increased transparency would allow them to observe how individuals across DE Computers are being recognised and rewarded. Perhaps future research could examine Blockchain technology as a potential solution for managing distributed groups. Blockchain has been cited as improving levels of trust (Beck et al., 2016; Cholewa & Shanmugam, 2017), facilitating pseudonymous contributions (Beck et al., 2018), creating a single source of record across a distributed network, and increasing transparency (Hyvärinen et al., 2017).

5.6.3 Limitations of the study

The limitations of this study must also be recognised, primarily the scope of the data gathered. As outlined in the methodology of this study, we conducted a series of exploratory interviews with participants within the same multinational organisation, each of whom operated in a team with members distributed across different departments and across the globe. The reason for this approach was that it facilitated better ease and speed of data collection. However, it must be conceded that this is a limitation of the research. It is encouraged that future research should broaden the scope of the data gathering process to include participants from virtual teams and online communities with increased diversity of background.

As we have discussed, Distributed Collaboration is a multidisciplinary, diverse concept which has been applied in almost every industry. Therefore, it should be noted that the results presented in this study may not be directly transferable across all industries. DE computers in primarily an IT company and the findings may be reflective of this. Future research should assess the relevance of these findings across Distributed Collaboration as it is applied in different domains.

Chapter 6. Designing a Blockchain system for Creative Ancestry in Distributed Collaboration

6.1 Abstract

Distributed Collaborations allow teams to pool knowledge from multiple domains, often across dispersed geographic locations to find innovative solutions for complex, multi-faceted problems. However, motivating individuals within these dynamic groups can prove difficult, as individual contributions are easily missed or forgotten. This study introduces the design construct of Creative Ancestry, which describes how collaborative outputs can be traced back to the individual contributions that preceded them. This construct is operationally enabled by emerging Blockchain technologies, which we argue are naturally suited to maintain an immutable and irrevocable view of individual contributions in Distributed Collaborations. We build a proof-of-concept decentralised application on the Ethereum Blockchain to demonstrate how Creative Ancestry can benefit Distributed Collaborations. An experiment-based evaluation suggests the addition of Creative Ancestry has a positive impact on perceptions of social justice, which in turn has a positive effect on the perceived quality of the collaboration.

Keywords: Distributed Collaboration; Social Justice; Blockchain; Creative Ancestry

6.2 Introduction

The growth of digital technologies has created an increasing appetite for Distributed Collaborations, i.e. the pursuit of a shared objective by groups that include non-proximate members, whose participation is facilitated by ICT (Asatiani & Penttinen, 2019; Cheng et al., 2016; Liu et al., 2017; Tapscott & Williams, 2008). These collaborations have typically taken place on the web, where large projects can attract vast numbers of participants from different areas and with different interests (Kotlarsky & Oshri, 2005; Ransbotham & Kane, 2011). Common examples include mass-produced publicly-editable archives of information such as Wikipedia, global social questions and answers sites such as Yahoo! Answers, and large open source software projects such as Apache Hadoop. Similar developments have been taking place within large organisations, as intra-organisational platforms have emerged to facilitate globally dispersed teams and work-from-home employees (O'Leary & Cummings, 2007). Thus, many organisations rely on distributed teams interacting through voice, video, and text; meaning they may not work in a fixed space or even at the same time (Robert Jr et al., 2008). This allows individuals with a range of backgrounds, expertise, and geographical locations to bring new perspectives to bear on various complex problems (Faraj & Sproull, 2000; Surowiecki, 2004).

Distributed Collaboration has changed the landscape for many industries, from entertainment, to software development, and even gold mining (Tapscott & Williams, 2008). Traditionally structured companies face competition from dynamic online communities which can harness the collective wisdom and talents of a global audience quickly and cheaply due to their ability to leverage flat, decentralised structures (Gupta et al., 2009). Yet concerns persist whether these Distributed Collaborations do enough to recognise individual contributions (Wang & Fesenmaier, 2003). This is important, as many individuals require some form of formal or informal acknowledgement (Wasko & Faraj, 2005).

Traditional management structures impose strict controls and measures to determine the performance of individuals and sub-teams. This strategy is more challenging with Distributed Collaborations, due to sheer number of contributions, and the changing roles required. For example, large numbers of non-specialised individuals tend to be effective at rooting out bad contributions; however, they may struggle when it comes to separating the good from the great (Klein & Garcia, 2015). This places a premium on expert evaluations at some parts of the process but not others. Similar challenges occur when one individual proposes an idea and another adapts it, or when some individuals' contribution is an enabler of others (Forte, Larco, & Bruckman, 2009; Scarbrough, Panourgias, & Nandhakumar, 2015). Hence, perceived fairness, or social justice has been found to be a key element in ensuring the success of collaborative groups (Son & Kim, 2008; Wasko & Faraj, 2000; Wu & Chiu, 2018). Yet it is not clear how such fairness can be accommodated. Transparency is often touted as the most important enabling quality (Sharma, Sugumaran, & Rajagopalan, 2002). Yet the value of transparency decreases where there are large numbers of unstructured interactions, as this limits both the reliability of their capture and our capacity to inspect them (Oldroyd & Morris, 2012; Woods, Patterson, & Roth, 2002).

This study presents an alternative approach to perceived fairness in Distributed Collaboration, specifically the design construct of *Creative Ancestry*, i.e. the ability of a collaborative system to take some particular output of note and navigate backwards through the individual contributions that preceded it in a consistently structured, inspectable, and immutable manner. This construct avoids the information overload associated with transparency, while minimizing the complexity of assembling and integrating data to analyse individual contributions.

The emergence of Blockchain has obvious relevance for Creative Ancestry. Blockchain has received much attention over the last number of years, largely due to its links with the cryptocurrency market. However, Blockchain is more than an enabler of financial exchange; it is a way of recording interactions in a structured, secure, and scrutinizable manner, offering increased fault tolerance and availability (Pahl, El Ioini, & Helmer, 2018; Peters & Panayi, 2016; Swan, 2015; Tapscott & Tapscott, 2016). Thus, Blockchain technologies have already been extended to create supply chain management tools to capture the origins of component products, for example, *Provenance* in product assembly (Provenance, 2015) and *Everledger* in the diamonds industry (Everledger, 2017). Although they may only be in their infancy, these developments have inspired several companies including Microsoft, IBM and Maersk to conduct their own research and develop proof-of-concept Blockchain solutions to fit their respective needs (Beck & Müller-Bloch, 2017; Hyvärinen et al., 2017). We argue the same security, scalability, and scrutiny which Blockchain has brought to these industries can also benefit Distributed Collaboration. Thus, the objective of this study is to *design a system for Distributed Collaborations that improves collaboration quality and perceived fairness by implementing Creative Ancestry using Blockchain technologies.*

We adopt a design science perspective to achieve this objective (Gregor & Hevner, 2013; Hevner et al., 2004; March & Smith, 1995) and follow the design science research model proposed by Peffers et al. (2007). The next section discusses the problem identification and motivation, in this case the need for perceived fairness and individual acknowledgment in Distributed Collaboration. Following this, we lay out the objectives of a solution based on existing literature on social justice (Konovsky, 2000; Martínez-Tur, Peiró, Ramos, & Moliner, 2006; Son & Kim, 2008; Wu & Chiu, 2018). Then we present the design and development, in which an embedded design-relevant causal model (Kuechler & Vaishnavi, 2012) is proposed to explain how increased Creative Ancestry for individual contributions could increase perceived fairness and, consequently, the perceived quality of the collaboration. Next is the demonstration; a proof-of-concept Blockchain system that instantiates the embedded model linking Creative Ancestry to perceived collaboration quality. The evaluation follows, based on an experiment that simulates a Distributed Collaboration. Findings support the role of Creative Ancestry as an enabler of perceived collaboration quality. Structural equation modelling also shows the complex relationship between Creative Ancestry, different elements of perceived fairness, and moderating factors of cognitive group consensus and perceived group creativity. Finally, the implications of these findings are discussed for industry and research.

6.3 Problem Identification and Motivation: Perceptions of Fairness in Distributed Collaboration

Distributed Collaboration has been referred to under a number of different synonyms in extant literature including, mass collaboration, online communities, and virtual work, based off these terms, we define Distributed Collaboration as *the pursuit of a shared objective by groups that include non-proximate members, whose participation is facilitated by ICT* (Asatiani & Penttinen, 2019; Cheng et al., 2016; Liu et al., 2017; Tapscott & Williams, 2008). Such collaborations have become increasingly common inside and outside of organisations, as projects rely on large numbers of diverse participants to achieve the depth, breadth, and scale of expertise required (Kane & Ransbotham, 2016). This has created a new ‘flat world’ of participation, where old collaborative hierarchies give way to more open and inclusive collaborations involving large numbers of distributed collaborators - collaborations that organisations must embrace within evolving and boundary-spanning technological ecosystems (Friedman, 2005).

The types of creative tasks performed through Distributed Collaboration may vary. First, participation may require a selective skillset, so limiting the inclusion of contributors. For example, Open Source Software Development draws upon a dynamic community of actors and commons of inputs to synergistically create a complex information good (Crowston & Wade, 2010). Yet extensive participation requires a level of technical experience that not all users possess, placing practical restraints on what some potential contributors can do (Bagozzi & Dholakia, 2006). This contrasts with High-Inclusion platforms such as wikis, where low technical barriers encourage contribution from individuals with a wider range of backgrounds (Pei Lyn Grace, 2009). Second, contributions may be essentially cooperative and iterative, as in wikis and Open Source Software Development, or contributions may be in high-competition, i.e. one or more contributions is selected from a larger set of less-desirable alternatives. An example of Low-Inclusion / High-Competition collaboration is Threadless; a platform where graphic designers put forward ideas for imagery on clothing and other users vote on which are put into production. An example of High-Inclusion / High-Competition collaboration is Walker’s crowdsourcing initiative/platform ‘Do Us a Flavour’ competition, where members of the public suggested new flavours for crisps, then voted for the eventual winner (Forbes & Schaefer, 2017).

Distributed Collaboration is fuelled by four qualities, specifically openness, peering, sharing, and acting globally (Tapscott & Williams, 2008). The first three qualities can be operationalised in local 'small worlds' (Xiaobao, Wei, & Yuzhen, 2013), yet the final quality, acting globally, is challenging to integrate into design. Individuals interacting outside their familiar social groups are likely to struggle with uncertain norms and roles (Dionysiou & Tsoukas, 2013) . Further, psychological ownership of global ventures typically relies on some perceived individual connection to leaders (Scott & Lane, 2000). Perhaps most importantly, the push to create 'global actors' may create tensions with the need for individual acknowledgement when ideas are successful, as Distributed Collaboration pools large amounts of disparate competencies in a way that is often difficult to disentangle (Tapscott & Williams, 2008; Yan et al., 2018).

This tension is meaningful, as individual acknowledgement is key for repeated participation. For contributors, a lack of intellectual, social, or material reward means there is little motivation to continuously engage (Wasko & Faraj, 2005). This is especially problematic when competition between contributions is high and/or inclusivity is high among contributors. This leads to phenomena such as free-riding; a common occurrence in online collaborations where participants exert less effort on a collaborative task than they would on a comparable individual task (Ling et al., 2005). Perhaps more importantly, the ability to identify others making valuable contributions is an important antecedent to relationship-building (Altschuller & Benbunan-Fich, 2013). Hence, Distributed Collaboration systems require a balance of group-level feedback and individual accountability, suggesting the origins and evolution of group outputs must be part of the evaluation process (Suleiman & Watson, 2008; Wang & Fesenmaier, 2003).

6.4 Objectives of a Solutions: Key Predictors of Perceived Social Justice

Social justice (also referred to as perceived fairness) is perceived along multiple dimensions, notably between employees (Masterson, Lewis, Goldman, & Taylor, 2000), between managers and employees (McFarlin & Sweeney, 1992), and between the organisation as an entity and its employees (Greenberg, 1988). Previous research has noted the importance of perceived social justice in Distributed Collaboration, where contrasting perceptions of surveillance and depersonalisation may create suspicions the paradigm will be abused (Alge, 2001; Wu & Chiu, 2018; Zweig & Webster, 2002). The following subsections discuss the three major components of social justice, specifically *distributive justice*, *procedural justice*, and *interactional justice*.

6.4.1 Distributive Justice

Distributive justice primarily relates to the perceived fairness of outcomes that one party receives from another party based on their inputs into an exchange relationship (Son & Kim, 2008). Son and Kim (2008) go on to describe that this can be applied to a customer-retailer relationship, where a customer inputs money and/or time into the relationship in expectation of goods or services. Similarly, in an online setting, users must make the decision of whether or not to expose their personal data to the service they are using in exchange for the benefits of using the service (Son & Kim, 2008).

The idea of *distributive justice* has been around for many decades (Folger & Konovsky, 1989; McFarlin & Sweeney, 1992). It may even be argued the idea of *distributive justice* was central to the rise of Blockchain technologies, which grew at the same time as the 2007/2008 financial crisis. That crisis that gave rise to numerous accusations of outcome-related favouritism in the prevailing financial systems, particularly towards wealthy individuals and organisations (Earle, 2009; Uslaner, 2010). This was exemplified by social movements such as Occupy Wall Street (Calhoun, 2013) and national protests in Greece, Ireland, and other countries (Karanikolos et al., 2013; Theodossopoulos et al., 2013). It was against this backdrop that Bitcoin was proposed as a distributed, equitable, and fair alternative to traditional systems of financial exchange; one in which no central body could skew outcomes in their favour (Nakamoto, 2008).

6.4.2 Procedural Justice

Procedural justice refers to the perceived fairness of the process associated with the allocation of limited resources for members, relative to demand (Wu & Chiu, 2018). *Procedural justice* can be further subcategorised into subjective and objective *procedural justice*, where objective *procedural justice* refers to actual or factual justice, and subjective *procedural justice* refers to perceptions of objective procedures and their capacity to enhance fairness judgements (Konovsky, 2000).

Procedural justice is typically associated with the overarching governance bodies, as individuals must determine whether they believe the rules and laws governing behaviour, and the enforcement of those rules and laws, are fair (Alge, 2001; Cropanzano, Prehar, & Chen, 2002). For this reason, the idea of *procedural justice* has also been a dominant concept during the rise of Blockchain technologies. Unlike many traditional systems, Blockchain minimises the role of the 'enforcer' by integrating these procedures directly into the technology. This is key, as the disintermediation of central bodies relies on each person's faith in the procedural integrity of interactions with peers (Beck et al., 2016; Tapscott & Tapscott, 2016). Blockchain interactions take place in an open setting where fraudulent or impermissible interactions are rejected by the network, while accepted interactions become part of distributed ledger once the network reaches consensus

(Nakamoto, 2008; Peters & Panayi, 2016). This means users can't dispute or delay legitimate interactions when it benefits them to do so (Swan, 2015).

6.4.3 Interactional Justice

Interactional justice describes the manner in which an individual perceives their interpersonal treatment from decision makers during an exchange relationship (Cropanzano et al., 2002). This differs from *procedural justice*, as *interactional justice* focuses on the social instance-specific component of an exchange, rather than the generalised formal standards and rules for interactions (Wu & Chiu, 2018). Thus, perceptions of *interactional justice* are closely linked to interpersonal trust between parties involved in an exchange (Lu, 2006).

This link between trust and *interactional justice* is particularly relevant for Distributed Collaboration (Altschuller & Benbunan-Fich, 2013; Kanawattanachai & Yoo, 2002). Collaboration asks individuals to commit time and effort to shared goals in the hope others will do the same (Piccoli & Ives, 2003; Wasko & Faraj, 2005). Local teams manage this need for bilateral effort with normative systems of formal and informal controls, which sanction those who stray from common expectations (Kirsch, 1997). However, this becomes more challenging for Distributed Collaborations as (i) remote collaborators operate under limited moment-to-moment visibility (Boss, Kirsch, Angermeier, Shingler, & Boss, 2009; Kirsch, Sambamurthy, Ko, & Purvis, 2002) (ii) diverse collaborators may have only partial understanding of other domains, meaning task complexity or effort can be overstated (Kirsch et al., 2002; Saam, 2007) (iii) collaborators can leave specific projects, rather than accept social conditions they find unpleasant (Brawley & Pury, 2016).

6.5 Design & Development: Creative Ancestry as a Design Construct

This study employed a Design Science Research (DSR) methodology, the principles of which are described in detail in Chapter 3. This study focuses on three types of design contribution. First, is the design construct of *Creative Ancestry*, defined and discussed here with particular regard to Blockchain as an enabling technology. Second, is the embedded design-relevant explanatory/predictive theory (Kuechler & Vaishnavi, 2012), which draws on social justice theory to explain how *Creative Ancestry* impacts on Distributed Collaboration via perceived fairness. Third, is the design instantiation. This instantiation demonstrates how a Blockchain-enabled system can introduce *Creative Ancestry* to increase perceived fairness and improve the perceived quality of Distributed Collaborations. This instantiation is presented as a second iteration of this system. Building on the first iteration which was presented in Chapter 3, the system has been refined and redeveloped based on the findings presented in Chapters 4 and 5.

6.5.1 Creative Ancestry as a Design Construct

Distributed Collaborations allow large numbers of individuals to contribute to a project, either by producing/suggesting content directly or by filtering mass-produced content into more manageable siloes of quality contributions (Klein & Garcia, 2015; Ransbotham & Kane, 2011). However, most collaborations are sustainable only if the relative contribution of each individual can be identified and acknowledged (Ling et al., 2005). This identification and acknowledgement of individual contributions presents three problems for Distributed Collaboration.

First, the relationship is not always positive between a collaborator's frequency of collaboration and their creative/constructive impact. Many collaborations have been hijacked by a subset of contributors, who use their frequent interactions to impose selfishly-desirable goals and hierarchies (Kittur & Kraut, 2008). This can mean many individuals who appear disengaged or 'free-riding' were actually struggling to have their voice heard before becoming disillusioned and giving up (Bandura et al., 1996; Latané et al., 1979). Research on crowdsourcing further suggests this sense of limited interaction also decreases collaborators' psychological ownership of the outputs (Gleasure & Feller, 2016; Zheng, Xu, Zhang, & Wang, 2018b).

Second, an inability to determine the origins of an idea means it is difficult to acknowledge/reward those who contributed most. This creates resentment among the more committed collaborators and reinforces lazy or selfish behaviours among the least committed (George, 1992; Suleiman & Watson, 2008). Such resentment alienates core community members over time, stagnating progress and diluting interest among specialists (Chidambaram & Tung, 2005; Kidwell & Bennett, 1993).

Third, the inability to trace the evolution of ideas creates problems for managing intellectual property (IP) rights. This is especially challenging for Distributed Collaborations, the purpose of which is ultimately to produce emergent knowledge that transcends the understanding of any one person or group involved (Kittur & Kraut, 2008; Surowiecki, 2004). This is a significant issue, given IP ownership is a key asset for many individuals and firms and the threat of uncertain ownership and/or theft can create serious issues (UK Government Office for Science, 2016).

The intuitive answer to address these issues is to accommodate inspect ability and ensure all interactions are open to scrutiny (Sharma et al., 2002). However, such a solution is not practical. Large Distributed Collaborations may have hundreds of thousands of interactions, meaning even if they could all be reliably captured, the scale prohibits extensive inspection (Oldroyd & Morris, 2012; Woods et al., 2002). Perhaps most importantly, it also does not align with the output-specific backwards-traversing needs of the practical problem. Not all collaborations need to be inspected; only those that eventually produced some outcome of note. Hence, we propose the design construct of 'Creative Ancestry', i.e. *the ability of a collaborative system to take some particular output of note and navigate backwards through the individual contributions that preceded it in a consistently structured, inspectable, and immutable manner*.

The presence of consistent structure is important, as the ability to inspect interactions shrinks if the presentation and format of those interactions requires continuous interpretation. This has been demonstrated in studies of mental load, which show repeating presentational structure and hierarchy lowers attentional and working-memory demands (DeStefano & LeFevre, 2007). Thus, consistent structure allows inspecting agents to separate details of interest from other data or meta-data.

The presence of interaction-level inspectability is important, as this allows each interaction to be evaluated independently by collaborators. This is important, as systems must typically not only take efforts to be fair; they must also take efforts to demonstrate their intentions to be fair (Fulmer & Gelfand, 2012). This is often referred to in studies of platform or institutional trustworthiness as 'integrity' (Robert et al., 2009), meaning collaborators not only believe evaluators are capable and benevolent, they also understand how those evaluators are making judgements.

The presence of immutability is important, as this prevents malicious or dishonest parties from attempting to interfere with records of interactions. Without such immutability, the reliability of these records would rely on the competence and integrity of some controlling body or group. This can be problematic if trust in that controlling body or group is undermined, at which point the value of legitimate inspectability is compromised by suspicions of selective record-keeping (Allcott & Gentzkow, 2017).

Thus, *Creative Ancestry* avoids the information overload of full transparency, while minimizing complexity of assembling and integrating data when analysing individual contributions.

6.5.2 Embedded Design-Relevant Explanatory/Predictive Theory

Embedded in many designs (albeit often implicitly) is a mid-range causal theory that shows the mechanism by which design interventions interact with moderating variables to produce desired outcomes (Kuechler & Vaishnavi, 2012). This model grounds design assumptions in existing literature and provides additional diagnostic clarity when evaluating outcomes (Gleasure, Feller, & O'Flaherty, 2012; Goldkuhl, 2004). The embedded causal model linking *Creative Ancestry* to perceived social justice and the quality of a Distributed Collaboration is presented in Figure 6.1. This model builds upon models proposed and validated by Folger and Konovsky (1989), Colquitt (2001), Tyler and Blader (2003), and Wu and Chiu (2018).

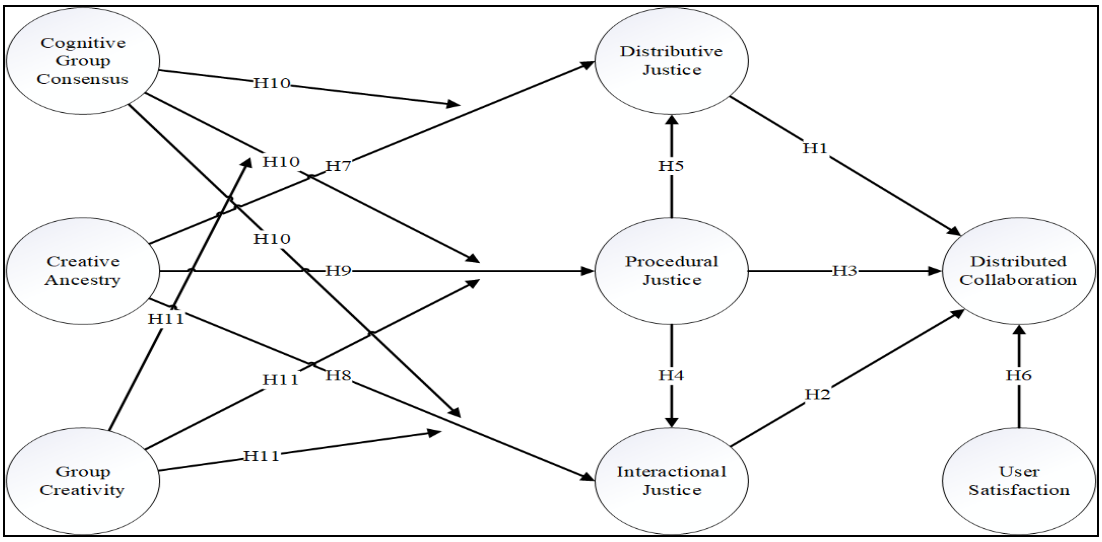


Figure 6.1 Core Research Model

The impact of perceived *distributive justice* on collaboration is well-established in contexts where individuals, groups, and organisations must work together towards common goals (Griffith, Harvey, & Lusch, 2006; Wu & Chiu, 2018). In some cases, such collaborations occur within organisations, e.g. as regards perceptions of power disparity with managers in large organisations (Cropanzano, Bowen, & Gilliland, 2007). These perceptions of perceived *distributive justice* may take on many forms, notably regarding benefits and pay (Tremblay, Sire, & Balkin, 2000). In many other cases, perceptions of *distributive justice* have a strong impact when individuals in one organisation collaborate with individuals in another. For example, it was found that perceived *distributive justice* played an important role in the formation of satisfactory supply chains, as partners were reluctant to engage with other entities with whom power relations were asymmetrical (Wu & Chiu, 2018). We predict a similar positive impact for Distributed Collaborations:

Hypothesis 1. Perceived distributive justice positively impacts on Distributed Collaboration.

The impact of perceived *interactional justice* on collaborations is also well-established. Perceptions of interaction justice are incrementally embedded in a social exchange climate and it is this accumulation of instance-level social exchanges that differentiates *interactional justice* from *procedural justice* (Cropanzano et al., 2002). *Interactional justice* considers the quality of interpersonal treatment perceived by exchange partners, higher levels of which lead to greater mutual collaborative effort (Luo, 2007). However, *interactional justice* is not only perceived at an individual-level. As with, *distributive justice*, *interactional justice* has been found to positively impact supply-chain collaborations, in which well-defined input-output structures can reassure collaborators the relationship is beneficial and reciprocal in the long term (Griffith et al., 2006). Thus, we also predict a positive impact for perceived *interactional justice* on Distributed Collaboration:

Hypothesis 2. Perceived interactional justice positively impacts on Distributed Collaboration.

The impact of perceived *procedural justice* is potentially more complicated than *distributive justice* and *interactional justice*. *Procedural justice* relates to the formal policies and procedures which manage a relationship (Masterson et al., 2000). This ultimately represents the core agreed-upon collaborative structure for the group; a structure that should transcend identity and encourage bilateral commitment (Tyler & Blader, 2003). However, while *distributive* and *interactional justice* operate, at least partly, independently, the perception of *procedural justice* is entangled with other forms of justice. One collaborator may interact badly with another without there necessarily being any distributive injustice. Similarly, distributive injustice does not necessarily imply interactional injustice. Yet, either interactional or distributive injustice is required for there to be procedural injustice. For example, the presence of distributive injustice around water shortages create a heightened importance for *procedural justice* between the affected individuals and the authorities (Tyler & Degoey, 1995). Similarly, when some employees are reluctant to share important workplace concerns (e.g. grievances) and interactional injustice is perceived, it is *procedural justice* that moderates their willingness to come forward (Tangirala & Ramanujam, 2008). Put differently, the perceived fairness of the laws is most important when the system is under threat. It is not clear the extent to which *procedural justice* has an impact on Distributed Collaboration outside of these moderated relationships. Thus, we predict both a direct impact of *procedural justice* and a moderated effect via *distributive justice* and *interactional justice*:

Hypothesis 3. Perceived procedural justice positively impacts on Distributed Collaboration.

Hypothesis 4. Procedural justice positively impacts on perceived interactional justice.

Hypothesis 5. Procedural justice positively impacts on perceived distributive justice.

In addition to perceived justice around the distribution of resources, the nature of individual interactions, and the guiding procedures, the individuals must also be satisfied with the system used for collaborations (Wu & Chiu, 2018). This is because attitudes towards a platform may change how an individual perceives an interaction, particularly if users have doubts about the ability of the system to behave as expected (Pavlou & Gefen, 2004). Thus, we expect users' satisfaction with the collaborative system to positively impact on perceptions of Distributed Collaboration.

Hypothesis 6. Satisfaction positively impacts on Distributed Collaboration.

We predict that *Creative Ancestry* will have a positive impact on each dimension of perceived social justice. For *distributive justice*, where high-resource individuals (intellectual, social, or material) share freely and make best use of their assets, *Creative Ancestry* should bring attention to the higher proportional contribution of those individuals. Similarly, *Creative Ancestry* should provide greater visibility where those high-resource individuals choose to behave selfishly. This ability to identify selfish individuals is important so other collaborators can hold them accountable and factor their behaviours into future collaborations (Bertot, Jaeger, & Grimes, 2010).

Hypothesis 7. Creative ancestry positively impacts on perceived distributive justice.

For *interactional justice*, the addition of *Creative Ancestry* reduces the opportunity for duplicitous individuals to present themselves differently to some groups than others. This is important, as one of the main enablers of oppression and bullying is the ability to isolate individuals, spread reputation-harming rumours, and create barriers to information-sharing (Newman, Holden, & Delville, 2005). This allows third party perceptions to be manipulated in a way that hides abusive behaviours, so reducing the likelihood of formal or informal sanctioning (Rayner & Hoel, 1997; Van der Wal, De Wit, & Hirasing, 2003). Thus, *Creative Ancestry* limits the potential for oppressive or otherwise unfair interactions by creating a traversable and exhaustive record of interactions that is openly visible to all.

Hypothesis 8. Creative ancestry positively impacts on perceived interactional justice.

For *procedural justice*, the addition of *Creative Ancestry* affords scrutiny over the application of rules and processes, any attempts to circumvent them, and how they are enforced (Bertot et al., 2010; Mawby, 1999). A common legal dictum states 'Justice should not only be done, but should manifestly and undoubtedly be seen to be done' (attributed to Lord Chief Justice Hewart in the 1924, quoted from (Marmor, 2005). Thus, *Creative Ancestry* is essential for widespread confidence that collaborative interactions cannot be skewed in favour of specific individuals or escape scrutiny.

Hypothesis 9. Creative ancestry positively impacts on perceived procedural justice.

Two additional control variables are included in the form of *cognitive group consensus* (Mohammed, 2001; Mohammed & Ringseis, 2001) and *perceived group creativity* (Nunamaker Jr, Applegate, & Konsynski, 1987; Paulus & Nijstad, 2003). The effect of *Creative Ancestry* on *perceived social justice* assumes some shared output has been produced. However, this is not necessarily the case for all collaborations, particularly Distributed Collaborations. First, large numbers of heterarchical participants means consensus may not occur. This is often the case in large open source software collaborations, which can 'fork' into multiple separate projects (Stewart & Gosain, 2006). It also occurs in sites such as Wikipedia, where contributing groups can become adversarial and territorial (Kittur & Kraut, 2008). Under these conditions, the positive potential of *Creative Ancestry* is less obvious, as increased visibility may bring negative aspects of the collaboration to light, perhaps increasing the sense of injustice. Second, not all collaborations produce creative outcomes likely to inspire collaborators to seek credit. Some collaborations simply peter out over time, often resulting in those responsible becoming dispassionate (Martin & Eisenhardt, 2010). Hence, a lack of meaningful output may also mean the impact of *Creative Ancestry* diminishes, as there is nothing of note to inspect. Thus, the following moderating relationships are also considered.

Hypothesis 10. The impact of Creative Ancestry on the perception of distributive, interactional, and *procedural justice* is positively moderated by cognitive consensus.

Hypothesis 11. The impact of Creative Ancestry on the perception of distributive, interactional, and procedural justice is positively moderated by perceived group creativity.

6.5.3 Blockchain and Creative Ancestry

The digital nature of most Distributed Collaborations means digital discourse can be captured with comparatively little effort as a by-product of other behaviours (Morey, Forbath, & Schoop, 2015). Thus, digital technologies provide an essential prerequisite to *Creative Ancestry* by creating visibility of collaborative interactions that does not necessarily exist in other media. Yet this visibility does not imply *Creative Ancestry*, as they do not ensure inspect ability (data can be lost or hidden), consistent structures (formatting validation may be loose or non-existent), immutability (the integrity and of data is not independently guaranteed), and perhaps most importantly sequential interactions may become uncoupled and unrelatable to specific outputs. Fortunately, the emergence of Blockchain technologies addresses each of these limitations.

Regarding the ability to relate outputs to specific interactions, Blockchain allows interactions to be traversed backwards from some output at a given point in time. While this ability is often associated with uses of Blockchain as a platform for financial currencies (which are arguably themselves a form of Distributed Collaboration) (Hyvärinen et al., 2017; Peters & Panayi, 2016), it has also been applied to numerous other domains with similar demands for traceability. For example, sites such as SteemIt (an online peer-driven news site) pay members for posting and curating content using micropayments based on the site's own cryptocurrency Steem (Thelwall, 2017). Blockchain has also been proposed as a means of tracking food ingredient (Aitken, 2017) and keeping track of medical records (Azaria, Ekblaw, Vieira, & Lippman, 2016). There have also been calls for Blockchain-enabled systems to track embedded IP by the UK Government's Chief Scientific Advisor in 2016, who argued "Enabling companies to register their Intellectual Property (IP) within a distributed ledger, rather than through traditional patent applications, may reduce the overall number of contract disputes" (UK Government Office for Science, 2016).

Regarding the need for immutability, Blockchain records and validates individual interactions continuously into a distributed ledger (Swan, 2015). This makes it increasingly unfeasible to fabricate or remove interactions as a Blockchain network grows (Nakamoto, 2008). This ability to withstand attempts to distort records of longitudinal was a driving motivation for the application of Blockchain to cryptocurrencies, as this capacity was seen as pivotal to the immutability of the system (Risius & Spohrer, 2017; UK Government Office for Science, 2016). It has also motivated Blockchain platforms in other high-stakes industries. Take for example, *Everledger* a company that has introduced Blockchain-based systems to encourage responsible sourcing in the diamond industry.

Specifically, *Everledger* have used Blockchain to develop a digital ledger that tracks diamonds (and potentially other valuable assets) during their lifecycle; a ledger that is then used by various stakeholders across the assets supply chain to form provenance and verify authenticity (Everledger, 2017). Similarly, *Provenance* have created a 'digital passport' for any physical asset to create an auditable record of the lifecycle of those assets. Each operation is recorded and archived across the network so auditing becomes as simple as joining that network and replaying the operation of the past (Provenance, 2015).

Regarding the need for interaction-level inspect ability, Blockchain affords this is two key ways. First, they can provide records in the form of a comprehensive and borderless open registry (Locher, Obermeier, & Pignolet, 2018). This, combined with the immutability of the system, means exhaustive inspect ability is built into Blockchain platforms. Second, Blockchain systems ensure a persistent connection to pseudonymous nodes; hence they provide a single source of the truth (Beck et al., 2018). Once again, this is a key reason why Blockchain is touted as a strong technical fit with the data management needs of intellectual property (Tapscott & Tapscott, 2016), digital art (Swan, 2015), notary services (Hyvärinen et al., 2017; Locher et al., 2018), or proof of origin for important documents (Fridgen, Guggenmoos, Lockl, Rieger, & Schweizer, 2018).

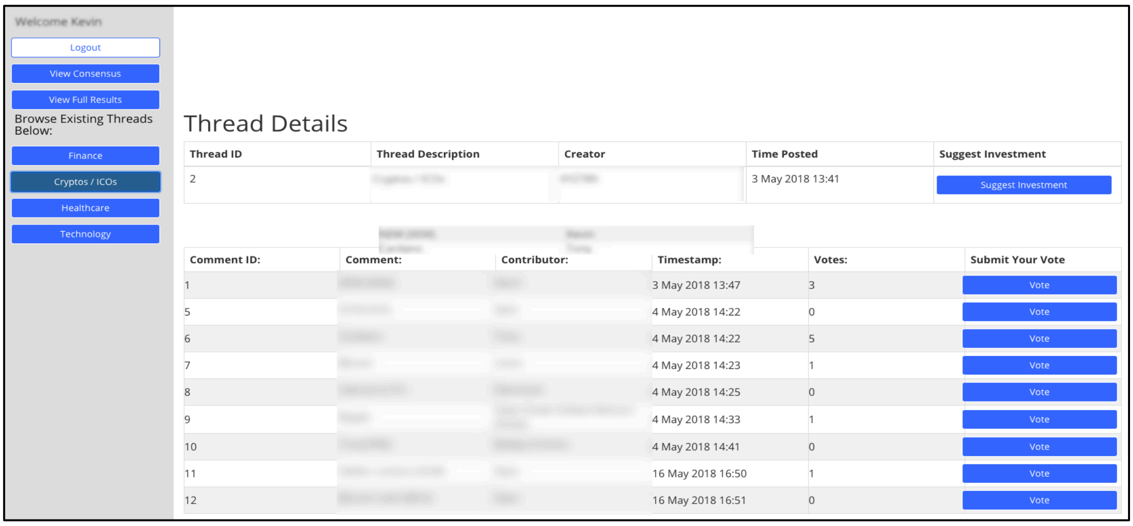
Finally, regarding the need for consistent structure, Blockchain systems build a consistent structure into the recorded interactions at the point of design. Records of these interactions are created from both the content of the new interaction and algorithmic derivatives of the preceding records (Nakamoto, 2008). Hence the ability for structural drift is limited. Equally importantly, where some programming code is uploaded to assist with the storage or exchange of information, that code itself becomes an immutable part of the Blockchain, often taking the form of a ‘smart contract’ coordinating between multiple parties (Wüst & Gervais, 2017).

This is not to suggest *Creative Ancestry* could not be accommodated with a centralised database. Platforms such as GitHub, Wikipedia, and Innocentive might each argue they fulfil the individual requirements of *Creative Ancestry* using traditional (non-Blockchain) data storage. Nonetheless, Blockchain appears particularly well-suited, given its pronounced capacity for resisting faults and/or malicious interference (Beck et al., 2016; Pahl et al., 2018), for linking interactions with individuals (Hawlitschek, Notheisen, & Teubner, 2018; Locher et al., 2018), and for providing inspect ability and independent oversight (Beck, Becker, Lindman, & Rossi, 2017b; Nair & Sutter, 2018).

6.6 Demonstration: A Blockchain-based Distributed Collaboration system

The demonstration sought to create a Distributed Collaboration system where both inclusion and competition are high, as these conditions place most strain on *Creative Ancestry*. Thus, the Distributed Collaboration Blockchain system was demonstrated as an ideation platform, in which individuals could put forward ideas and ‘up-vote’ specific ideas put forward by others.

Individual threads were created around different topics of ideation and users were free to make recommendations/vote in any thread they wished. Once a recommendation received five ‘up-votes’, that idea was selected for shortlisting and the corresponding thread was closed. This concept has been suggested in previous research as an effect way of engaging collaborators to improve data quality by evaluating, and filtering the large volume of contributions in Distributed Collaboration (Blohm, Leimeister, & Krcmar, 2013; Klein & Garcia, 2015). A screenshot is presented in Figure 6.2.



Thread Details

Thread ID	Thread Description	Creator	Time Posted	Suggest Investment
2	[redacted]	[redacted]	3 May 2018 13:41	Suggest Investment

Comment ID:	Comment:	Contributor:	Timestamp:	Votes:	Submit Your Vote
1	[redacted]	[redacted]	3 May 2018 13:47	3	Vote
5	[redacted]	[redacted]	4 May 2018 14:22	0	Vote
6	[redacted]	[redacted]	4 May 2018 14:22	5	Vote
7	[redacted]	[redacted]	4 May 2018 14:23	1	Vote
8	[redacted]	[redacted]	4 May 2018 14:25	0	Vote
9	[redacted]	[redacted]	4 May 2018 14:33	1	Vote
10	[redacted]	[redacted]	4 May 2018 14:41	0	Vote
11	[redacted]	[redacted]	16 May 2018 16:50	1	Vote
12	[redacted]	[redacted]	16 May 2018 16:51	0	Vote

Figure 6.2 Screenshot of recommendation page (details blurred for anonymity purposes)

6.6.1 Design process

Design took place over multiple agile iterations intended to allow flexibility and exploration in the early stages, while progressively hardening the design into a rigorously testable artefact (Conboy et al., 2015). Earlier prototypes were built using Truffle, a development environment, testing framework and asset pipeline for Ethereum. Truffle handles a large amount of the technical complexity for simple Ethereum solutions (Truffle, 2017). Also, latency issues associated with Blockchain systems (Casino et al., 2018; Lindman et al., 2017) were avoided by using TestRPC, a Node.js based Ethereum client for testing and development. TestRPC is a complete Blockchain-in-memory that runs on your local machine. Transactions are processed instantly rather than having to wait for the default block time, which allows a developer to test code faster and be notified of errors immediately (TestRPC, 2017). This allowed a preliminary system to be produced quickly for the purposes of prototyping.

Early Truffle/ TestRPC-based prototypes were demonstrated to academic audiences at research symposiums and conferences in universities in North-West Europe and South-

East China, and also in industry workshops with large multinational financial services and software development firms. Feedback refined the scope of the use-case and the corresponding features of the system. Having established the practical demand for the system, a more sophisticated technical solution was developed to facilitate simulation-based testing. This was necessary to move beyond hypothetical scenarios and speculation and observe how system features impacted on actual behaviours and perceptions. Thus, the subsequent iteration was built using more robust and scalable Amazon Web Services (AWS) and Ropsten platforms.

6.6.2 Technical overview

The system was built on the Ethereum network. Ethereum is a public, permissionless network, meaning anyone is free to participate in the network, as opposed to networks such as Hyperledger which are private and permissioned, allowing only approved users to engage (Casino et al., 2018). Ethereum is arguably the largest Blockchain system widely in circulation that is not limited to just financial transactions (Sapuric et al., 2017). Instead, Ethereum supports the development of ‘smart contracts’ (Casino et al., 2018; Lindman et al., 2017); a piece of code that the Ethereum Virtual Machine (EVM) is able to execute on the Blockchain. Once this piece of code has been added to the Blockchain, the smart contract itself cannot be altered, only the storage of the smart contract can. This means a piece of code now exists that is available for anyone to use (Beck et al., 2016; Swan, 2015). Specific to this study, this meant smart contracts could be developed to capture on the Blockchain both the ideas put forward by individuals and the votes to back up specific ideas.

The three main technical components involved in the development were Amazon Web Services Elastic Cloud Compute (EC2) instance, the Web3 API, and Ropsten Ethereum testnet.

The user interface was created using traditional web development languages, HTML, CSS, PHP, and JavaScript. These were then hosted on the EC2 instance provided by AWS. We used the web3 object provided by the web3.js library to run the system on the Ethereum network. This communicates behind the scenes to a local node through RPC (Remote Procedure Call) calls, as web3.js is configured to work with any Ethereum node which exposes an RPC layer (Web3, 2017). In this instance the web3 interface was handled using the Metamask extension for Google Chrome. Metamask allows users to run Ethereum dApps right from their browser without having to run a full Ethereum node (Metamask, 2018). This was essential as, by hosting the front-end application on AWS, users were able to access the system from their own machines. We asked each participant to add the Metamask extension to their Chrome. This allowed them to interact with the Blockchain-enabled application.

The smart contracts were coded using Solidity and mined to the Ropsten Ethereum testnet. The ropsten testnet is a simple version of the Ethereum network that was developed for testing. Hence it uses test *ether* which cost nothing and can be drawn down from a faucet (Dannen, 2017). Participants in each of our demo sessions started by funding their Metamask accounts by requesting ether from a faucet (https://faucet.metamask.io/).

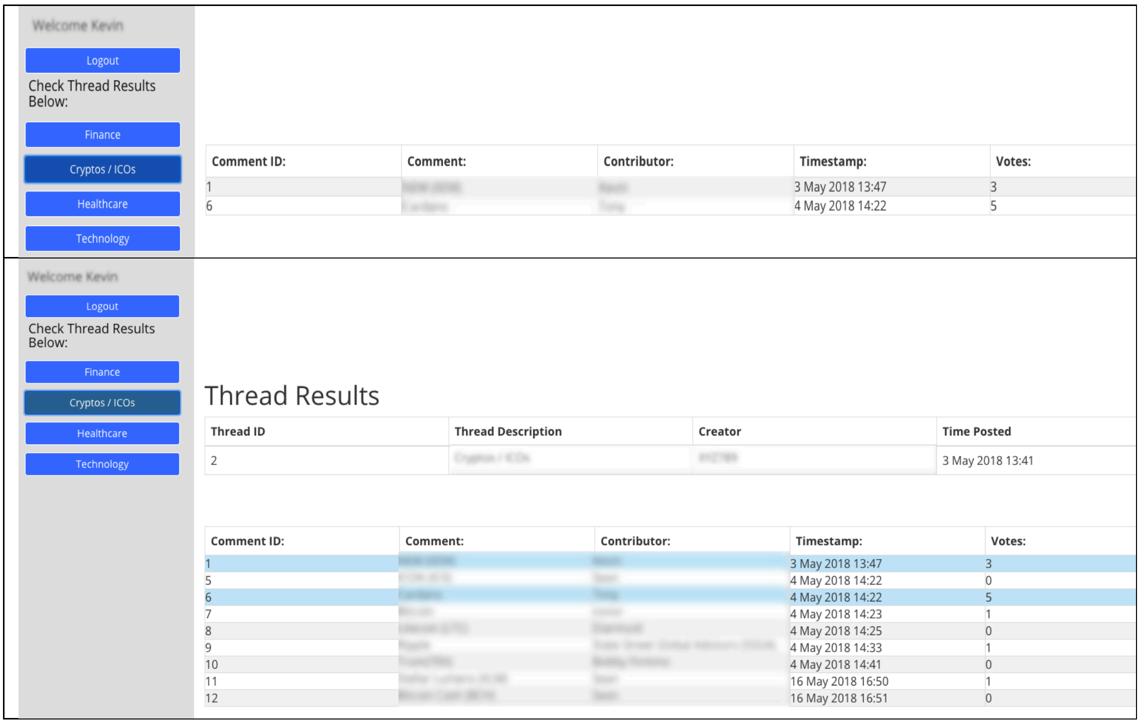
6.6.3 Implementing Creative Ancestry

Throughout the experiment, participants uploaded recommendations and voted on those put forward by others. Participants were also free to browse the shortlisted recommendations, as well as those that preceded them. Each preceding recommendations was presented in a backwards-traversible sequence, allowing individual contributions to be independently evaluated against the contributions on which they built.

A consistent structure was imposed, meaning each comment (including preceding recommendations) was displayed in an identical tabular format that laid out the text of the comment, the contributor, and a timestamp. Immutability was ensured by the technical mechanics of the Ethereum Blockchain and by allowing users to independently navigate records and compare them them with their own experience and memory.

Two additional details were added in the interests of interaction-level inspectability. The first was the number of votes received by selected or preceding recommendations. This created visibility over the progression of collective approval from collaborators as discussion neared the selected idea, particularly when combined with the timestamp data. The second was the comment ID for each selected or preceding recommendation. This was arguably unnecessary; however, it represented the last item of data stored on the ideation system so was included to ensure no details were withheld from users.

For comparative purposes, a second system was also built that did not facilitate *Creative Ancestry* for selected ideas. This second system did not display the recommendations that preceded shortlisted ideas (see Figure 6.3). Thus, while interactions were similarly structured, immutable, and inspectable as they happened, successful collaborations could not be backwards-traversed in a structured, immutable, and inspectable manner.



Comment ID:	Comment:	Contributor:	Timestamp:	Votes:
1	[redacted]	[redacted]	3 May 2018 13:47	3
6	[redacted]	[redacted]	4 May 2018 14:22	5

Thread Results

Thread ID	Thread Description	Creator	Time Posted
2	[redacted]	[redacted]	3 May 2018 13:41

Comment ID:	Comment:	Contributor:	Timestamp:	Votes:
1	[redacted]	[redacted]	3 May 2018 13:47	3
5	[redacted]	[redacted]	4 May 2018 14:22	0
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8	[redacted]	[redacted]	4 May 2018 14:25	0
9	[redacted]	[redacted]	4 May 2018 14:33	1
10	[redacted]	[redacted]	4 May 2018 14:41	0
11	[redacted]	[redacted]	16 May 2018 16:50	1
12	[redacted]	[redacted]	16 May 2018 16:51	0

Figure 6.3 Screenshot of recommendation-filtering stage with Creative Ancestry (bottom) and without (top) (details blurred for anonymity purposes)

6.6.4 Implementing distributive, procedural, and interactional justice with Creative Ancestry

The system leveraged *Creative Ancestry* to facilitate each form of social justice (distributive, procedural, and interactional). It did this at three levels; a technical-level, an interface design-level, and an interaction/context-level.

Distributive justice was enabled at a technical-level by ensuring collaborators operate under a pseudonym. Pseudonymous interactions are typical in Blockchain environments such as Ethereum (Lindman et al., 2017). This is valuable, as there is a tendency in many collaborations for junior or shy individuals to refrain from sharing their ideas in case they come under ridicule; a tendency referred to as 'evaluation apprehension' (Diehl & Stroebe, 1987). Allowing individuals to contribute without disclosing their identity has been found to reduce these effects and increase participation (Connolly et al., 1990), particularly where groups contain recognised experts (Collaros & Anderson, 1969).

Hence, the interface design of the system further limited anything that would enable individuals to add additional contextual information to their profiles, e.g. job titles, bios, or images. A separate problem occurs where groups contain a subset of members that have collaborated previously, as these individuals often communicate independently and become gatekeepers of vital information (Robert Jr et al., 2008). For this reason, the interaction/context design avoided any direct or ancillary communication channels that could result in privileged information sharing or offline discussion.

Procedural justice was enabled at a technical-level through the implementation of smart contracts. These smart contracts operate as a governance mechanism for the system, autonomously enforcing predefined rules in the system (Beck et al., 2018). This satisfies three key rules for fair procedures (i) the consistency rule, which states that the allocation of procedures should be consistent across persons and over time (ii) the bias-suppression rule, which states that personal self-interests and decision-makers should be prevented from operating during the allocation process and (iii) the representativeness rule, which states that needs, values and, outlooks of all parties should be considered equal in the process (Leventhal, 1976). However, it must also be noted that even seemingly fair and democratic procedures can also be undermined where individuals manufacture criticism to drown out positive support and foster distrust (Lewicki, McAllister, & Bies, 1998; Sundaramurthy & Lewis, 2003). Hence, after extensive consideration and discussion, the design of the system did not allow users to ‘down-vote’ ideas; they could only express their support with positive ‘up-votes’ or non-support by abstaining. Interaction/context design reinforced this by presenting selected ideas as interesting enough to warrant further consideration, rather than ‘winners’ for future roll-out.

Interactional justice was enabled at a technical-level by (i) ensuring users were tied to their specific pseudonyms indefinitely and (ii) removing any capacity to remove or amend records of interactions. This is important, individuals often voice ideas early in the collaborative process that are deemed of marginal value, only to have those ideas re-emerge later on with little or no credit to the original contributor (Diehl & Stroebe, 1987). Distributed Collaborations are particularly vulnerable to this effect, as much of the benefit comes from allowing individuals to operate in parallel when groups are large (Gallupe et al., 1992). *Interactional justice* was further enabled at an interface design-level by ensuring screens allow historic interactions to be browsed all the way back to the beginning of the collaboration. This reassures individuals that even minor or indirect contributions are visible; an important quality for collaborators who assume important supporting roles (George, 1992; Jones, 1984). The interaction/context-level design supports this by encouraging users to scrutinise interactions when viewing specific outputs, rather than assuming the collaboration is no longer of interest once ideas have been selected.

6.7 Evaluation

An experiment was used to evaluate the system, as this allows for greater contextual control and the isolation of specific effects (Venable, Pries-Heje, & Baskerville, 2016). Participants were university students with a background in IT. The use of students is recognised as appropriate for social/organisational/business research, provided the research questions focus on general traits, rather than comparative questions demanding representative between-subject diversity (see discussion in Greenberg (1987); Peterson (2001); Bello, Leung, Radebaugh, Tung, and Van Witteloostuijn (2009)). No such constraints apply for this study, which focuses on helping contributors bring different ideas to bear on a collaboration, not whether those contributors offer a balanced representation of the population at large. Hence, the use of student participants was deemed suitable and these students participated as part of coursework.

The first group contained 52 participants, the second contained 28, and the third contained 41 (N = 121 participants overall). The evaluation took place before a national holiday, the context of which was integrated into the experimental collaboration task. Specifically, participants were asked how businesses in certain industries (retails, transport, pubs/nightclubs and café/restaurant) could take advantage of the busy weekend ahead. All participants were equally free to make suggestions and once these suggestions were verified on the ropsten testnet, they were visible to all other participants. Participants could then either vote on ideas they felt were relevant or make a recommendation of their own.

Three identical smart contracts were created, and we manipulated the JavaScript file on our EC2 instance to read and write data from a new contract address for each session to allow each session to operate with their own set of ideas. At the end of each session, we divided the groups in half and each participant was presented with the shortlisted recommendations from the vote. Half the participants (randomly determined) received the full list of recommendations with *Creative Ancestry* around shortlisted recommendations. The alternative group were presented with only the full list of shortlisted recommendations (no *Creative Ancestry*). After each session participants were asked to complete a survey to measure each item in the embedded design-relevant explanatory/predictive model.

A components-based estimation approach to structural equation modelling was taken to reflect the exploratory nature of theory building, specifically the partial least squares (PLS) method (Gefen & Straub, 2005; Gefen, Straub, & Boudreau, 2000). A detailed discussion of these testing methods is presented in Appendix 9.11, and the results of these tests are detailed in Tables 6.1 to 6.5 below.

Table 6.1 Discriminant Validity

Construct	Coll	DJ	IJ	PJ	CA	US
Collaboration Quality	0.75	-	-	-	-	-
Dist. Justice	0.72	0.74	-	-	-	-
Inter. Justice	0.72	0.67	0.71	-	-	-
Proc. Justice	0.57	0.70	0.67	0.79	-	-
Creative Ancestry	0.65	0.64	0.61	0.68	0.72	-
User Satis.	0.64	0.57	0.59	0.58	0.59	0.85
Coll=Collaboration Quality, DJ=Distributed Justice, IJ=Interactional Justice, PJ=Procedural Justice, CA=Creative Ancestry, US=User Satisfaction						

Table 6.2 Convergent Validity

Construct	AVE	Composite Reliability	R Square	Cronbach's Alpha	Communality	Redundancy
Coll. Quality	0.56	0.86	0.66	0.80	0.56	0.23
Dist. Justice	0.55	0.83	0.40	0.72	0.55	0.22
Inter. Justice	0.50	0.80	0.37	0.67	0.50	0.18
Proc. Justice	0.63	0.84	0.47	0.71	0.63	0.29
Creative Ancestry	0.52	0.81	0.00	0.69	0.52	0.00
User Satis.	0.72	0.88	0.00	0.80	0.72	0.00

Table 6.3 Comparison of constructs for Creative Ancestry group and control group

Construct	CA. mean	Control mean	St. dev.	T Stat.	P val.	Mann-Whit. W	P val.
Creative Ancestry***†	2.73	2.12	1.02	3.43	<.001	14417	<.001
Collaboration Quality†	2.99	2.74	1.05	1.31	.19	14513	<.001
Procedural Justice**†	2.72	2.17	1.01	3.14	.002	14353	<.001
Interactional Justice†	3.05	2.84	0.99	1.11	.268	14545	<.001
Distributive justice**†	2.70	2.14	0.98	3.38	.001	14481	<.001
User Satisfaction*†	2.88	2.37	1.13	2.53	.012	14385	<.001
Cognitive group consensus**†	3.17	2.58	1.14	2.97	.003	14417	<.001
Group creativity*†	2.69	2.29	1.04	2.09	.038	14417	<.001
*p < .05, **p < .01, ***p < .001, †p<.001 (non-parametric tests)							

Table 6.4 Results of bootstrapping for inner model

Relationship	Original Sample	Sample Mean	Standard Error	T Statistic	P Value
Distr. Just. -> Coll. Quality***	0.3867	0.3987	0.1038	3.7255	<.001
Inter. Just.-> Coll. Quality***	0.3828	0.3872	0.0966	3.9612	<.001
Proced. Just. -> Coll. Quality	-0.1073	-0.1094	0.1256	0.8544	0.394
Proced. Just. -> Distr. Just***	0.5053	0.5001	0.0923	5.4741	<.001
Proced. Just. -> Inter. Just.***	0.4791	0.4758	0.101	4.7422	<.001
Creative Ancestry -> Distr. Just.***	0.2934	0.3087	0.1027	2.8577	<.001
Creative Ancestry -> Inter. Just.*	0.2792	0.2809	0.1121	2.4898	0.013
Creative Ancestry -> Proced. Just.***	0.6821	0.6921	0.0518	13.1782	<.001
Sat -> Coll. Quality*	0.2586	0.2448	0.1012	2.5559	0.011
*p < .05, **p < .01, ***p < .001					

Table 6.5 Results of bootstrapping with moderating variables

Relationship	Original Sample	Sample Mean	SE	T Stat.	P Val.
Cog. Gr. Consensus -> Distr. Just.**	0.2792	0.2712	0.1027	2.7178	0.007
Cog. Gr. Consensus -> Inter. Just.	0.0109	0.0091	0.1146	0.0947	0.924
Cog. Gr. Consensus -> Proced. Just.	0.0676	0.062	0.133	0.508	0.612
Group Creativity -> Distr. Just.	0.1723	0.1804	0.0949	1.8145	0.071
Group Creativity -> Inter. Just.**	0.3312	0.3241	0.1043	3.1751	0.002
Group Creativity -> Proced. Just.*	0.2248	0.2305	0.1079	2.0829	0.038
Distr. Just. -> Coll. Quality***	0.4039	0.4068	0.0992	4.0729	<.001
Inter. Just.-> Coll. Quality***	0.3728	0.3733	0.0853	4.372	<.001
Proced. Just. -> Coll. Quality	-0.1065	-0.1034	0.1221	0.872	0.383
Proced. Just. -> Distr. Just***	0.3799	0.3765	0.1039	3.6553	<.001
Proced. Just. -> Inter. Just.**	0.36	0.3581	0.1093	3.2943	0.001
Creative Ancestry -> Cg. Gr. Consensus***	0.5922	0.5974	0.0662	8.9506	<.001
Creative Ancestry -> Group Creativity***	0.5062	0.5177	0.0805	6.2915	<.001
Creative Ancestry -> Distr. Just.	0.122	0.1328	0.1177	1.0368	0.301
Creative Ancestry -> Inter. Just.	0.1866	0.1969	0.1249	1.4938	0.136
Creative Ancestry -> Proced. Just.***	0.5271	0.5307	0.0923	5.7123	<.001
Sat -> Collaboration*	0.2525	0.246	0.1081	2.3364	0.020

*p < .05, **p < .01, ***p < .001

When looking at *perceived collaboration quality*, the data in Table 6.4 suggests perceived *distributive justice* and *interactional justice* both positively affect *perceived collaboration quality* with path coefficients of 0.3867 and 0.383 respectively (p<0.001). Therefore, H1 and H2 are both supported. H3 was rejected with a path coefficient of 0.107 and a p-value of 0.39, suggesting no direct impact for *procedural justice* on *perceived collaboration quality*. H4 and H5 were supported, however, suggesting *procedural justice* has a positive impact on both perceived *distribute justice* and *interactional justice*.

The data support positive relationships between *Creative Ancestry* and the perception of *distributive*, *procedural*, and *interactional justice* in the unmoderated model, with path coefficients of 0.293, 0.682, and 0.279, respectively. Thus, hypotheses 7, 8, and 9 are supported.

Table 6.5 further shows the results of moderation tests with *cognitive group consensus* and *perceived group creativity*. The introduction of *cognitive group consensus* and *perceived group creativity* into path modelling suggested two of these relationships are moderated. The first is the relationship between *Creative Ancestry* and *distributive justice*, which is moderated by *cognitive group consensus*. The second is the relationship between *Creative Ancestry* and *interactional justice*, which is moderated by *perceived group creativity*. Thus, hypotheses 10 and 11 are partially supported.

6.8 Communication: Discussion and Implications

This study has explored the broad potential of Distributed Collaboration systems and identified the key role played by perceived social justice in the success of such systems. Drawing on prior research, the study theorises the construct of *Creative Ancestry* as a key enabler of perceived social justice. In order to leverage *Creative Ancestry* in an effective way, systems must provide consistent structure, inspect ability, and immutability for records of contributions. We argue Blockchain technologies provide a clear foundation for implementing such systems. A design science approach was adopted to bound the idea of *Creative Ancestry* as a design construct, to build an embedded model linking *Creative Ancestry* to *perceived collaboration quality*, and to demonstrate and evaluate a Distributed Collaboration system that puts this construct and model in action.

6.8.1 Contributions to Knowledge

The study provides three key high-level scientific contributions. First, the study improves our understanding of the relationship between perceived social justice and the effectiveness of Distributed Collaboration. *Distributive justice* (fairness of reward) and *interactional justice* (fairness of treatment), have direct impacts on *perceived collaboration qual-*

ity. Additionally, the impact of *procedural justice* (fairness of process) is indirect, moderated by *distributive* and *interactional justice*. These findings point to the primacy of the individual experience (the relationship between individual input and reward, and the experience of individual relationships), and the support role played by the process itself. In other words, fair procedures are not important in isolation; rather fair procedures enable the fair distribution of resources and fair interactions between collaborators. This supports historic findings from the management literature that position perceptions of *procedural justice* as an important, though often subtle, enabler of organisational culture (Cropanzano et al., 2002; Folger & Konovsky, 1989; Greenberg, 1987).

Second, the study demonstrates the impact of *Creative Ancestry*, as an emerging theoretical construct, on perceived social justice. In the evaluation, collaborators scored the *Creative Ancestry*-enabled system more highly than the control system along every measured dimension, even though collaborators' experiences up to the point of evaluation should have been identical. Collaborators weren't notified in advance of the differences between the systems, nor were individuals invited to compare their version of the system with the alternative. Nonetheless, the addition of *Creative Ancestry* clearly added to perceptions of fairness and the favourability of outcomes. We interpret these findings as evidence that *Creative Ancestry* is a significant asset for Distributed Collaboration systems.

Third, the study demonstrates the utility of Blockchain technologies for implementing *Creative Ancestry*. Specifically, it was revealed that the technical characteristics of Blockchain can have a significant effect on subjective social experiences when they are used to support *Creative Ancestry*. This finding extends our understanding of the potential of Blockchain; specifically, it encourages us to think of Blockchain as a human-facing technology with implications for the front-end user experience.

6.8.2 Implications for practice

This study has implications for practice at three main levels of abstraction. First, at the instance-level, this study has produced a system that demonstrates how Distributed Collaboration can be accommodated on a Blockchain-enabled system. This provides a tangible exposition to show both *that* and *how* such a system can be developed (Gregor & Jones, 2007). The empirically-demonstrated utility of the system further supports its relevance as an IT artefact of note for system developers and information systems professionals.

Second, at the design construct-level, this study illustrates the importance of *Creative Ancestry* in facilitating the mechanism of social justice for improving perceptions of fairness in Distributed Collaborations. While such *Creative Ancestry* is possible in traditional non-Blockchain systems, the underlying architecture of Blockchain makes it increasingly salient and practical for systems design. This helps to answer one of the most pressing questions facing Blockchain – what novel value does it offer compared to existing systems (Lindman et al., 2017)?

Third, at the explanation-level, this study shows how the impact of a Blockchain-based system enabling *Creative Ancestry* is dependent on perceptions of social justice. At the heart of this relationship is *perceived procedural justice*, i.e. the laws of interaction, which mediate other situational perceptions of *distributive* or *interactional justice*. System designers and developers must, therefore, understand the importance of defined procedures for the perceptions of collaborators. Put differently, if designers/developers are to leverage the benefits of Blockchain-enabled *Creative Ancestry*, they must understand that an exchange is being managed in the absence of a designated third party, meaning these exchanges must be perceived to be fair. It further places responsibility on developers to develop systems that take their security and reliability responsibilities seriously; something that has been found to be an issue in the past (Atzei, Bartoletti, & Cimoli, 2017).

6.8.3 Limitations and future research

Four limitations must be acknowledged for this study. The first has to do with the relatively synchronicity of collaborations in the simulation. Unlike many Distributed Collaborations, which can take place over days, weeks, or even years, the simulation asked collaborators to participate during the same one-hour period. This has the potential to increase interaction richness and shared social presence by increasing the capacity for rapid feedback among those communicating (Yoo & Alavi, 2001). This was offset in the experiment by the natural delay in uploading recommendations and 'up-votes' on the Ethereum network. As well as the gas cost of executing transactions on the Ethereum network, transactions take time before they are verified – a process that takes anywhere from 15 seconds to a couple of minutes. Collaborators were, therefore, encouraged to browse other threads and continuously refresh their browser during the pre-simulation brief; behaviours that more closely resemble the asynchronous interactions of real-world Distributed Collaborations. Separately, this limitation is also something that must be considered by future designers. If a collaboration is time sensitive and requires instantaneous feedback, typical Blockchain technologies may present limitations.

The second limitation has to do with the lack of repeated use by collaborators over extended periods. Many online systems rely on repeat users to generate and sustain collaborations. For example, many Innocentive solvers reuse similar solutions for multiple problems to offset the amount of effort required for uncertain rewards (Cahalane, Feller, Finnegan, Hayes, & OReilly, 2014). Similarly, Wikipedia contributors often rely on long-term culture-building to build consensus around ideas (McIntosh, 2008). Future research must consider how Blockchain-enabled *Creative Ancestry* impacts on longer-term behaviours.

The third limitation concerns the restricted collaborative behaviours available. Several valuable suggestions for use-cases and features emerged during the demonstration of preliminary systems to academic and industrial audiences, e.g. the potential for big data analyses to deconstruct successful creative patterns and the scope for a Blockchain-enabled 'engineer's notebook'. These experiences suggested the range of use-cases needs to be explored in depth, rather than attempting to recreate existing platforms and follow existing online practices.

The final limitation was the use of the Ethereum network. This system has many benefits, including the relative simplicity of development. This allowed development efforts to move quickly and focus on topics of theoretical interest over technical granularity. However, where collaborative systems are being designed for use within an organisation, or where discussion is not intended to be publicly visible, there may be strong justification for a private, permissioned Blockchain network such as Hyperledger (Hyperledger, 2017). The impact of this decreased visibility outside of collaborating parties may change some of the dynamics, particularly where future access to the collaboration is limited. This also needs to be investigated in future research.

Chapter 7. Conclusion

7.1 Chapter Introduction

The objective of this chapter is to leverage the overall findings of this research which have been presented in the preceding chapters in order to articulate the contributions this study makes to research, theory, and practice. Section 7.2 provides an overview of each of the papers included in this thesis. Section 7.3 then articulates the thesis level contributions of my research. Section 7.4 considers the limitations of the study. Section 7.5 outlines potential avenues for further research while Section 7.6 concludes the research.

7.2 Overview of Research Papers

The overall objective of my thesis has been *to explore Distributed Collaboration and the potential of Blockchain as an enabling technology*. To achieve this objective, I undertook research, as illustrated in Figure 7.1. Due to the evolving nature of this research domain it was imperative to adopt multiple research approaches across the different studies included in this body of work.

Initially, **Chapter 2** provided a unique perspective on Distributed Collaboration and the role of Blockchain as an enabling technology by analysing the cryptocurrency market as a network of distributed collaborators, evaluating Blockchain as a technology. Over 700 observations of daily price data for Bitcoin, Ethereum, and Litecoin were analysed using vector autoregression and polynomial regression, providing a macro-level view of the research domain. This study highlighted that unlike traditional stocks or fiat currencies, there is no established framework for valuing cryptocurrencies; in the absence of a consensus, cryptocurrencies are valued purely on social perceptions, resulting in exaggerated price movements. In addition, this paper suggests that Ethereum is actually a better predictor of price changes than Bitcoin, possibly representing that perceptions of Blockchain as a technology and not as an alternative financial asset, are driving price movements.

Chapter 3 presented my first iteration of Design Science Research (DSR), introducing the concept of Distributed Collaboration as ‘cross-functional group projects’, the challenges faced in these groups, as well as the potential of a Blockchain-enabled system which would alleviate these problems. This research found that Blockchain had the potential to add value to an organisation’s innovation process and recognition and reward programs, as well as addressing the problem of free-riding. In keeping with the iterative nature of DSR, the subsequent chapters examined Distributed Collaboration and its challenges in isolation to inform a second iteration of this study.

Chapter 4 presented a literature review; this was necessary to build a comprehensive understanding of Distributed Collaboration. I searched for literature published in Senior Scholars Basket of 8 IS Journals in AIS Electronic Library (AISel); Web of Science; and Google Scholar for articles published between 2000 and 2019 with a set of 25 different synonyms for Distributed Collaboration. This chapter provided a comprehensive understanding of Distributed Collaboration. First, by synthesising a single definition from an array of synonyms used in the existing literature. Second, by presenting a core model of the contributing factors to successful Distributed Collaboration (Figure 4.1) along with the resulting benefits.

Chapter 5 outlined the results of an exploratory study with industry participants and their experience of the challenges in Distributed Collaboration. Semi-structured interviews were held with a series of managers and their subordinates who operated in Distributed

Collaboration. Rather than dealing with the ideal scenario of successful Distributed Collaboration as is presented in Figure 4.1, this chapter discussed the reality of this type of work with industry participants and presented their insights. This chapter gives a perspective of the day-to-day operations of Distributed Collaboration, specifically Low-Inclusion / Low-Competition. While this study found that Blockchain could enable this form of Distributed Collaboration, it was not an ideal solution, therefore, I decided to focus on High-Inclusion / High-Competition in the next chapter.

Chapter 6 presented the second iteration of DSR. This chapter built on the foundation of knowledge developed in Chapters 4 and 5 by developing a system instantiation which implements the theoretical construct of *Creative Ancestry*. The system was built using smart contracts on the Ethereum Blockchain network and evaluated by 121 participants. The two main contributions of this chapter are the artefacts developed. First, the construct of *Creative Ancestry* which provided a mechanism to improve perceptions of fairness in Distributed Collaboration by increasing transparency of individual contributions. Second, a *Blockchain-enabled system instantiation* which implemented Creative Ancestry. This paper not only shows *that* Blockchain can enable Distributed Collaboration but also *how* this can be achieved, both from a technical and theoretical perspective.

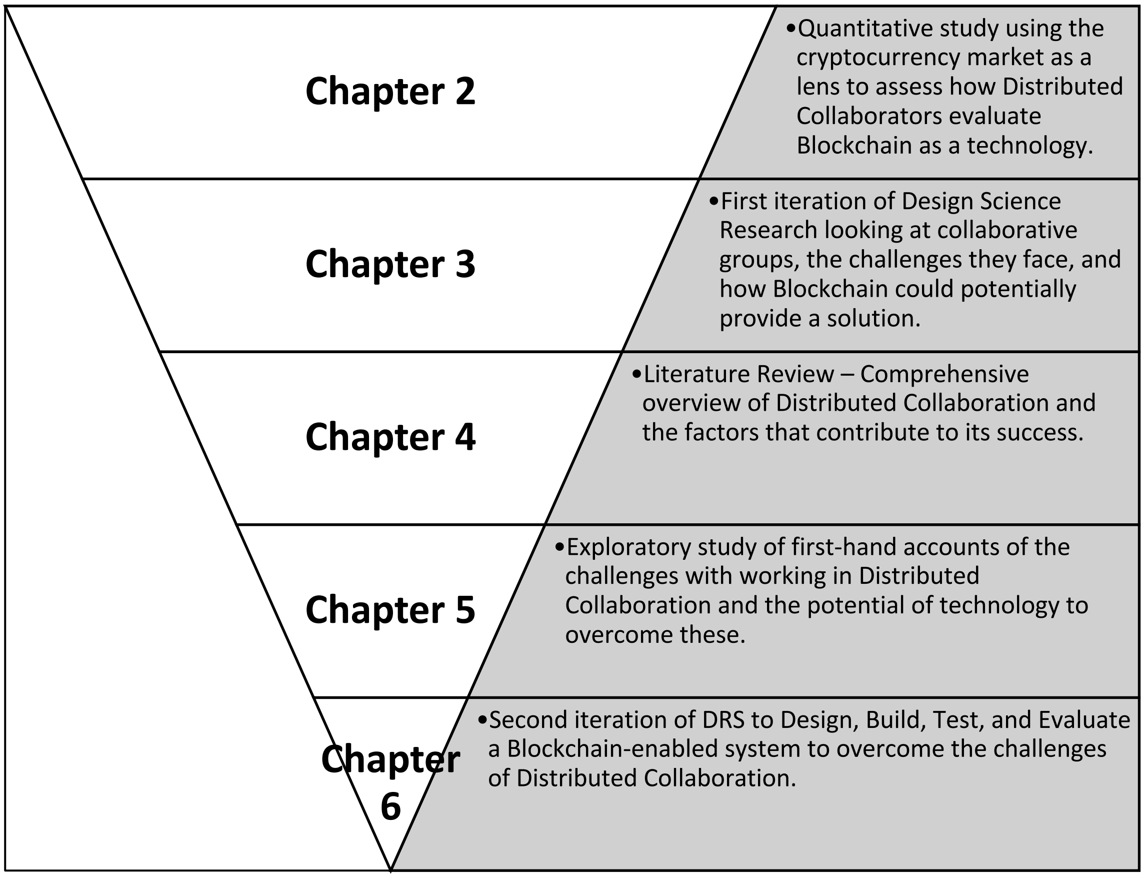


Figure 7.1 Thesis Conceptual Structure

7.3 Thesis Contributions

The following sections will illustrate the main contributions of this thesis. In keeping with the overall objective of this research, the contributions presented are multidisciplinary in their nature, providing valuable insights to researchers and practitioners alike with interest in Distributed Collaboration as an innovative working arrangement, as well as Blockchain as a disruptive, emerging technology.

As stated already, the overall research objective of this thesis is to *explore Distributed Collaboration and the potential of Blockchain as an enabling technology*. In keeping with this objective, the contributions of this research relate first, to Distributed Collaboration and how my research examines this as a social construct. Second, this thesis extends our understanding of how Distributed Collaboration is facilitated by technology. Additionally, my research contributes to our understanding of Blockchain, its applications beyond finance, the need to differentiate the technology from cryptocurrencies, and the novelty of Blockchain systems versus traditional technologies.

Table 7.1 Thesis Contributions

Contribution	Value Add
An analysis of Distributed Collaboration as a social construct.	This examines multiple forms of Distributed Collaboration and the common elements which lead to their success.
An assessment of the role of technology in collaborative groups.	This provides an overview of how technology facilitated the evolution of collaboration from co-located to distributed environments.
Feasibility study of the application of Blockchain technology for non-financial use-cases.	Illustrates the steps involved in applying Blockchain to a use-case.
The need to differentiate Blockchain technology from cryptocurrencies.	This emphasises the different value propositions offered by opposing Blockchain networks.
Highlighting the unique user experience of Blockchain-enabled application.	This informs researchers and practitioners about how a Blockchain-enabled system operates differently compared to traditional systems.

First, I will present how my research has contributed to the theoretical understanding of Distributed Collaboration as a social construct. **Chapter 4** presents a definition of Distributed Collaboration, *the pursuit of a shared objective by groups that include non-proximate members, whose participation is facilitated by ICT*. This definition stresses the social element of Distributed Collaboration as it requires coordinated participation from multiple members. Figure 7.3 details how my research has examined the social elements of Distributed Collaboration. I believe that examining Distributed Collaboration in this manner has revealed that a common determinant for successful Distributed Collaboration is *transparency across the network of collaborators.*

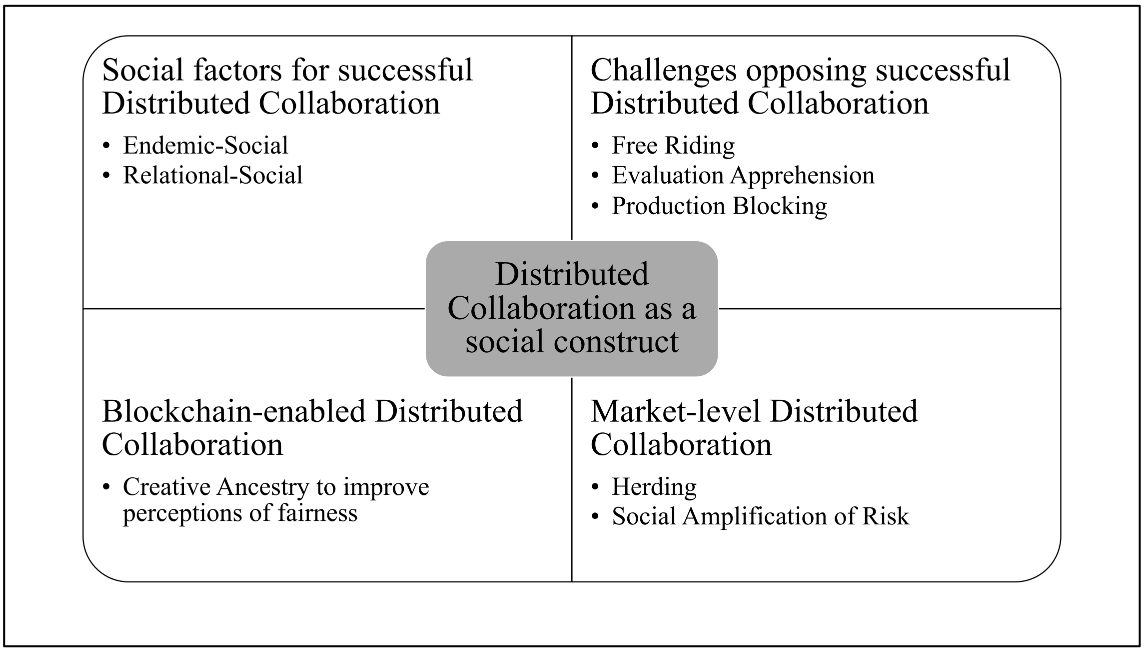


Figure 7.2 Distributed Collaboration as a social construct

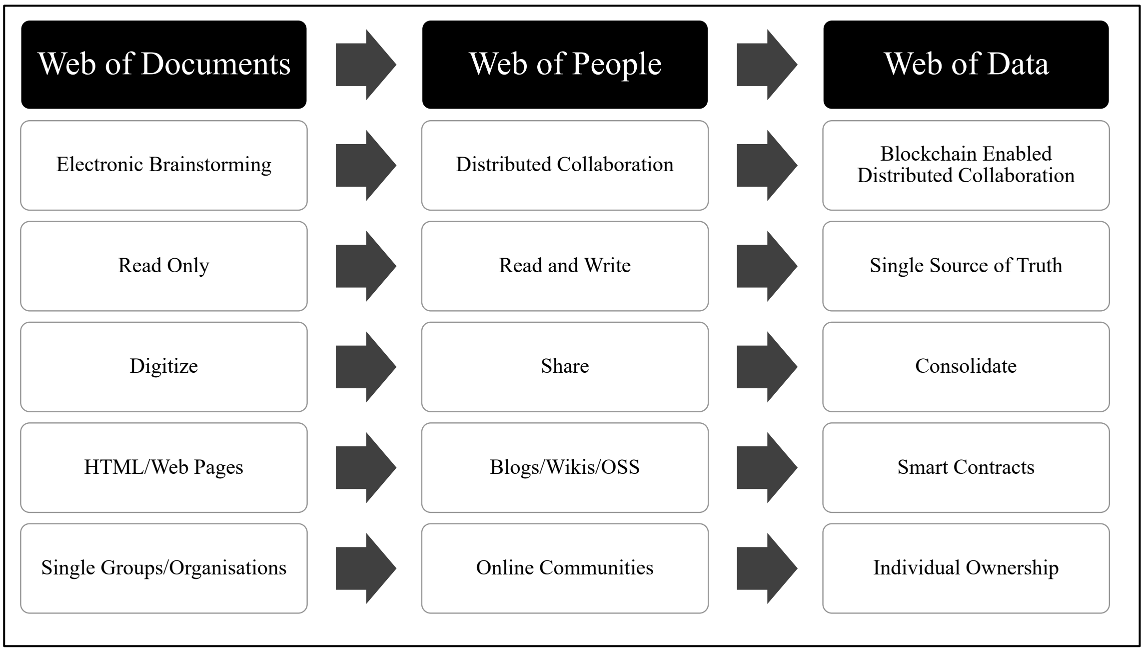
Chapter 2 argues that, distributed collaborators interacting in a market context are prone to herding behaviour, i.e. when some agents imitate the prior actions (Cakan et al., 2019; Deng et al., 2018; Rompotis, 2018) and social amplification of risk, which is where people tend to over or under-react to risk when it must be evaluated based on social observations (Kasperson et al., 1988). This shows the effects of information asymmetry across an entire market. In the absence of established mechanisms, market participants have been unable to evaluate Blockchain in an efficient manner.

Chapter 4 presented the human elements necessary for successful collaboration as endemic-social and relational-social factors (Figure 4.1). Endemic-social factors represent the characteristics of the individual collaborator, such as leadership skills (Oh et al., 2016; Pauleen, 2003) and personality (Brown et al., 2004). Relational-social represents how members of the group interact with one another, including shared understanding within the group (Mathieu et al., 2000; Minas et al., 2014; Park et al., 2019) and effective coordination among group members (Espinosa et al., 2007; Lindberg et al., 2016; Yang et al., 2015). Relational-social factors, in particular, illustrate the need for transparency across the group. Successful Distributed Collaboration results when members have a shared objective, and their efforts are appropriately coordinated.

While the model presented in Figure 4.1 illustrated successful Distributed Collaboration, **Chapter 5** discussed the social challenges of these groups. Free-riding occurs when team members decrease their own efforts and expect others to pick up the slack (Suleiman & Watson, 2008), this can be due to a belief that one's contribution is dispensable and does not contribute to the success of the group (Dennis & Valacich, 1993; George, 1992; Kudrowitz & Wallace, 2013; Paulus, 2000). Evaluation apprehension deters an individual from contributing for fear of embarrassment, hostile evaluation, the pressure to conform as well as other social forces (Collaros & Anderson, 1969; McGrath, 2015; Paulus, 2000). Production blocking occurs when members do not have the opportunity to contribute their ideas, thus reducing productivity in collaborative groups (Camacho & Paulus, 1995; Dennis & Valacich, 1993; Diehl & Stroebe, 1987). These challenges are ultimately the result of information asymmetry where individuals are unaware if they will have the opportunity to contribute, how their contributions will be received by their peers, and how their contributions affect the overall group objective. Reducing contributions from members will have a negative effect on the potential benefits which result from Distributed Collaboration, for example mutual learning (Figure 4.1) as ideas will not be generated, shared, and recombined to create synergies.

Finally, **Chapter 6** proposed that Blockchain could facilitate Creative Ancestry, i.e. *the ability of a collaborative system to take some particular output of note and navigate backwards through the individual contributions that preceded it in a consistently structured, inspectable, and immutable manner.* Creative Ancestry could improve perceived fairness or social justice, thereby ensuring the success of collaborative groups (Son & Kim, 2008; Wasko & Faraj, 2000). Creative Ancestry is a proposed solution to the information asymmetry which can exist in Distributed Collaboration. By providing a transparent, immutable record of contributions across the entire network of collaborators, members are aware of how their efforts determine the success of the entire group. This enables a number of factors which are listed in Figure 4.1 as central to successful Distributed Collaboration, for example implementing knowledge tracking fulfilment, motivating further knowledge sharing, and improving task specific alignment.

The second contribution of this research relates to our theoretical understanding of the role of technology and its potential to support collaboration. This thesis not only analyses the potential of Blockchain in enabling Distributed Collaboration, as is stated in the research objective but also illustrates the evolving role of technology in facilitating collaboration. Figure 7.3 illustrates how the changing nature of collaboration from co-located groups to distributed environments and the role of technology to support this.



Web of Documents		Web of People		Web of Data
Electronic Brainstorming	➡	Distributed Collaboration	➡	Blockchain Enabled Distributed Collaboration
Read Only	➡	Read and Write	➡	Single Source of Truth
Digitize	➡	Share	➡	Consolidate
HTML/Web Pages	➡	Blogs/Wikis/OSS	➡	Smart Contracts
Single Groups/Organisations	➡	Online Communities	➡	Individual Ownership

Figure 7.3 The evolving role of technology in enabling collaboration

The development and growth of the world-wide-web is commonly categorised under three generations; originally, *The Web of Documents* consisted primarily of static HTML pages, following this, *The Web of People*, provided a more dynamic, social environment where people could share information with one another, today, *The Web of Data* aims to run on individually developed smart applications (Hiremath & Kenchakkanavar, 2016; Patel, 2013).

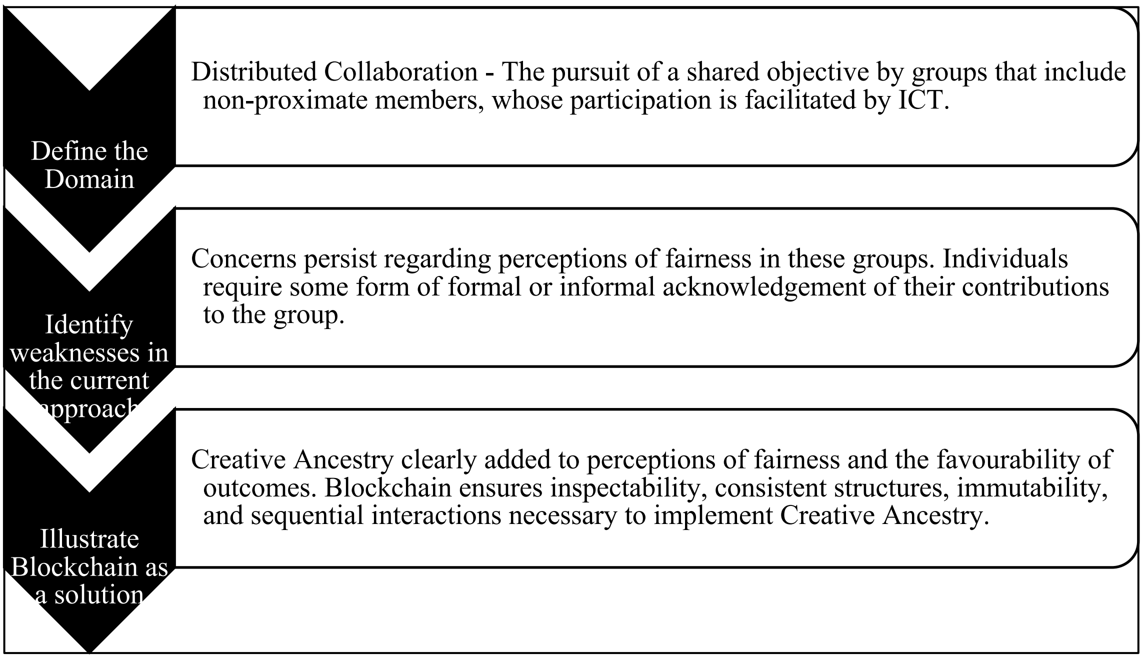
The way in which we collaborate with one another has developed in concert with the progression through each generation of the web. *The Web of Documents* created an opportunity for *electronic brainstorming* whereby individuals could contribute to a group electronically rather than waiting for their chance to speak in a group setting (Dennis & Valacich, 1993; Gallupe et al., 1992; Nijstad et al., 2003; Paulus & Yang, 2000).

The Web of People created a social web environment where people could both read and write information. This generation of the web led to the emergence of online communities and virtual teams where dispersed contributors worked via wikis, blogs, and open-source software initiatives (Colazo & Fang, 2010; Forte et al., 2009; Ransbotham & Kane, 2011; Von Krogh et al., 2012). The Web of People facilitated what I have defined in this thesis as *Distributed Collaboration.*

My research has illustrated the potential of Blockchain to offer an enhanced solution to support Distributed Collaboration. These findings demonstrate how the nature of collaboration can change dramatically with emerging technologies, which are largely focused on enhancing participation and collaboration (Garrigos-Simon, Lapiedra Alcami, & Barbera Ribera, 2012). *The Web of Data* will be built on smart contracts and smart applications to consolidate information and create a single version of the truth (Hiremath &

Kenchakkanavar, 2016; Patel, 2013). This next generation of the web focuses on empowering the individual in an increasingly distributed environment.

Third, my thesis represents a comprehensive feasibility study of the application of Blockchain for a non-financial use-case, the process of which is illustrated in Figure 7.4. Blockchain technology has garnered increased interest over recent years, primarily for its applications in finance and related fields, as is demonstrated by Holub and Johnson (2018). However, a number of major industry members have also invested R&D resources in exploring the application of Blockchain for diverse use-cases (Beck et al., 2016).



Distributed Collaboration - The pursuit of a shared objective by groups that include non-proximate members, whose participation is facilitated by ICT.

Concerns persist regarding perceptions of fairness in these groups. Individuals require some form of formal or informal acknowledgement of their contributions to the group.

Creative Ancestry clearly added to perceptions of fairness and the favourability of outcomes. Blockchain ensures inspectability, consistent structures, immutability, and sequential interactions necessary to implement Creative Ancestry.

Figure 7.4 Process of applying Blockchain to a non-financial use-case

Previous studies have detailed efforts to build and evaluate Blockchain applications for a variety of applications including Beck et al. (2016) which built a proof-of-concept Blockchain application coffee shop payment solution and Beck et al. (2018) which explored the *Swarm City* Blockchain case which provides a Blockchain infrastructure for the sharing economy. My thesis extends this work by going beyond focusing on the design and development of a Blockchain-enabled system and understanding its role as an enabler of Distributed Collaboration. First, I present a comprehensive understanding of Distributed Collaboration, the domain for which Blockchain may serve as an enabling technology. This is essential in any feasibility study to understand the as-is process and identify any inadequacies. I execute this by conducting both a systematic literature review of the existing research in this domain and also, carrying out exploratory interviews with industry participants with first-hand experience of the daily operations of distributed groups.

These steps identified a number of weaknesses which exist in the current approach. Specifically, concerns persist whether these Distributed Collaborations do enough to recognise individual contributions (Wang & Fesenmaier, 2003). This is important, as many individuals require some form of formal or informal acknowledgement (Wasko & Faraj, 2005). Hence, perceived fairness, or social justice has been found to be a key element in ensuring the success of collaborative groups (Son & Kim, 2008; Wasko & Faraj, 2000; Wu & Chiu, 2018). Yet it is not clear how such fairness can be accommodated.

Once a sufficient knowledge of the existing use-case has been demonstrated, the next step was to illustrate *that* Blockchain could serve as an enabling technology. This involved two sub-processes. First, I harnessed the work of Wüst and Gervais (2017) which detailed if Blockchain is an appropriate solution for Distributed Collaboration, this discussion is detailed in Appendix 9.1. Second, assured that Blockchain could support Distributed Collaboration, I analysed the benefits it would offer. These are presented in Appendix 9.3.

Third, having formed a foundational understanding of Distributed Collaboration and established *that* Blockchain would, the final step was to show *how* Blockchain can enable Distributed Collaboration. My study presented in **Chapter 6** provides a detailed account of the design and development of a Blockchain-enabled system to track individual contributions. This study presents Distributed Collaboration as a supply chain relationship between dispersed collaborators exchanging intellectual property. The immutability, traceability, and transparency afforded by Blockchain make it an ideal technology for managing such relationships. I believe this research could inform practitioners looking to apply Blockchain to any supply chain use-case.

The fourth contribution of my thesis is, throughout my research, I found that because of widespread media attention, Blockchain is synonymous with Bitcoin and cryptocurrencies. Therefore, participants limited knowledge was often sullied by a negative or false predisposition towards the technology and its potential. I believe that there is a need to disentangle Blockchain from cryptocurrencies. Although there is a symbiotic relationship between Blockchain and cryptocurrencies as an instantiation of that technology, the term 'cryptocurrency' carries primarily financial connotations, which therefore, is not fully representative of Blockchains potential.

Different cryptocurrencies have disparate purposes, for instance, Bitcoin was introduced by Satoshi Nakamoto in 2008 as a "peer-to-peer version of electronic cash", intending to be a viable alternative to the traditional financial system and allow people to buy and sell products and services in exchange for Bitcoin. Bitcoin has been the leading cryptocurrency ever since, and as a result a common misunderstanding is that all cryptocurrencies are also a form of alternative finance.

However, Ether, the cryptocurrency of the Ethereum network, has a vastly different value proposition. Unlike Bitcoin, Ether is not intended to act as a token of exchange for good and services; rather it is seen as a "fuel" to run the smart contract development platform that is the Ethereum network. Ethereum was launched in 2015 to address what Ethereum developers perceived to be a weakness in Bitcoin, that Bitcoin transactions could not support smart contracts. A smart contract is a piece of code that the Ethereum Virtual Machine (EVM) is able to execute on the Blockchain. By supporting smart contracts, Ethereum increases the potential of Blockchain beyond just finance to any number of use-cases including intellectual property, health care, supply chain management and, legal.

The juxtaposition of cryptocurrencies and Blockchain was especially pronounced during my research as the cryptocurrency market experienced unprecedented growth in 2017. Bitcoin reported a rise in price of over 1300% in 2017 while the price of Ether increased by more than 9,000% the same year. My research certainly benefited as a result of this increased interest in all things Blockchain and cryptocurrency as I had ample opportunities to present my work and discuss my opinions on the topic with those who wanted to learn more. However, it quickly became apparent that the majority of people I encountered had exaggerated expectations for the potential of cryptocurrencies. The term 'HODL' became popular online during this bullish period in the cryptocurrency market, it is assumed to be an acronym for Hold On for Dear Life, which I believe to be the perfect metaphor for the failure of most people to see the potential of Blockchain and instead rush into the market expecting to turn an easy profit. From personal anecdotal evidence I can say that the majority of people who bought cryptocurrency in 2017 never used their Bitcoin to pay for a coffee and, struggled to pronounce Ethereum, never mind develop or even interact with a smart contract application. When the bubble inevitably burst in 2018, many of these market investors labelled cryptocurrencies as a failure and by association, Blockchain.

The fifth contribution of this thesis is a discussion of the unique user experience involved when interacting with Blockchain-based applications compared to traditional technologies. The study presented in **Chapter 6** involved 121 participants interacting with my Blockchain-enabled system, the vast majority of whom had never experienced such a system before. In order to overcome this issue, it was necessary to first, give each group an overview of Blockchain, and second, to design the system to be as interactive and intuitive as possible.

When giving an overview of the technology, I had a number of topics to cover — first, the rise of Blockchain, its relationship with Bitcoin, and the emergence of Ethereum. Second, smart contracts, their benefits but also their limitations. Third, the importance of code correctness in smart contracts and the importance of a solution which requires Blockchain rather than Blockchain being a solution looking for a problem. Fourth, I would introduce the novel features of a Blockchain application such as the latency of Blockchain transactions, the transparency of Blockchain transactions, the cost of transacting on the Ethereum network, and the pseudonymity of users.

In designing the system, I made an effort to make these elements of Blockchain as intuitive as possible. Starting with the pseudonymity of users, I built my system on the Ethereum network, a public, permissionless network, meaning that anyone can join and access the network. Ethereum users are represented by a persistent alphanumeric account address for example “0x627306090abab3a6e1400e9345bc60c78a8bef57”. The persistence is key here as it means users are not strictly anonymous as all their transactions correspond to the same account address. However, with 121 participants it can be difficult to distinguish between different users. Therefore, for the purpose of display all users were asked to create their own username which were simply saved to a MySQL database along with their Ethereum account address. Transactions then rendered alongside a readable username rather than an alphanumeric string. I found this to be the most effective way of highlighting the benefit of pseudonymity.

The next challenge to address was how users would complete transactions on my system. *Transaction* refers to posting on the system, just as you would on a traditional system such as Twitter. There are three unique elements to a Blockchain transaction when compared to traditional technologies: transaction cost; transaction latency; transaction transparency. All three elements were facilitated by a simple Google Chrome extension I used called *Metamask.* Metamask acts as a bridge to allow users to access the Ethereum network and interact with dApps on their browser. In order to submit a transaction on the system, users first had to 'top-up' their Metamask accounts in order to pay for the cost of their transaction. Participants in each of our demo sessions started by funding their Metamask accounts by requesting ether from a faucet (https://faucet.metamask.io/). This is a foreign concept to any user of internet technologies as we have become accustomed to free internet usage. However, the integrity of the Ethereum distributed ledger is maintained by multiple nodes executing computations which consume a lot of energy. Therefore, they require reimbursement for their efforts in the form of these transaction costs. I found that this resulted in users justifying their posts before executing them and paying the necessary price. The cost involved in Blockchain-based transactions may introduce a unique set of challenges for Blockchain-enabled applications, analysing and overcoming these challenges was deemed out of scope for my research, this will be discussed further in the limitations of my research in section 7.4.

Once the cost is overcome, users were faced with another novel experience, transaction latency. Time is necessary in order to allow for a distributed network to maintain consistent integrity of data across the entire network. In the case of Ethereum, this latency period is roughly 15 seconds. I found that participants struggled to adapt to this and were concerned when their posts were not immediately rendering on screen. However, Metamask does provide status updates on all transactions which helped reassure users that everything was working as expected and users became increasingly comfortable as time progressed.

Finally, transaction transparency was an important feature of Blockchain that I made an effort to illustrate to participants. I built my system on a public, permissionless network, meaning that all users could view all transactions, not just their own, through their browser (https://ropsten.etherscan.io/address/0xc3c543fec8531bc10dda16e1c39aa34d3cf094b5). Participants enjoyed the ability to dig deeper into the transaction details and see who sent a transaction, when transactions were confirmed, and how much they cost.

Overall, my research has made contributions to literature from diverse fields. First, in the field of Distributed Collaboration. While existing research has focused on specific factors which influence the success of Distributed Collaboration, for example trust (Jarvenpaa et al., 2004; Ridings et al., 2002), leadership (Eseryel & Eseryel, 2013; Johnson et al., 2015; Kayworth & Leidner, 2002) and communication (Bartelt & Dennis, 2014; Sarker et al., 2011), my research synthesis these findings to provide a single definition of Distributed Collaboration and a core model for its success.

Second, my research extends our understanding of the role of social justice and perceived fairness in collaboration. Perceived fairness, or social justice has been found to be a key element in ensuring the success of these groups (Son & Kim, 2008; Wasko & Faraj, 2000; Wu & Chiu, 2018). My research has found this to be true for Distributed Collaboration and illustrated the potential of Blockchain to facilitate this. In addition, this research contributes to an emerging body of research which explores the implementation of Blockchain-enabled applications (Beck et al., 2016; Beck et al., 2018).

Third, my research builds on an emerging body of extant literature which has found volatility connectedness and herding behaviour in the cryptocurrency market, especially in periods of uncertainty (Bouri et al., 2018; da Gama Silva et al., 2019; Stavroyiannis & Babalos, 2019; Vidal-Tomás et al., 2018; Yi et al., 2018). This study contributes to the existing research by extending the findings on herding in the market through the application of the Social Amplification of Risk Framework (SARF). SARF is traditionally applied when researching responses to disaster situations, explaining how individuals rely on social observation in situations where the stakes are high and information is limited (Kasperson & Kasperson, 1996; Renn et al., 1992). I applied SARF to my research to show how participants in the cryptocurrency market also lack complete information, and therefore, rely on social observations when evaluating cryptocurrencies.

7.4 Limitations of the thesis

Although I am satisfied that the research outlined in this thesis has been executed to a high standard and has made significant contributions to both research and practice, all of which have been outlined in detail above, I also acknowledge that there will inevitably be limitations which must be taken into consideration when assessing this work.

First, I draw attention to limitations in relation to size and scope. By size and scope, I refer to a number of factors which were considered throughout my studies. Distributed Collaboration is a broad term I have applied in this research to encapsulate a large spectrum of working environments; this spectrum is discussed in more detail and illustrated in Figure 7.1. Although I believe findings from my research can be applied to all forms of Distributed Collaboration, for the purpose of this research I made the decision to focus on one area in particular, which I define as being 'High-Inclusion / High-Competition', this is discussed in detail in Appendix 9.2.

Another element relating to size and scope, which I accept to be a limitation of my research is the limited scope of my evaluation methods. I conducted exploratory interviews in an intraorganizational Distributed Collaboration environment. For the purpose of consistency and ease of data collection, these interviews were conducted within a single multinational organisation, referred to as 'DE Computers'. Also, when evaluating the proof-of-concept Blockchain platform, it was evaluated in a simulated environment, perhaps alternative results could have been yielded had this been implemented within an organisation or an established collaborative group over a longer period of time.

Second, this research has focused on the application of Blockchain and cryptocurrencies, an emerging area which has experienced significant research and development in recent years; therefore, I must acknowledge and accept the limitations associated. As has been outlined throughout this thesis, Blockchain is simply the technology which underpins cryptocurrencies and smart contract development platforms. Blockchain itself comes in many flavours, the primary options being public vs private Blockchains. This research has exclusively leveraged public Blockchains, primarily focusing on Bitcoin, Ethereum and Litecoin. The reasons for this choice have been discussed in the appropriate Chapters. Ethereum is the first major cryptocurrency to establish itself as a smart contract development platform. Also, due to its open-source nature and ever-growing community of developers it was an obvious choice to use for POC development. I do acknowledge the benefits of private Blockchains, such as Hyperledger and the significant benefits they may offer over public Blockchains, especially for large, established organisations who are concerned with security and scalability issues associated with Blockchain.

As for the cryptocurrencies studied, Bitcoin is the leading cryptocurrency and most renowned application of Blockchain technology. Bitcoin has held this position consistently for the duration of this research effort and has paved the way for all subsequent developments; therefore, overlooking Bitcoin would be ill-advised. Litecoin was arguably the first and leading ‘altcoin’, a brand of cryptocurrency which took advantage of the open-source nature of Bitcoin; therefore, I chose Litecoin as a representation of this fragment of the overall cryptocurrency market.

Third, through developing the second iteration of the system instantiation presented in Chapter 6 I found that the concept of incurring a cost for transactions on a Blockchain-enabled system could pose additional challenges for the users of the system. Analysing these challenges and how they could be overcome was considered out of scope for my research, however I must acknowledge their potential impact. The system presented in this Chapter 6 facilitates idea generation through a Blockchain-enabled application. When the user is faced with a cost for contributing to the system, they may deem that their contribution no longer makes economic sense, thus reducing the knowledge shared within the group, a factor which I have identified as key to the success of collaborative groups (Figure 4.1). Additionally, if users are required to fund their own accounts, less wealthy individuals will be affected more than affluent users.

7.5 Opportunities for Further Research

In light of the contributions this research has made thus far to the field of Distributed Collaboration and Blockchain as a technology, as well as the limitations of this research as highlighted above, it is apparent that continual research efforts will be required to keep pace as this area continues to grow and develop. Unfortunately, there came the point where I had to draw a line in the sand and deem certain avenues of beyond the scope of this body of work. I would now like to take the opportunity to suggest a selection of these topics as areas for potential future research efforts to build on the contributions which I have made.

First, the scope and potential for distributed groups to organise, collaborate and produce seem to be growing at an exponential rate. With the emergence of *the Web of Data*, Distributed Collaboration, as has been presented in this thesis could change dramatically. The evolution of a semantic web is believed to allow for the development of machine learning and artificial intelligence (O'Reilly, 2007). Not only will individuals be able to communicate and collaborate from anywhere on the globe, but also machines will be able to communicate with one another. The continued adoption of VR and AR technologies has the potential to greatly improve media richness and communication between dispersed members (Baccon, Chiarovano, & MacDougall, 2019; Campbell, Holz, Cosgrove, Harlick, & O'Sullivan, 2019; Rosedale, 2017), which could help overcome many of the challenges discussed throughout this research.

Second, although I am proud of my efforts to conduct this research with an action-oriented approach by building, testing and, evaluating a Blockchain-enabled system, I accept that the system was tested under a limited time frame. This was largely due to the maturity of the technology at the time of development as well as the low levels of end-user knowledge of Blockchain systems. Blockchain-enabled solutions are now becoming more common with large organisations expressing their interests in developing with the technology; it is expected that such systems will be rolled out into production in the coming years. Therefore, I feel it would be appropriate to revisit a simulation such as that presented in this research with a more robust solution which could be implemented within a Distributed Collaboration environment over an extended period of time in order to perhaps capture more detailed results.

Third, it would also be beneficial to research the potential for a private Blockchain solution to enable Distributed Collaboration. I chose to implement a solution using the Ethereum network as a public, permissionless network allowed for fast, affordable development. Also, at the time of development, Ethereum itself was in its infancy, and there were not a lot of established alternatives to choose from, this is no longer the case. Future research should assess their options and build on the network, which they feel best facilitates their desired solution.

Of course, as well as increased options for Blockchain development platforms, the cryptocurrency market upon which many of these networks are evaluated by an open market is also continually growing due to the open-source nature of many cryptocurrency protocols. This research and the results presented within are representative of the state of this field at the time of writing. Considering the pace of expansion, I acknowledge that the specific details of these results will be outdated soon after this work has been completed. To illustrate this point, upon commencing this research there were 590 cryptocurrencies overall and the price of the three which I have largely focused on, Bitcoin, Ether and Litecoin stood at $629, $13, $4 respectively, At the time of writing this conclusion, there over 2300 cryptocurrencies in circulation and the prices of Bitcoin, Ether and Litecoin stand approximately $10,000, $200, $90 respectively. Future researchers will likely produce different results as the market continues to expand, mature, and gain mainstream adoption.

Finally, with such rapid growth, there also comes increased threats to Blockchain, both in the form of competing solutions and threats to the security of the network. One of the leading technologies looking to compete with Blockchain at the time of writing is Hashgraphs. Hashgraphs boast a solution which also provides consensus in the form of a public ledger, however, it claims to have far greater transaction throughput (250,000 tps vs 7-10 tps), better cost and performance as it does not waste resources as is the case with proof-of-work mining mechanisms which are implemented in Blockchain networks, and improved fairness of transactions as they are serialised and timestamped as they happen rather than being grouped in blocks and batch verified as occurs in Blockchain (Baird, Harmon, & Madsen, 2018; Choe, 2018; Hoxha, 2018). As for threats to the security of Blockchain networks, quantum computing is the focus of extensive research efforts which believe that it could potentially break the security mechanisms which maintain the network, in particular, asymmetric cryptography. In simple terms, asymmetric cryptography relies on the difficulty of *prime factorisation*, i.e. the breaking up of a number into its factors, all of which are prime (Shor, 1999). Since finding prime factors of extremely large numbers is virtually impossible for classical computers, Blockchains are essentially tamper-proof (Kiktenko et al., 2018). However, Shor's algorithm shows that quantum computers, using superposition, could perform prime factorisation in polynomial time rather than exponential time (Shor, 1999), potentially exposing the security of Blockchain networks. Threats such as these will inevitably change the landscape of Blockchain and warrant further research in this domain.

7.6 Chapter Summary and Conclusion

Finally, I am very pleased to have taken the opportunity to conduct my research in an emerging and exciting domain. This research presented an opportunity for me to distinguish myself from others, I believe that I have achieved this and through the work I have completed over the past three years. Adopting a selection of different research approaches allowed me to experience both Blockchain and Distributed Collaboration from multiple perspectives, develop a rich understanding of each, and contribute to the research and practitioner communities by continuously collaborating and communicating my findings. I am looking forward to applying the knowledge I have accumulated from my research in an industry setting as this domain develops further over the coming years.

Thank you for taking the time to review my research, I hope you enjoyed it and found the contributions to be insightful and thought-provoking.

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Chapter 9. Appendix

9.1 Blockchain Decision Model

The application of Blockchain to a particular use-case can be guilty of being a solution looking for a problem. In order to avoid this criticism of my work I adapted the decision model put forward by Wüst and Gervais (2017), to analyse the appropriateness of Blockchain to enable Distributed Collaboration. Figure 9.1 illustrates the steps in the model and the decisions as they relate to Distributed Collaboration.

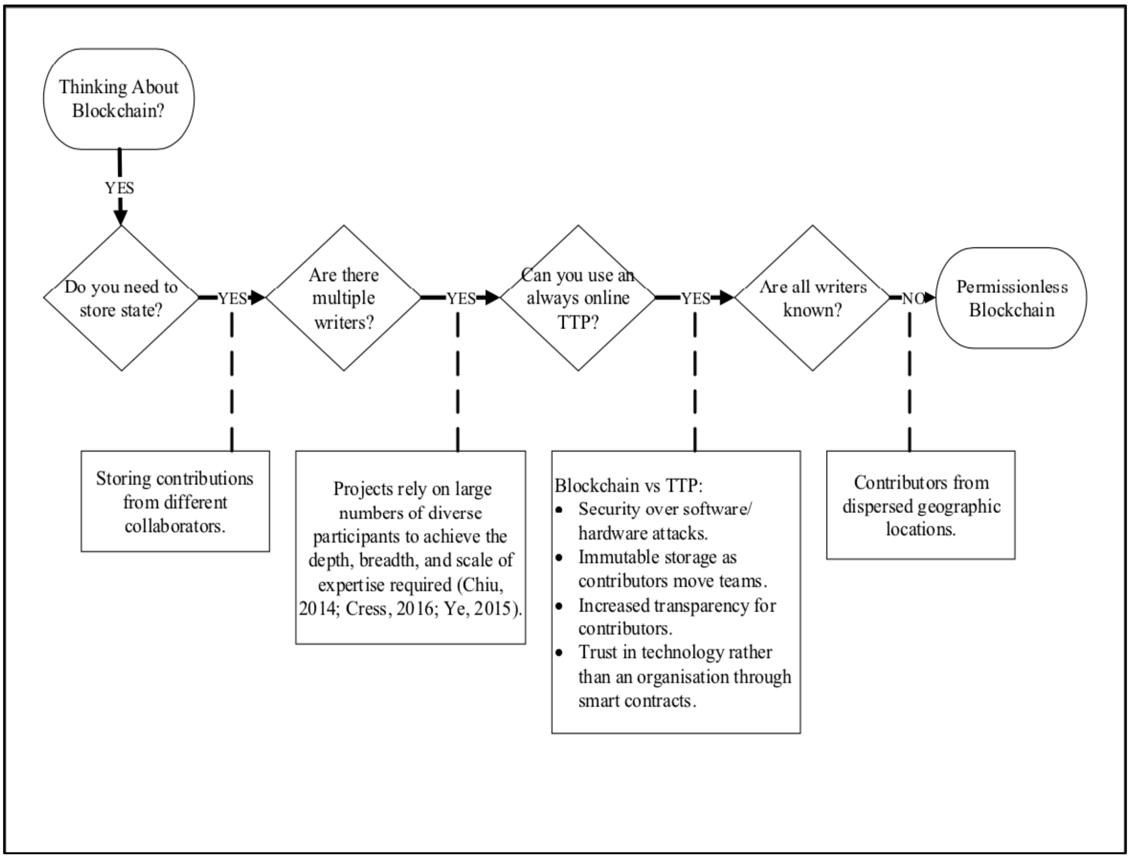

Figure 9.1 Blockchain Decision Model adapted from (Wüst & Gervais, 2017)

The definition of Creative Ancestry detailed in **Chapter 5** addresses the requirement of storing state/data in this use-case; the ability of a collaborative system to take some particular output of note and navigate backwards through the individual contributions that preceded it in a consistently structured, inspectable, and immutable manner. As we have eluded to previously, a major benefit of Distributed Collaboration is that it attracts multiple parties from across the world with diverse interests and skills (Cormode & Krishnamurthy, 2008; Faraj & Sproull, 2000; Howe, 2006; Surowiecki, 2004). Therefore, we can be sure that the use-case involves multiple parties who may not know one another, all requiring write-access to the system. The distributed nature of these teams also makes trust more difficult to establish between members as individuals struggle to develop relationships with one another (affective trust) and assess one another competencies (cognitive trust) (Altschuller & Benbunan-Fich, 2013; Iacono & Weisband, 1997; Kanawattanachai & Yoo, 2002). Another challenge which Distributed Collaboration must overcome is free-riding, which results from the lack of face-to-face interaction in these environments leading to reduced accountability (Bandura et al., 1996; Boughzala et al., 2012). Again, through smart contracts and the public verifiability of a solution built on a public Blockchain such as Ethereum, this issue can be eradicated (Beck et al., 2018; Nair & Sutter, 2018).

The final factor to consider is whether or not a solution could be delivered using a Trusted Third Party (TTP) which would be built on a centralised database. TTP solutions such as GitHub, Wikipedia, Innocentive, or any intra-organization solution to name a few already exist to facilitate Distributed Collaboration. However, we argue that these centralised solutions still have weaknesses. First, storing all contributions on a centralised storage system can be a security risk both from software and hardware attacks. Blockchain increases fault tolerance and availability of the system as one node failing will not bring down the entire network (Beck et al., 2016; Lewis, Larsen, & Goh, 2016; Pahl et al., 2018). TTP solutions accommodate niche use-cases. However, Distributed Collaboration is known for having high member turnover. Therefore, contributors are unable to retain a complete record of all their contributions across multiple projects they have worked on, again Blockchain offers a solution to this (Hawlitschek et al., 2018; Locher et al., 2018). Blockchain provides increased transparency so contributors can verify that their contributions have been recorded (Beck et al., 2017b; Nair & Sutter, 2018). We utilised this in our POC, as detailed in **Chapter 5**. All contributions from the workshops we conducted in this study can be verified through a web browser. Finally, in an intra-organizational solution, the trusted third party is usually management; however, employees still feel they do not receive appropriate recognition for their contributions (Chidambaram & Tung, 2005). Blockchain can improve this as it allows for 'the creation of trust without the need for a concrete third-party watcher who has vested authority and impartiality' (Nair & Sutter, 2018). Blockchain shifts the focus of trust from trust with an institution to trust in the technology (Beck et al., 2017b). Also, smart contracts could extend this by automatically rewarding contributors when certain conditions are met (Beck et al., 2016; Beck et al., 2018; Walsh et al., 2016).

9.2 Forms of Distributed Collaboration

As presented in **Chapter 3,** Distributed Collaboration is defined as *the pursuit of a shared objective by groups that include non-proximate members, whose participation is facilitated by ICT*. According to this definition, Distributed Collaboration encapsulates a large class of applications, servicing disparate purposes. We attempt to categorise and illustrate these different use-cases in Figure 9.2 below.

We have identified forms of Distributed Collaboration along two axes; the range of collaboration participation and, the competition between inputs. The range of collaboration participation refers to the variety of skills and, backgrounds which are introduced to the group with each new contributor. In Figure 9.2 we use Open Source Software as an example of Distributed Collaboration with a relatively low range of collaboration participation. OSS benefits from the Distributed Collaboration as technology enables that the best individuals to work together on the development of software (Chou & He, 2011; Lin, 2006). However, all contributors require a background in software development. Applications such as Wikipedia benefit from Distributed Collaboration not only because it connects talented individuals, but also because contributors often have assorted backgrounds and introduce novel perspectives (Kittur, Chi, Pendleton, Suh, & Mytkowicz, 2007; Tapscott & Williams, 2008).

Along the horizontal axis of Figure 9.2 we categorise Distributed Collaboration by the level of competition between individuals' inputs. Examples such as OSS and Wikipedia allow for individuals to build on top of one another's contributions and create a product or service which contains multiple individual contributions (Howison & Crowston, 2014; Kyriakou, Nickerson, & Sabnis, 2017; Ransbotham & Kane, 2011). As the level of competition between inputs increases, individual contributions are more independent of one another. For example, Threadless is an online t-shirt company that crowdsources the design process for its shirts through an ongoing online competition (Brabham, 2010). Each contribution is an individual design, and each contribution competes with one another to receive the highest number of votes. However, similar to OSS, this form of Distributed Collaboration requires a certain level of design competency. An example of Distributed Collaboration which includes competition between inputs as well as a range of collaboration participation is Walker's 'Do Us a Flavour' competition (Forbes & Schaefer, 2017). Individual contributions compete to get the greatest number of votes, the benefit of Distributed Collaboration here is that multiple contributions coming from diverse backgrounds as there are no obvious prerequisite skills to suggest a new flavour.

The POC developed in **Chapter 5** facilitates Distributed Collaboration with high levels of both ranges of collaboration participation as well as competition between inputs. With the increase in competition in these use-cases there is also increased incentive to act dishonestly (Cartwright & Menezes, 2014; Rick et al., 2008). Therefore, we propose that the addition of *Creative Ancestry* will inflate perceptions of fairness and, overall quality in the collaboration.

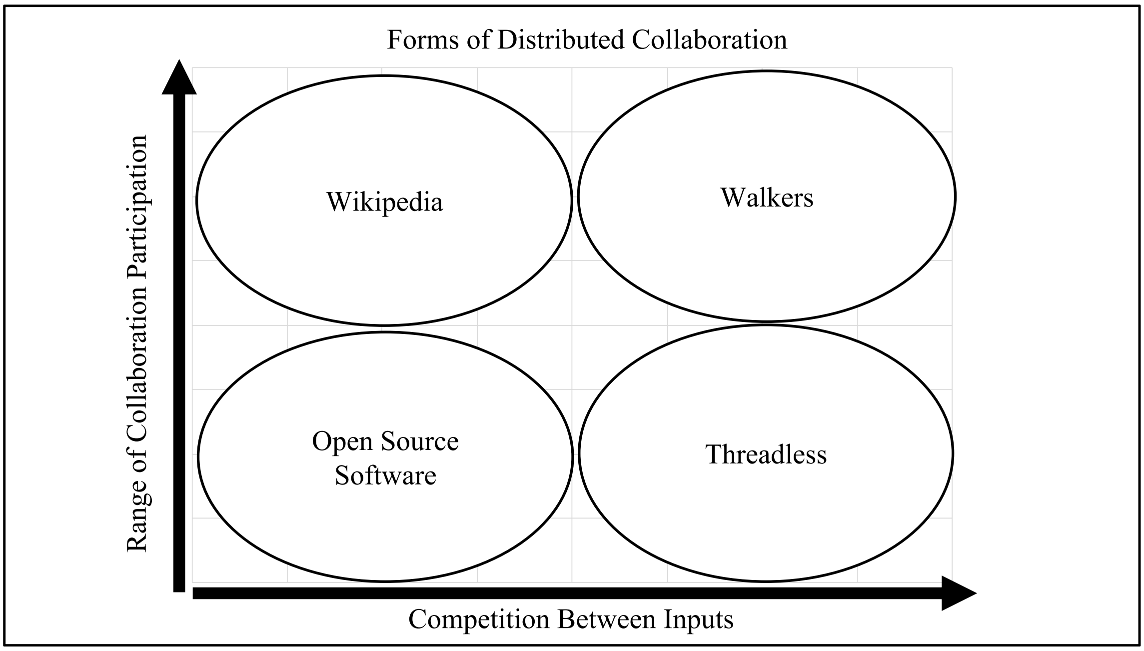

Figure 9.2 Forms of Distributed Collaboration

9.3 Benefits of Blockchain as they relate to Distributed Collaboration

We conducted a brief systematic literature review of journal papers related to Blockchain, published in the last ten years. We searched for papers in four academic databases; AIS Electronic Library, Web of Science, ProQuest, and Google Scholar, paying particular attention to studies published in the “IS Senior Scholars Basket”, an approach recommended by previous studies (Alter, 2018; Steininger, 2018). From our analysis of the prior literature we were able to determine several benefits which are provided by Blockchain technology. We then categorised these benefits as they relate to; the ability of Blockchain to capture individual contributions, the performance of a Blockchain system for Distributed Collaboration, the ability of a system to prevent malicious behaviour in a collaborative environment, and the ability of the system to manage interactions among collaborators. A complete record of the benefits we found is presented in Table 9.1 below.

Table 9.1 Review of the benefits of Blockchain as they relate to Distributed Collaboration

	Benefit	Source
Ability to capture individual contribu-	Transparency/ Auditability	(Marten Risius, 2017) (Hyvärinen et al., 2017) (Nofer, Gomber, Hinz, & Schiereck, 2017) (Cholewa & Shanmugam, 2017) (Niederman et al., 2017) (Avital, 2018) (Mendling, Decker, Richard, Hajo, & Ingo, 2018) (Lacity, 2018) (Tapscott & Tapscott, 2017) (Wang et al., 2018) (Moyano & Ross, 2017) (Gozman, Liebenau, & Mangan, 2018) (Gomber, Kauffman, Parker, & Weber, 2018) (Egelund-Müller, Elsman, Henglein, & Ross, 2017) (Mendling et al., 2018) (Tapscott & Tapscott, 2017) (Zheng et al., 2018a) (Clemons, Dewan, Kauffman, & Weber, 2017)
	Prevent Double Spend	(Hyvärinen et al., 2017) (Cholewa & Shanmugam, 2017) (Yuan, Xia, Chen, Zang, & Xie, 2018) (Gao et al., 2018) (Derks, Gordijn, & Siegmann, 2018) (Clemons et al., 2017)

	Availability / Consistency/ Single Truth	(Marten Risius, 2017) (Egelund-Müller et al., 2017) (Nofer et al., 2017) (Cholewa & Shanmugam, 2017) (Mendling et al., 2018) (Yuan et al., 2018) (Lacity, 2018) (Moyano & Ross, 2017) (Gao et al., 2018) (Beck et al., 2018) (Hyvärinen et al., 2017) (Tapscott & Tapscott, 2017) (Zheng et al., 2018a) (Derks et al., 2018) (Gozman et al., 2018) (Clemons et al., 2017)
	Immutability	(Marten Risius, 2017) (Hyvärinen et al., 2017) (Cholewa & Shanmugam, 2017) (Mendling et al., 2018) (Yuan et al., 2018) (Lacity, 2018) (Tapscott & Tapscott, 2017) (Wang et al., 2018) (Moyano & Ross, 2017) (Gao et al., 2018) (Gozman et al., 2018) (Clemons et al., 2017) (Gomber et al., 2018)
	Accessibility	(Marten Risius, 2017) (Hyvärinen et al., 2017) (Cholewa & Shanmugam, 2017) (Gozman et al., 2018)
System Performance	Interoperability	(Marten Risius, 2017) (Hyvärinen et al., 2017) (Wang et al., 2018) (Moyano & Ross, 2017)
	Modularity	(Marten Risius, 2017) (Cholewa & Shanmugam, 2017) (Avital, 2018)
	Reduce Costs	(Hyvärinen et al., 2017) (Egelund-Müller et al., 2017) (Nofer et al., 2017) (Cholewa & Shanmugam, 2017) (Yuan et al., 2018) (Lacity, 2018) (Tapscott & Tapscott, 2017) (Moyano & Ross, 2017) (Gozman et al., 2018) (Gomber et al., 2018) (Beck et al., 2018)
	Scalability	(Avital, 2018) (Zheng et al., 2018a)
Ability of a system to prevent malicious	Fraud Resistant	(Marten Risius, 2017) (Hyvärinen et al., 2017) (Beck, Avital, Rossi, & Thatcher, 2017a) (Avital, 2018) (Yuan et al., 2018) (Lacity, 2018) (Tapscott & Tapscott, 2017) (Zheng et al., 2018a) (Wang et al., 2018) (Gao et al., 2018) (Steininger, 2018) (Beck et al., 2018)
	Security	(Hyvärinen et al., 2017) (Egelund-Müller et al., 2017) (Nofer et al., 2017) (Nofer et al., 2017) (Cholewa & Shanmugam, 2017) (Niederman et al., 2017) (Thatcher, Pu, & Pienta, 2018) (Avital, 2018) (Yuan et al., 2018) (Lacity, 2018) (Tapscott & Tapscott, 2017) (Zheng et al., 2018a) (Wang et al., 2018) (Gao et al., 2018) (Derks et al., 2018) (Clemons et al., 2017) (Gomber et al., 2018) (Beck et al., 2018)
	Privacy	(Zheng et al., 2018a) (Yuan et al., 2018) (Derks et al., 2018)

Ability of the system to manage interactions	Trust/ Disintermediation	(Marten Risius, 2017) (Nofer et al., 2017) (Beck et al., 2017a) (Cholewa & Shanmugam, 2017) (Niederman et al., 2017) (Thatcher et al., 2018) (Mendling et al., 2018) (Yuan et al., 2018) (Lacity, 2018) (Tapscott & Tapscott, 2017) (Zheng et al., 2018a) (Wang et al., 2018) (Moyano & Ross, 2017) (Derks et al., 2018) (Clemons et al., 2017) (Gomber et al., 2018) (Steininger, 2018) (Beck et al., 2018) (Hyvärinen et al., 2017) (Egelund-Müller et al., 2017) (Avital, 2018) (Kane, 2016) (Gao et al., 2018) (Steininger, 2018)
	Anonymity	(Marten Risius, 2017) (Moyano & Ross, 2017) (Beck et al., 2018)
	Token Transfer	(Hyvärinen et al., 2017) (Avital, 2018) (Moyano & Ross, 2017)
	Authentication	(Hyvärinen et al., 2017) (Cholewa & Shanmugam, 2017) (Mendling et al., 2018) (Lacity, 2018) (Beck et al., 2018)

9.4 Technical Architecture of Blockchain Proof-of-Concept

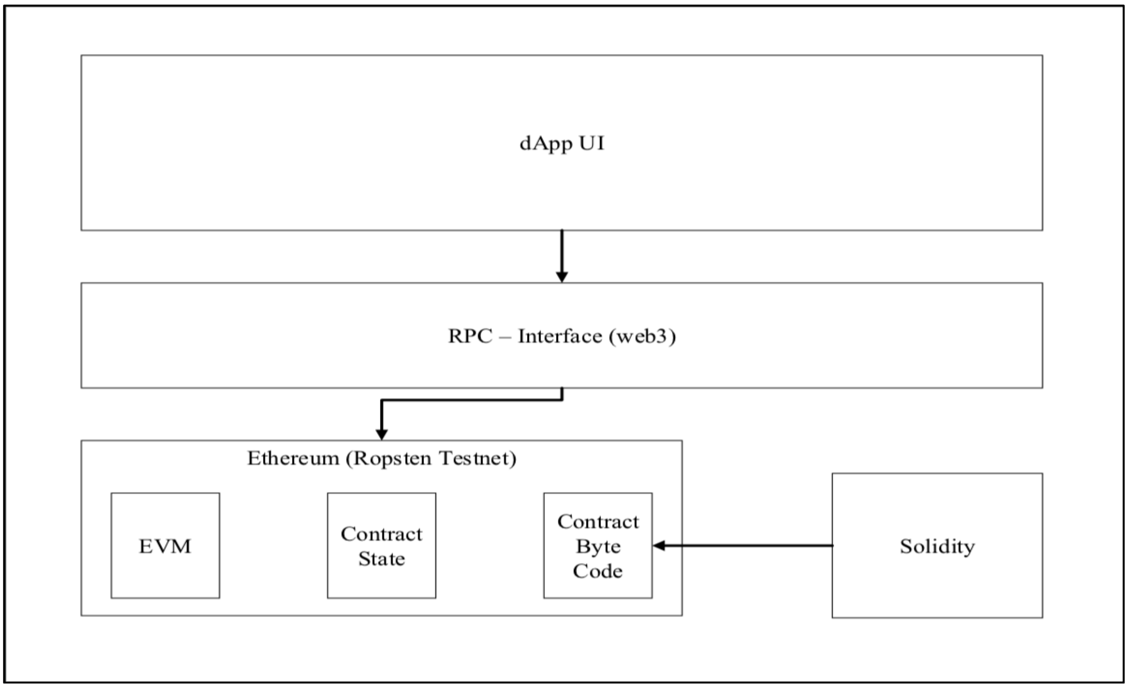

Figure 9.3 dApp Architecture, adapted from (Koppelmann, 2016)

The three main technical components involved in the development were Amazon Web Services Elastic Cloud Compute (EC2) instance, the Web3 API, and Ropsten Ethereum testnet.

Concerning Figure 9.3 above, the AWS EC2 instance is represented by the 'DAPP - UI' element. We created our user interface using traditional web development languages, HTML, CSS, PHP, and JavaScript. These were then hosted on the EC2 instance provided by AWS.

We used the web3 object provided by the web3.js library to run the system on the Ethereum network. Behind the scenes it communicates to a local node through RPC (Remote Procedure Call) calls, as web3.js is configured to work with any Ethereum node which exposes an RPC layer (Web3, 2017). In our instance the web3 interface was handled using the Metamask extension for Google Chrome. Metamask allows users to run Ethereum dApps right from their browser without having to run a full Ethereum node

(Metamask, 2018). Metamask was essential in order for users to participate in our system demo. By hosting the front-end application on AWS, users were able to access the system from their machines, we then had each participant add the Metamask extension to their Chrome which allowed them to interact with the Blockchain-enabled application.

The smart contracts were coded using Solidity and mined to the Ropsten Ethereum testnet (Appendix 9.6). The ropsten testnet is simply a version of the Ethereum network which is no different from the live network except for the fact that it was developed for testing and uses test ether which costs nothing and can be drawn down from a faucet (Dannen, 2017).

9.5 Cutter Prediction Article – Cryptocurrency Adoption in 2018

2017 was, without doubt, the breakout year for cryptocurrencies. As of 31 December 2017, the total market cap was over US $614 billion; a week later, it reached an all-time high of over $820 billion (coinmarketcap.com, 2019). This wealth is spread across 1,340 different cryptocurrencies, the leading two being Bitcoin and Ethereum with market caps of over $191 billion and $116 billion respectively, at the time of writing. Indeed, both Bitcoin and Ethereum have experienced incredible growth during the last 12 months. Bitcoin's closing price as of 1 January 2017 was $958.70. It closed out the year at $14,156.40, representing a 1,477% rise, having reached a record high in December of $17,899.70. While Bitcoin grabbed most of the headlines due to its long-established position as the crypto-market leader, Ethereum outperformed Bitcoin in terms of percentage increase. The number two currency rose in value by 8,688% this year, from a closing price of $8.17 on New Year's Day 2017 to $756.73 on New Year's Eve. Naturally, these eye-watering figures have led to suggestions that the market is in a dangerous bubble that is about to pop. For instance, Jamie Dimon, CEO of JP Morgan stated that Bitcoin traders are "stupid" and if he were to catch one of his employees trading Bitcoin, that person would be fired on the spot (Son, Levitt, & Louis, 2017).

This article focuses on Bitcoin and Ethereum and how 2018 will prove to be a make-or-break year for both cryptocurrencies, where they will either continue to be viewed as highly volatile, speculative assets, or transition to commercially viable instantiations of Blockchain technology.

The term "cryptocurrency" has been used to describe both currencies. However, they each represent unique Blockchain networks with disparate value propositions. Bitcoin is "[a] purely peer-to-peer version of electronic cash [that] allow[s] online payments to be sent directly from one party to another without going through a financial institution" (Nakamoto, 2008). Ethereum is "[a] decentralised platform that runs smart contracts: applications that run as programmed without any possibility of downtime, censorship, fraud, or third-party interference" (Ethereum, 2018). However, several studies have shown that users of the cryptocurrencies have only entered the market to trade the currencies as speculative assets and to cash in on their returns for traditional fiat currency (Glaser et al., 2014). Speculative trading is not the purpose of either currency or as the prices of both assets increase, their adoption for their originally intended purpose becomes less likely.

The Winklevoss twins, widely known for their IP theft lawsuit with Facebook, recently became the first "Bitcoin Billionaires" (Morris, 2017). The brothers invested $11 million of their pay-out from Facebook into the cryptocurrency in April 2013. However, they have reportedly never sold a single coin, meaning that their crypto-portfolio is only worth a fortune on paper.

The reality is that they still buy their coffees using US dollars. The cruel irony in all this is that if news broke that the Winklevoss twins had sold a portion of their holdings, it would likely be taken as a sign that they had lost confidence in the currency, leading to a mass sell-off in the market. In fact, despite widespread media attention focusing on Bitcoin, until it is possible to be paid in Bitcoin, and pay rent in Bitcoin, the cryptocurrency remains unsuccessful.

9.5.1 Bitcoin and Ethereum: The Year Ahead

As the price of Bitcoin continues to rise, retailers become more reluctant to accept it as a means of payment. For instance, online gaming service Steam announced in December that it would stop accepting Bitcoin payments, citing "high fees and volatility" as the reason for its decision (Dinkins, 2017). Worse still, it was recently disclosed that the

North American Bitcoin Conference no longer accepts Bitcoin payments due to network congestion and manual processing (Price, 2018). Unfortunately, I predict that this trend will continue, and Bitcoin will struggle to be accepted as a viable alternative to fiat currencies.

In addition to rising prices, increased transaction fees, and network congestion, another serious threat to Bitcoin adoption in 2018 will be energy consumption. Over the last month or so, media attention has increasingly focused on the amount of energy the Bitcoin network consumes during the proof-of-work (POW) mining process, with many sources reporting that the network requires the same amount of electricity in a year as entire countries such as Denmark or Ireland (Compare, 2018). China has already started to crack down on this issue and has announced that it plans to shut down Bitcoin miners. I believe that more governments will adopt a similar approach to regulating Bitcoin in the year ahead.

Similarly, despite a meteoric rise in market price in 2017, Ethereum also remains relatively unsuccessful. The vision for Ethereum is to create a platform for others to develop smart contracts. Ether, the cryptocurrency, is simply a fuel to run this platform. Therefore, the rise in the price of Ether over the past 12 months is a double-edged sword in that it has now become more expensive to develop and interact with smart contract applications hosted on the Ethereum network.

However, there have been signs of progress to come, tongue-in-cheek though it may appear. November 2017 saw the launch of perhaps the first viral Ethereum application, CryptoKitties (CryptoKitties, 2018). CryptoKitties is an online marketplace where users can buy virtual cats with Ethereum and then breed them with other users of the service. Although CryptoKitties may not be an industry-focused application, it proves the ability of the Ethereum network to host a smart contract application that tracks the provenance of digital assets in a secure, verifiable, and immutable fashion.

Plans for more serious applications have been announced, and we will likely see many of these go live in the next 12 months. In May 2017, Bank of America demonstrated the progress it had made on an Ethereum-based application that automates the process of creating a standby letter of credit ("Bank of America Reveals Progress on Ethereum-Based Application for Global Treasuries," 2017). Both the Canadian and Russian governments have expressed significant interest in Ethereum as well, perhaps due to Vitalik Buterin, founder of the network, holding dual citizenship in these countries. Moreover, the Enterprise Ethereum Alliance, formed in May 2017, now consists of roughly 200 companies, ranging from *Fortune* 500 companies to start-ups, all working to develop smart contract applications on the Ethereum platform (Alliance, 2017). I predict that 2018 will be the year that these applications begin to go live.

Another significant value proposition offered by Ethereum is that it is actively working on moving from the energy-sapping POW mining process to proof-of-stake (POS), which is said to be far more environmentally friendly and more efficient to run. Ethereum expects this transition to be completed in the next year.

Although 2017 was the year that the cryptocurrency market exploded, I believe that the unprecedented growth has exposed Bitcoin as an impractical alternative to traditional, government-backed currencies. Ethereum, on the other hand, has benefited from the increased attention over the last 12 months, and I feel it is set to thrive in 2018.

9.6 Survey Questions from Chapter 5

Questionnaire
Questions for Management
Are the teams in your organisation distributed among; different departments in the same office, different offices in the same country, different offices in multiple countries?
Do project teams in your organisation consist of members from the same operating department or many different operating departments?
What is the typical size of a project team in your organisation? 4 or less, 4-10, 10+
How do you currently track and reward individual contributions to an overall group project? (End-of-week Timesheet system or a more holistic approach)
From a managerial perspective, do you see any weaknesses in the current approach to tracking individual contributions? What do you believe is not being captured by the current system which should be captured in order to properly reflect an individual's output.
From a user-experience perspective, what are the primary pain points you encounter when using this system?
When conducting performance reviews, what metrics do you currently use to assess employee performance?
What additional metrics would you like to have data on if it were possible to assist you in your review?
Do you believe that when operating as part of a Distributed Collaboration group, individual members begin to feel less responsible for the overall success or failure of a project?
If so how do you attempt to combat this?
Do you believe that when operating as part of a Distributed Collaboration group, individual members find it difficult to establish a personal relationship with their colleagues due to a lack of face-to-face social interaction?
If so how do you attempt to combat this?
Do you currently recognise or reward unsuccessful attempts to innovate/solve problems being faced by a group in your organisation?
Do you believe that individuals are reluctant to contribute an innovative idea to assist in a group project for fear that their IP will not be recognised or rewarded?
Do you experience issues with task allocation in group projects whereby multiple streams are attempting to tackle the same issue rather than each member adopting separate approaches and then sharing their results with one another?
Do you believe that employees in your organisation recognise the personal benefits of contributing to the overall objective of a group project (are your employees intrinsically motivated to contribute)?
Do you believe that a system that would record each individuals contribution to a group project could improve employee motivation to work?
If there was a system in place for tracking individual contributions to group projects, what do you believe would be the key factors to success for this system?
If there was a system in place for tracking individual contributions to group projects, what would be your primary concerns for adopting such a system in your organisation?

Questions for Employees
Do you believe that when operating as part of a Distributed Collaboration group, your own contribution is being recognised and rewarded by management?
How is your contribution to group projects currently recorded? Timesheet systems etc.
From a user-experience perspective, what are the primary pain points you encounter when using this system?
Do you believe that the current approach is effectively capturing a true reflection of the contribution you make to your team?
What aspects of your work would you like to see captured by a system in order to guarantee that management is aware of your efforts?
When operating in group projects, what performance metrics are you judged on?
What additional metrics would you like to see gathered and analysed by management to present a better representation of your performance?
Do you believe that when operating as part of a Distributed Collaboration group, your own contributions contribute directly to the overall success or failure of the group?
Do you believe that when operating as part of a Distributed Collaboration group, members from other business functions are often the cause of issues within the group that lead to project failure?
Do you believe that when operating as part of a Distributed Collaboration group, it is difficult to establish a personal relationship with their colleagues due to a lack of face-to-face social interaction?
When operating as part of a Distributed Collaboration group have you ever been reluctant to contribute an idea to the team for fear that your IP will be consumed by the team and your individual effort will not be recognised and rewarded?
In terms of end of year bonuses or internal rewards, do you believe these are allocated based on performance data that has been analysed by management or a more personal selection process?
Do you believe that a data-driven approach to these programs would be more suitable?
If there was a system in place for tracking individual contributions to group projects, what do you believe would be the key factors to success for this system?
If there was a system in place for tracking individual contributions to group projects, what would be your primary concerns for adopting such a system in your organisation?

9.7 Survey Questions from Chapter 6

Questionnaire
Creative Ancestry
The system makes it easy for everyone to see the ideas that were presented by different people.
I feel it would be difficult for someone to take all the credit by hiding the contribution made by other people.
The system makes it easy to see the specific people responsible for developing an idea.
It was easy to see how individual ideas grew from previous ideas put forward by other people.
I could see how a particular idea emerged as part of a larger conversation involving multiple people.
Perceived distributive justice
I had an important contribution to this ideation collaboration.
The credit I receive from this ideation collaboration is likely to be fair.
Each person had an important contribution to this ideation collaboration.
The credit each person receives from this ideation collaboration is likely to be fair.
Perceived procedural justice
The system used for this ideation collaboration has fair policies for each person using it.
The system used for this ideation collaboration generally treats all people using it fairly.
The system used for this ideation collaboration is equitable in its treatment of each person using it.
Perceived interactional justice
Each person participating in this ideation collaboration is honest in dealing with other people.
Each person participating in this ideation collaboration respects the other people using it.
Each person participating in this ideation collaboration always communicates with other people using it openly and directly.
Each person participating in this ideation collaboration always provides other people using it timely feedback.
Collaboration
The people participating in this ideation collaboration figured out effective ways to communicate.
The people participating in this ideation collaboration worked together in developing new high-level topics.
The people participating in this ideation collaboration collaborated in coming up with new ideas.
The people participating in this ideation collaboration collaborated in fleshing out the details of ideas.
The people participating in this ideation collaboration had frequent interactions when problems with ideas or high-level topics occurred.
User satisfaction

The ideation collaboration system was satisfactory as a whole.
The ideation collaboration system is of high quality.
The ideation collaboration system meets my expectations.
Group Creativity
We were insightful in our work
I felt like we were innovative in our thinking
Overall, I think our ideas were creative
Cognitive Group Consensus
I am confident in the ideas the group put forward
I feel the ideas selected were the best ideas the group came up with
I personally argued for specific ideas before they were selected
The ideas selected were consistent with my own personal priorities and interests
Behavioural intention to use
Assuming that I have access to mobile banking systems, I intend to use them.
I intend to increase my use of mobile banking in the future.
Control variables
Did you contribute one or more ideas? (Y/N)
Did you vote on one or more other people's ideas? (Y/N)
Age: __/prefer not to say
Gender: Male/Female/Other or prefer not to say

9.8 Solidity Smart Contract

```
pragma solidity ^0.4.19;
contract Threads {
  struct IdeaStruct {
    uint ideaID;
    string ideaText;
    address ideaOwner;
    string ownerName;
    uint ideaTime;
    uint ideaVotes;
    bool isIdea;
    bool isAgreed;
  }
  struct CommentStruct {
    uint ideaID;
    uint commentID;
    string commentText;
    address commentOwner;
    string ownerName;
    uint commentTime;
    uint commentVotes;
    bool isComment;
```

```
    bool isAgreed;
  }
  mapping(uint => IdeaStruct) public ideaStructs;
  mapping(uint => CommentStruct) public commentStructs;
  event NewIdea(uint indexed _ideaID, string _ideaText, address _ideaOwner, string ownerName, uint _ideaTime, uint _ideaVotes, bool _isIdea, bool _isAgreed);
event NewComment(uint indexed _ideaID, uint indexed _commentID, string _commentText, address _commentOwner, string ownerName, uint _commentTime, uint _commentVotes, bool _isComment, bool _isAgreed);
  uint[] public ideaList;
  uint[] public commentList;
  function isIdea(uint ideaID) public constant returns(bool isIndeed) {
    return ideaStructs[ideaID].isIdea;
  }
  function ideaVoteCount (uint ideaID) public constant returns(uint voteCount){
    return ideaStructs[ideaID].ideaVotes;
  }
  function isIdeaAgreed(uint ideaID) public constant returns(bool isIndeedAgreed) {
    return ideaStructs[ideaID].isAgreed;
  }
  function isComment(uint commentID) public constant returns(bool isIndeed) {
    return commentStructs[commentID].isComment;
```

```
 }
 function commentVoteCount (uint commentID) public constant returns(uint voteCount){
    return commentStructs[commentID].commentVotes;
 }
 function isCommentAgreed(uint commentID) public constant returns(bool isIndeedAgreed) {
    return commentStructs[commentID].isAgreed;
 }
 function getIdeaCount() public constant returns(uint ideaCount) {
   return ideaList.length;
 }
 function getCommentCount() public constant returns(uint commentCount) {
   return commentList.length;
 }
 function newIdea(string ideaText, string ownerName) public returns(uint rowNumber) {
   uint IdeaCount = ideaList.length;
   uint ID = IdeaCount + 1;
   require (!isIdea(ID));
   ideaStructs[ID].ideaID = ID;
   ideaStructs[ID].ideaText = ideaText;
```

```
    ideaStructs[ID].ideaOwner = msg.sender;
    ideaStructs[ID].ownerName = ownerName;
    ideaStructs[ID].ideaTime = now;
    ideaStructs[ID].ideaVotes = 0;
    ideaStructs[ID].isIdea = true;
    ideaStructs[ID].isAgreed = false;
    NewIdea(ID, ideaText, msg.sender, ownerName, now, 0, true, false);
    return ideaList.push(ID) - 1;
  }
  function newComment(uint ideaID, string commentText, string ownerName) public returns(uint rowNumber) {
    uint CommentCount = commentList.length;
    uint ID = CommentCount + 1;
    require (!isComment(ID));
    commentStructs[ID].ideaID = ideaID;
    commentStructs[ID].commentID = ID;
    commentStructs[ID].commentText = commentText;
    commentStructs[ID].commentOwner = msg.sender;
    commentStructs[ID].ownerName = ownerName;
    commentStructs[ID].commentTime = now;
    commentStructs[ID].commentVotes = 0;
    commentStructs[ID].isComment = true;
```

```
    commentStructs[ID].isAgreed = false;
    NewComment(ideaID,ID, commentText, msg.sender, ownerName, now, 0, true, false);
    return commentList.push(ID) - 1;
  }
  function updateIdeaVotes(uint ideaID) public returns(bool success) {
    require (isIdea(ideaID));
    require (!isIdeaAgreed(ideaID));
    if (ideaVoteCount(ideaID) == 4){
    ideaStructs[ideaID].ideaVotes ++;
    ideaStructs[ideaID].isAgreed = true;
    }
    else{
    ideaStructs[ideaID].ideaVotes ++;
    return true;
  }
  }
  function updateCommentVotes(uint commentID) public returns(bool success) {
    require(isComment(commentID));
    require (!isCommentAgreed(commentID));
    if (commentVoteCount(commentID) == 4){
        commentStructs[commentID].commentVotes ++;
```

```
        commentStructs[commentID].isAgreed = true;
    }
    else{
    commentStructs[commentID].commentVotes ++;
    return true;
  }
  }
}
```

9.9 R Scripts for Cryptocurrency Market Analysis

9.9.1 Transform Raw Data

```r
library(vars)
library(forecast)
library(tseries)
library(dplyr)
library(sandwich)
library(urca)
library(corrplot)
library(ggplot2)
#Daily Data
Bitcoin <- read.csv("/Users/kevinoleary/College Drive/State Street ATC/4.Crypto Market Paper/ECIS 2019/Data Analysis/Raw Data/BTC-USD.csv")
Ether <- read.csv("/Users/kevinoleary/College Drive/State Street ATC/4.Crypto Market Paper/ECIS 2019/Data Analysis/Raw Data/ETH-USD.csv")
Litecoin <- read.csv("/Users/kevinoleary/College Drive/State Street ATC/4.Crypto Market Paper/ECIS 2019/Data Analysis/Raw Data/LTC-USD.csv")
Euro <- read.csv("/Users/kevinoleary/College Drive/State Street ATC/4.Crypto Market Paper/ECIS 2019/Data Analysis/Raw Data/EUR-USD.csv")
JapYen <- read.csv("/Users/kevinoleary/College Drive/State Street ATC/4.Crypto Market Paper/ECIS 2019/Data Analysis/Raw Data/JPY-USD.csv")
#Weekly Data
```

```
BTCweekly <- read.csv("/Users/kevinoleary/College Drive/State Street ATC/4.Crypto Market Paper/ECIS 2019/Data Analysis/Raw Data/Weekly Raw Data/BTC-USD.csv")
ETHweekly <- read.csv("/Users/kevinoleary/College Drive/State Street ATC/4.Crypto Market Paper/ECIS 2019/Data Analysis/Raw Data/Weekly Raw Data/ETH-USD.csv")
LTCweekly <- read.csv("/Users/kevinoleary/College Drive/State Street ATC/4.Crypto Market Paper/ECIS 2019/Data Analysis/Raw Data/Weekly Raw Data/LTC-USD.csv")
EURweekly <- read.csv("/Users/kevinoleary/College Drive/State Street ATC/4.Crypto Market Paper/ECIS 2019/Data Analysis/Raw Data/Weekly Raw Data/EUR-USD.csv")
GBPweekly <- read.csv("/Users/kevinoleary/College Drive/State Street ATC/4.Crypto Market Paper/ECIS 2019/Data Analysis/Raw Data/Weekly Raw Data/GBP-USD.csv")
JPYweekly <- read.csv("/Users/kevinoleary/College Drive/State Street ATC/4.Crypto Market Paper/ECIS 2019/Data Analysis/Raw Data/Weekly Raw Data/JPY-USD.csv")
# Transform weekly data
BTCweekly <- BTCweekly$Close
ETHweekly <- ETHweekly$Close
LTCweekly <- LTCweekly$Close
EURweekly <- EURweekly$Price
GBPweekly <- GBPweekly$Price
JPYweekly <- JPYweekly$Price
# Transform Bitcoin data
BTC <- Bitcoin$Close
BTClog <- log(BTC)
BTCdiff <- diff(BTC, differences = 1)
```

```
BTCdiff2 <- BTCdiff+((min(BTCdiff)*-1)+1)
confirm <- max(BTCdiff) - min(BTCdiff)
confirm2 <- max(BTCdiff2) - min(BTCdiff2)
BTClogdiff <- log(BTCdiff2)
BTCdiff2 <- diff(BTC, differences = 2)
# Transform Ether data
ETH <- Ether$Close
ETHlog <- log(ETH)
ETHdiff <- diff(ETH, differences = 1)
ETHdiff2 <- ETHdiff+((min(ETHdiff)*-1)+1)
confirm <- max(ETHdiff) - min(ETHdiff)
confirm2 <- max(ETHdiff2) - min(ETHdiff2)
ETHlogdiff <- log(ETHdiff2)
ETHdiff2 <- diff(ETH, differences = 2)
# Transform Litecoin data
LTC <- Litecoin$Close
LTClog <- log(LTC)
LTCdiff <- diff(LTC, differences = 1)
LTCdiff2 <- LTCdiff+((min(LTCdiff)*-1)+1)
confirm <- max(LTCdiff) - min(LTCdiff)
confirm2 <- max(LTCdiff2) - min(LTCdiff2)
confirm
```

```
confirm2
LTClogdiff <- log(LTCdiff2)
LTCdiff2 <- diff(LTC, differences = 2)
# Transform Euro data
EUR <- Euro$Price
EURlog <- log(EUR)
EURdiff <- diff(EUR, differences = 1)
EURdiff2 <- EURdiff+((min(EURdiff)*-1)+1)
confirm <- max(EURdiff) - min(EURdiff)
confirm2 <- max(EURdiff2) - min(EURdiff2)
EURlogdiff <- log(EURdiff2)
EURdiff2 <- diff(EUR, differences = 2)
# Transform JPYo data
JPY <- JapYen$Price
JPYlog <- log(JPY)
JPYdiff <- diff(JPY, differences = 1)
JPYdiff2 <- JPYdiff+((min(JPYdiff)*-1)+1)
confirm <- max(JPYdiff) - min(JPYdiff)
confirm2 <- max(JPYdiff2) - min(JPYdiff2)
JPYlogdiff <- log(JPYdiff2)
JPYdiff2 <- diff(JPY, differences = 2)
##Create Chart of Cryptos
```

```
CryptoPriceChart <- data.frame(BTC, ETH, LTC, XRP)
colnames(CryptoPriceChart) <- c("BTC","ETH","LTC","XRP")
plot.ts(CryptoPriceChart)
plot(BTCdiff)
plot(ETHdiff)
plot(LTCdiff)
plot(XRPdiff)
CurrenciesWeekly <- data.frame(BTCweekly, ETHweekly, LTCweekly, EURweekly, GBPweekly, JPYweekly)
colnames(CurrenciesWeekly) <- c("BTC","ETH","LTC", "EUR", "GBP", "JPY")
corrplot(corrplotCurrenciesWeekly, p.mat = res1$p, sig.level = .05)
corrplotCurrenciesWeekly <- cor(CurrenciesWeekly, method = c("pearson"))
summary(corrplotCurrenciesWeekly)
corrplot(corrplotCurrenciesWeekly)
col <- colorRampPalette(c("#BB4444", "#EE9988", "#FFFFFF", "#77AADD", "#4477AA"))
res1 <- cor.mtest(CurrenciesWeekly, conf.level = .95)
corrplot(corrplotCurrenciesWeekly, method="color", col=col(200),
    type="full",
    addCoef.col = "black", # Add coefficient of correlation
    tl.col="black", tl.srt=45) #Text label color and rotation)
corrplot(corrplotCurrenciesWeekly, method="color", col=col(200),
```

```
    type="full",
    p.mat = corrplotCurrenciesWeekly, insig = "p-value")
corrplot(corrplotCurrenciesWeekly, p.mat = res1$p, insig = "p-value")
BTCETHChart <- data.frame(BTC, ETH)
colnames(BTCETHChart) <- c("BTC","ETH")
plot(BTC, ETH)
```

9.9.2 Stationarity Tests

```
                              ############## ADF and KPSS tests for Stationarity
                              ############## ADF tests for Stationarity
# Run ADF tests for Bitcoin
BTCadf <- adf.test(BTC)
BTClogadf <- adf.test(BTClog)
BTCdiffadf <- adf.test(BTCdiff)
BTClogdiffadf <- adf.test(BTClogdiff)
BTCdiffadf2 <- adf.test(BTCdiff2)
# Run ADF tests for Ether
ETHadf <- adf.test(ETH)
ETHlogadf <- adf.test(ETHlog)
ETHdiffadf <- adf.test(ETHdiff)
ETHlogdiffadf <- adf.test(ETHlogdiff)
ETHdiffadf2 <- adf.test(ETHdiff2)
# Run ADF tests for Litecoin
```

```
LTCadf <- adf.test(LTC)
LTClogadf <- adf.test(LTClog)
LTCdiffadf <- adf.test(LTCdiff)
LTClogdiffadf <- adf.test(LTClogdiff)
LTCdiffadf2 <- adf.test(LTCdiff2)
# Run ADF tests for Euro
EURadf <- adf.test(EUR)
EURlogadf <- adf.test(EURlog)
EURdiffadf <- adf.test(EURdiff)
EURlogdiffadf <- adf.test(EURlogdiff)
EURdiffadf2 <- adf.test(EURdiff2)
# Run ADF tests for JPYo
JPYadf <- adf.test(JPY)
JPYlogadf <- adf.test(JPYlog)
JPYdiffadf <- adf.test(JPYdiff)
JPYlogdiffadf <- adf.test(JPYlogdiff)
JPYdiffadf2 <- adf.test(JPYdiff2)
############## ADF Tests Results
BTCadfpvalue <- BTCadf$p.value
BTClogadfpvalue <- BTClogadf$p.value
BTCdiffadfpvalue <- BTCdiffadf$p.value
BTClogdiffadfpvalue <- BTClogdiffadf$p.value
```

```
BTCdiffadfpvalue2 <- BTCdiffadf2$p.value
ETHadfpvalue <- ETHadf$p.value
ETHlogadfpvalue <- ETHlogadf$p.value
ETHdiffadfpvalue <- ETHdiffadf$p.value
ETHlogdiffadfpvalue <- ETHlogdiffadf$p.value
ETHdiffadfpvalue2 <- ETHdiffadf2$p.value
LTCadfpvalue <- LTCadf$p.value
LTClogadfpvalue <- LTClogadf$p.value
LTCdiffadfpvalue <- LTCdiffadf$p.value
LTClogdiffadfpvalue <- LTClogdiffadf$p.value
LTCdiffadfpvalue2 <- LTCdiffadf2$p.value
EURadfpvalue <- EURadf$p.value
EURlogadfpvalue <- EURlogadf$p.value
EURdiffadfpvalue <- EURdiffadf$p.value
EURlogdiffadfpvalue <- EURlogdiffadf$p.value
EURdiffadfpvalue2 <- EURdiffadf2$p.value
JPYadfpvalue <- JPYadf$p.value
JPYlogadfpvalue <- JPYlogadf$p.value
JPYdiffadfpvalue <- JPYdiffadf$p.value
JPYlogdiffadfpvalue <- JPYlogdiffadf$p.value
JPYdiffadfpvalue2 <- JPYdiffadf2$p.value
```

```
pvaluesadf <- c(BTCadfpvalue, BTClogadfpvalue, BTCdiffadfpvalue, BTClogdiffadfpvalue, BTCdiffadfpvalue,
        ETHadfpvalue, ETHlogadfpvalue, ETHdiffadfpvalue, ETHlogdiffadfpvalue, ETHdiffadfpvalue2,
        LTCadfpvalue, LTClogadfpvalue, LTCdiffadfpvalue, LTClogdiffadfpvalue, LTCdiffadfpvalue2,
        EURadfpvalue, EURlogadfpvalue, EURdiffadfpvalue, EURlogdiffadfpvalue, EURdiffadfpvalue2,
        JPYadfpvalue, JPYlogadfpvalue, JPYdiffadfpvalue, JPYlogdiffadfpvalue, JPYdiffadfpvalue2)
#Create adf Data Frame
dfadf <- data.frame(pvaluesadf)
rownames(dfadf) <- c("BTC", "BTClog", "BTCdiff", "BTClogdiff","BTCdiff2",
            "ETH", "ETHlog", "ETHdiff", "ETHlogdiff", "ETHdiff2",
            "LTC", "LTClog", "LTCdiff", "LTClogdiff", "LTCdiff2",
            "EUR", "EURlog", "EURdiff", "EURlogdiff", "EURdiff2",
            "JPY", "JPYlog", "JPYdiff", "JPYlogdiff", "JPYdiff2")
                              ############## KPSS tests for Stationarity
# Run KPSS tests for Bitcoin
BTCkpss <- kpss.test(BTC)
BTClogkpss <- kpss.test(BTClog)
BTCdiffkpss <- kpss.test(BTCdiff)
```

```
BTClogdiffkpss <- kpss.test(BTClogdiff)
BTCdiffkpss2 <- kpss.test(BTCdiff2)
# Run KPSS tests for Ether
ETHkpss <- kpss.test(ETH)
ETHlogkpss <- kpss.test(ETHlog)
ETHdiffkpss <- kpss.test(ETHdiff)
ETHlogdiffkpss <- kpss.test(ETHlogdiff)
ETHdiffkpss2 <- kpss.test(ETHdiff2)
# Run KPSS tests for Litecoin
LTCkpss <- kpss.test(LTC)
LTClogkpss <- kpss.test(LTClog)
LTCdiffkpss <- kpss.test(LTCdiff)
LTClogdiffkpss <- kpss.test(LTClogdiff)
LTCdiffkpss2 <- kpss.test(LTCdiff2)
# Run KPSS tests for Euro
EURkpss <- kpss.test(EUR)
EURlogkpss <- kpss.test(EURlog)
EURdiffkpss <- kpss.test(EURdiff)
EURlogdiffkpss <- kpss.test(EURlogdiff)
EURdiffkpss2 <- kpss.test(EURdiff2)
# Run KPSS tests for Euro
JPYkpss <- kpss.test(JPY)
```

```
JPYlogkpss <- kpss.test(JPYlog)
JPYdiffkpss <- kpss.test(JPYdiff)
JPYlogdiffkpss <- kpss.test(JPYlogdiff)
JPYdiffkpss2 <- kpss.test(JPYdiff2)
############## KPSS Tests Results
BTCkpsspvalue <- BTCkpss$p.value
BTClogkpsspvalue <- BTClogkpss$p.value
BTCdiffkpsspvalue <- BTCdiffkpss$p.value
BTClogdiffkpsspvalue <- BTClogdiffkpss$p.value
BTCdiffkpsspvalue2 <- BTCdiffkpss2$p.value
ETHkpsspvalue <- ETHkpss$p.value
ETHlogkpsspvalue <- ETHlogkpss$p.value
ETHdiffkpsspvalue <- ETHdiffkpss$p.value
ETHlogdiffkpsspvalue <- ETHlogdiffkpss$p.value
ETHdiffkpsspvalue2 <- ETHdiffkpss2$p.value
LTCkpsspvalue <- LTCkpss$p.value
LTClogkpsspvalue <- LTClogkpss$p.value
LTCdiffkpsspvalue <- LTCdiffkpss$p.value
LTClogdiffkpsspvalue <- LTClogdiffkpss$p.value
LTCdiffkpsspvalue2 <- LTCdiffkpss2$p.value
EURkpsspvalue <- EURkpss$p.value
EURlogkpsspvalue <- EURlogkpss$p.value
```

```
EURdiffkpsspvalue <- EURdiffkpss$p.value
EURlogdiffkpsspvalue <- EURlogdiffkpss$p.value
EURdiffkpsspvalue2 <- EURdiffkpss2$p.value
JPYkpsspvalue <- JPYkpss$p.value
JPYlogkpsspvalue <- JPYlogkpss$p.value
JPYdiffkpsspvalue <- JPYdiffkpss$p.value
JPYlogdiffkpsspvalue <- JPYlogdiffkpss$p.value
JPYdiffkpsspvalue2 <- JPYdiffkpss2$p.value
pvalueskpss <- c(BTCkpsspvalue, BTClogkpsspvalue, BTCdiffkpsspvalue, BTClogdiffkpsspvalue, BTCdiffkpsspvalue2,
    ETHkpsspvalue, ETHlogkpsspvalue, ETHdiffkpsspvalue, ETHlogdiffkpsspvalue, ETHdiffkpsspvalue2,
    LTCkpsspvalue, LTClogkpsspvalue, LTCdiffkpsspvalue, LTClogdiffkpsspvalue, LTCdiffkpsspvalue2,
    EURkpsspvalue, EURlogkpsspvalue, EURdiffkpsspvalue, EURlogdiffkpsspvalue, EURdiffkpsspvalue2,
    JPYkpsspvalue, JPYlogkpsspvalue, JPYdiffkpsspvalue, JPYlogdiffkpsspvalue, JPYdiffkpsspvalue2)
#Create kpss Data Frame
dfkpss <- data.frame(pvalueskpss)
rownames(dfkpss) <- c("BTC", "BTClog", "BTCdiff", "BTClogdiff", "BTCdiff2",
      "ETH", "ETHlog", "ETHdiff", "ETHlogdiff", "ETHdiff2",
```

```
             "LTC", "LTClog", "LTCdiff", "LTClogdiff", "LTCdiff2",

             "EUR", "EURlog", "EURdiff", "EURlogdiff", "EURdiff2",

             "JPY", "JPYlog", "JPYdiff", "JPYlogdiff", "JPYdiff2")

##Combined Data Frame of Both Results

dfStationarityPvalues <- cbind(dfkpss, dfadf)
```

9.9.3 VAR Tests

```
                              ####    Diff Log    #####

                               ###   BTC vs ETH  ####

BTCETHdifflog=cbind(BTClogdiff, ETHlogdiff)

BTCETHdifflog_VAR=VAR(BTCETHdifflog, type = "const", lag=1, ic="AIC")

BTCETHdifflog_VAR

##Null: btc does not cause eth

causality(BTCETHdifflog_VAR, cause = "BTClogdiff")$Granger

##Null: eth does not cause btc

causality(BTCETHdifflog_VAR, cause = "ETHlogdiff")$Granger

                                ###   BTC vs LTC  ####

BTCLTCdifflog=cbind(BTClogdiff, LTClogdiff)

BTCLTCdifflog_VAR=VAR(BTCLTCdifflog, type = "const", lag=1, ic="AIC")

BTCLTCdifflog_VAR

##Null: btc does not cause eth

causality(BTCLTCdifflog_VAR, cause = "BTClogdiff")$Granger

##Null: eth does not cause btc
```

```
causality(BTCLTCdifflog_VAR, cause = "LTClogdiff")$Granger
                                                  ###   ETH vs LTC  ####
ETHLTCdifflog=cbind(ETHlogdiff, LTClogdiff)
ETHLTCdifflog_VAR=VAR(ETHLTCdifflog, type = "const", lag=1, ic="AIC")
ETHLTCdifflog_VAR
##Null: Litecoin does not cause Ether
causality(ETHLTCdifflog_VAR, cause = "LTClogdiff")$Granger
##Null: Ether does not cause Litecoin
causality(ETHLTCdifflog_VAR, cause = "ETHlogdiff")$Granger
###   BTC vs EUR  ####
BTCEURdifflog=cbind(BTClogdiff, EURlogdiff)
BTCEURdifflog_VAR=VAR(BTCEURdifflog, type = "const", lag=1, ic="AIC")
BTCEURdifflog_VAR
##Null: btc does not cause EUR
causality(BTCEURdifflog_VAR, cause = "BTClogdiff")$Granger
##Null: EUR does not cause btc
causality(BTCEURdifflog_VAR, cause = "EURlogdiff")$Granger
###   LTC vs EUR  ####
LTCEURdifflog=cbind(LTClogdiff, EURlogdiff)
LTCEURdifflog_VAR=VAR(LTCEURdifflog, type = "const", lag=1, ic="AIC")
LTCEURdifflog_VAR
##Null: LTC does not cause EUR
```

```
causality(LTCEURdifflog_VAR, cause = "LTClogdiff")$Granger
##Null: EUR does not cause LTC
causality(LTCEURdifflog_VAR, cause = "EURlogdiff")$Granger
###   ETH vs EUR  ####
ETHEURdifflog=cbind(ETHlogdiff, EURlogdiff)
ETHEURdifflog_VAR=VAR(ETHEURdifflog, type = "const", lag=1, ic="AIC")
ETHEURdifflog_VAR
##Null: ETH does not cause EUR
causality(ETHEURdifflog_VAR, cause = "ETHlogdiff")$Granger
##Null: EUR does not cause ETH
causality(ETHEURdifflog_VAR, cause = "EURlogdiff")$Granger
###   BTC vs JPY  ####
BTCJPYdifflog=cbind(BTClogdiff, JPYlogdiff)
BTCJPYdifflog_VAR=VAR(BTCJPYdifflog, type = "const", lag=1, ic="AIC")
BTCJPYdifflog_VAR
##Null: btc does not cause JPY
causality(BTCJPYdifflog_VAR, cause = "BTClogdiff")$Granger
##Null: JPY does not cause btc
causality(BTCJPYdifflog_VAR, cause = "JPYlogdiff")$Granger
###   LTC vs JPY  ####
LTCJPYdifflog=cbind(LTClogdiff, JPYlogdiff)
LTCJPYdifflog_VAR=VAR(LTCJPYdifflog, type = "const", lag=1, ic="AIC")
```

```
LTCJPYdifflog_VAR
##Null: LTC does not cause JPY
causality(LTCJPYdifflog_VAR, cause = "LTClogdiff")$Granger
##Null: JPY does not cause LTC
causality(LTCJPYdifflog_VAR, cause = "JPYlogdiff")$Granger
###   ETH vs JPY  ####
ETHJPYdifflog=cbind(ETHlogdiff, JPYlogdiff)
ETHJPYdifflog_VAR=VAR(ETHJPYdifflog, type = "const", lag=1, ic="AIC")
ETHJPYdifflog_VAR
##Null: ETH does not cause JPY
causality(ETHJPYdifflog_VAR, cause = "ETHlogdiff")$Granger
##Null: JPY does not cause ETH
causality(ETHJPYdifflog_VAR, cause = "JPYlogdiff")$Granger
###   EUR vs JPY  ####
EURJPYdifflog=cbind(EURlogdiff, JPYlogdiff)
EURJPYdifflog_VAR=VAR(EURJPYdifflog, type = "const", lag=1, ic="AIC")
EURJPYdifflog_VAR
##Null: EUR does not cause JPY
causality(EURJPYdifflog_VAR, cause = "EURlogdiff")$Granger
##Null: JPY does not cause EUR
causality(EURJPYdifflog_VAR, cause = "JPYlogdiff")$Granger
```

9.9.4 IRF Graphs

```
                              ### BTC-ETH

#Forecast from shocks with impulse response

irf.BTCETH <-irf(BTCETHdifflog_VAR, impulse = "BTClogdiff",

                 response = "ETHlogdiff", boot =TRUE,

                 n.ahead=7,cumulative=TRUE,ci=0.95)

#Plot impulse response function

plot(irf.BTCETH, lwd=4)

#Forecast from shocks with impulse response

irf.ETHBTC <-irf(BTCETHdifflog_VAR, impulse = "ETHlogdiff",

                   response = "BTClogdiff", boot =TRUE,

                   n.ahead=7,cumulative=TRUE,ci=0.95)

#Plot impulse response function

plot(irf.ETHBTC, lwd=4)

                               ### BTC-LTC

#Forecast from shocks with impulse response

irf.BTCLTC <-irf(BTCLTCdifflog_VAR, impulse = "BTClogdiff",

            response = "LTClogdiff", boot =TRUE,

            n.ahead=7,cumulative=TRUE,ci=0.95)

#Plot impulse response function

plot(irf.BTCLTC, lwd=4)

#Forecast from shocks with impulse response
```

```
irf.LTCBTC <-irf(BTCLTCdifflog_VAR, impulse = "LTClogdiff",
        response = "BTClogdiff", boot =TRUE,
        n.ahead=7,cumulative=TRUE,ci=0.95)
#Plot impulse response function
plot(irf.LTCBTC, lwd=4)
                         ### LTC-ETH
#Forecast from shocks with impulse response
irf.LTCETH <-irf(ETHLTCdifflog_VAR, impulse = "LTClogdiff",
        response = "ETHlogdiff", boot =TRUE,
        n.ahead=7,cumulative=TRUE,ci=0.95)
#Plot impulse response function
plot(irf.LTCETH, lwd=4)
#Forecast from shocks with impulse response
irf.ETHLTC <-irf(ETHLTCdifflog_VAR, impulse = "ETHlogdiff",
        response = "LTClogdiff", boot =TRUE,
        n.ahead=7,cumulative=TRUE,ci=0.95)
#Plot impulse response function
plot(irf.ETHLTC, lwd=4)
### BTC-EUR
#Forecast from shocks with impulse response
irf.BTCEUR <-irf(BTCEURdifflog_VAR, impulse = "BTClogdiff",
        response = "EURlogdiff", boot =TRUE,
```

```
        n.ahead=7,cumulative=TRUE,ci=0.95)
#Plot impulse response function
plot(irf.BTCEUR, lwd=4)
#Forecast from shocks with impulse response
irf.EURBTC <-irf(BTCEURdifflog_VAR, impulse = "EURlogdiff",
        response = "BTClogdiff", boot =TRUE,
        n.ahead=7,cumulative=TRUE,ci=0.95)
#Plot impulse response function
plot(irf.EURBTC, lwd=4)
### LTC-EUR
#Forecast from shocks with impulse response
irf.LTCEUR <-irf(LTCEURdifflog_VAR, impulse = "LTClogdiff",
        response = "EURlogdiff", boot =TRUE,
        n.ahead=7,cumulative=TRUE,ci=0.95)
#Plot impulse response function
plot(irf.LTCEUR, lwd=4)
#Forecast from shocks with impulse response
irf.EURLTC <-irf(LTCEURdifflog_VAR, impulse = "EURlogdiff",
        response = "LTClogdiff", boot =TRUE,
        n.ahead=7,cumulative=TRUE,ci=0.95)
#Plot impulse response function
plot(irf.EURLTC, lwd=4)
```

```
### ETH-EUR
#Forecast from shocks with impulse response
irf.ETHEUR <-irf(ETHEURdifflog_VAR, impulse = "ETHlogdiff",
              response = "EURlogdiff", boot =TRUE,
              n.ahead=7,cumulative=TRUE,ci=0.95)
#Plot impulse response function
plot(irf.ETHEUR, lwd=4)
#Forecast from shocks with impulse response
irf.EURETH <-irf(ETHEURdifflog_VAR, impulse = "EURlogdiff",
              response = "ETHlogdiff", boot =TRUE,
              n.ahead=7,cumulative=TRUE,ci=0.95)
#Plot impulse response function
plot(irf.EURETH, lwd=4)
```

9.9.5 Polynomial Regression

```
##Original Series
###BTC vs ETH
plot(BTClog, ETHlog)
plot(LTClog, ETHlog)
plot(LTClog, BTClog)
plot(ETHlog, BTClog)
plot(BTClog, LTClog)
plot(LTClog, BTClog)
```

```
plot(LTClog, ETHlog)
plot(ETHlog, LTClog)
##  Ether as a predictor of Bitcoin
BTCtoETHcube <- lm(BTClog ~ ETHlog)
summary(BTCtoETHcube)
anova(BTCtoETHcube)
BTCtoETHcube2 <- lm(BTClog ~ poly(ETHlog,2, raw=TRUE))
summary(BTCtoETHcube2)
anova(BTCtoETHcube2)
BTCtoETHcube3 <- lm(BTClog ~ poly(ETHlog,3, raw=TRUE))
summary(BTCtoETHcube3)
anova(BTCtoETHcube3)
##  Ether as a predictor of Litecoin
LTCtoETHcubeLOG <- lm(LTClog ~ ETHlog)
summary(LTCtoETHcubeLOG)
anova(LTCtoETHcubeLOG)
LTCtoETHcubeLOG2 <- lm(LTClog ~ poly(ETHlog,2, raw=TRUE))
summary(LTCtoETHcubeLOG2)
anova(LTCtoETHcubeLOG2)
LTCtoETHcubeLOG3 <- lm(LTClog ~ poly(ETHlog,3, raw=TRUE))
summary(LTCtoETHcubeLOG3)
anova(LTCtoETHcubeLOG3)
```

```
##  Bitcoin as a predictor of Litecoin
LTCtoBTCcubeLOG <- lm(LTClog ~ BTClog)
summary(LTCtoBTCcubeLOG)
anova(LTCtoBTCcubeLOG)
LTCtoBTCcubeLOG2 <- lm(LTClog ~ poly(BTClog,2, raw=TRUE))
summary(LTCtoBTCcubeLOG2)
anova(LTCtoBTCcubeLOG2)
LTCtoBTCcubeLOG3 <- lm(LTClog ~ poly(BTClog,3, raw=TRUE))
summary(LTCtoBTCcubeLOG3)
anova(LTCtoBTCcubeLOG3)
###ETH vs BTC
plot(BTClog, ETHlog)
ETHtoBTCcube <- lm(ETHlog ~ BTClog)
summary(ETHtoBTCcube)
anova(ETHtoBTCcube)
ETHtoBTCcube2 <- lm(ETHlog ~ poly(BTClog,2, raw=TRUE))
summary(ETHtoBTCcube2)
anova(ETHtoBTCcube2)
ETHtoBTCcube3 <- lm(ETHlog ~ poly(BTClog,3, raw=TRUE))
summary(ETHtoBTCcube3)
anova(ETHtoBTCcube3)
###BTC vs LTC
```

```
plot(BTC, LTC)
BTCtoLTCcubeLOG <- lm(BTClog ~ LTClog)
summary(BTCtoLTCcubeLOG)
anova(BTCtoLTCcubeLOG)
BTCtoLTCcubeLOG2 <- lm(BTClog ~ poly(LTClog,2, raw=TRUE))
summary(BTCtoLTCcubeLOG2)
anova(BTCtoLTCcubeLOG2)
BTCtoLTCcubeLOG3 <- lm(BTClog ~ poly(LTClog,3, raw=TRUE))
summary(BTCtoLTCcubeLOG3)
anova(BTCtoLTCcubeLOG3)
###ETH vs LTC
ETHtoLTCcubeLOG <- lm(ETHlog ~ LTClog)
summary(ETHtoLTCcubeLOG)
anova(ETHtoLTCcubeLOG)
ETHtoLTCcubeLOG2 <- lm(ETHlog ~ poly(LTClog,2, raw=TRUE))
summary(ETHtoLTCcubeLOG2)
anova(ETHtoLTCcubeLOG2)
ETHtoLTCcubeLOG3 <- lm(ETHlog ~ poly(LTClog,3, raw=TRUE))
summary(ETHtoLTCcubeLOG3)
anova(ETHtoLTCcubeLOG3)
```

9.10 Description of Analysis Techniques Empoyed in Chapter 2.

9.10.1 Stationarity and cointegration

For each of the series, we tested their stationarity using KPSS (Kwiatkowski, Phillips, Schmidt, & Shin, 1992) and ADF (Dickey & Fuller, 1979) tests. The Kwiatkowski-Phillips-Schmidt-Shin (KPSS) and Augmented Dickey-Fuller (ADF) tests have opposite null and alternative hypotheses, thus forming an ideal pair for the stationarity versus unit root testing. Specifically, the KPSS tests are used for testing a null hypothesis that an observable time series is stationary (Kwiatkowski et al., 1992), whereas the ADF test is applied to test the null hypothesis that a unit root is present in a time series (Dickey & Fuller, 1979).

A summary of the results of these tests is detailed in Table 2.2. For the prices of Bitcoin, Litecoin, and Ether we find both their original series and logarithmic series to be non-stationary and to contain a unit root. Alternatively, we find the first difference series of Litecoin to be stationary. However, the same result is not found for the first difference series of Bitcoin or Ether. In fact, the results of these tests found the logarithmic difference series was the only transformation of all sets of data to be stationary. As detailed in Table 2.2 all three logarithmic difference series failed to reject the null hypothesis of stationarity in the KPSS test and rejected the null hypothesis of a unit root being present in the ADF test.

9.10.2 Vector Autoregression

The Vector Autoregressive (VAR) model is a model for two or more time series where each variable is modelled as a linear function of past values of all variables, plus disturbances that have zero means given all past values of the observed variables (Wooldridge, 2015). Vector Autoregression is a standard procedure for analysing causal relationships between multiple series (Lütkepohl & Krätzig, 2004; Sims, 1980). Using VAR, we can infer Granger Causality and impulse-response analysis. Impulse-response analysis is based on a vector moving average representation of VAR, showing the reaction of one variable to a unit shock in some other variable and how the effect vanishes over time (Enders, 2008; Hamilton, 1994).

9.10.3 Granger Causality Results

Based on the results from our VAR models, we were able to proceed to Granger Causality tests. This test is a key advantage of the VAR model as it follows the results of the model directly. Granger Causality is a statistical hypothesis test for determining whether one-time series is useful in forecasting another (Granger, 1969). The Granger Causality tests express p-values for the VAR model, under the null hypothesis of no Granger Causality. If we achieve results that are statistically significant in rejecting the null hypothesis, then we can claim that there is a causality relationship between the variables tested (Wooldridge, 2015). The results of our Granger Causality tests are presented in Table 2.3 and will be discussed in the findings section (Section 2.7). However, these results should be interpreted with caution as the term ‘causes’ in ‘Granger causes’ does not allow us to determine whether the variables are exogenous or endogenous (Wooldridge, 2015).

9.10.4 Impulse Response Functions

In addition, we calculated the impulse response functions of each variable to exogenous shocks on other variables, in the presence of correlated noise (Lütkepohl, 2005). The results of Granger Causality tests show whether or not a causal relationship exists between Bitcoin and the other altcoins. Impulse Response Functions represent how this effect persists over time. If there is a reaction of one variable to an impulse in another variable we may call the latter causal for the former (Lütkepohl, 2005).

The results of these tests are illustrated in Figures 6.1 - 6.6. The charts show the response of a corresponding variable to a shock in the impulse variable. The impulse response function estimates the propagation of a shock of 1 standard deviation on a variable to the other variables (Garcia et al., 2014). The number of steps is displayed along the x-axis of each graph, in this case, we chose to analyse 10 steps, which represents 10 days as we are working with daily price data. The response of the corresponding variable to the given one-unit impulse change is displayed along the y-axis. The area between the dotted lines of each graph represents the 95% confidence interval.

9.10.5 Polynomial Regression

Polynomial regression is a type of regression analysis used in statistics to model the relationship between an independent variable and a dependent variable. Polynomials are widely used in situations where the response is curvilinear (Montgomery, Peck, & Vining, 2012). Polynomial regression is advantageous over a standard linear regression in that it fits a non-linear relationship between the values of the independent and dependent variables. We estimate both quadratic and cubic polynomials on the logarithmic transformation of the original series of each data set in order to test our hypotheses by demonstrating that a polynomial regression of a higher order would be more predictive of the relationship between the dependent and independent variable.

9.11 Description on Analysis Techniques Employed in Chapter 6.

A components-based estimation approach to structural equation modelling was taken to reflect the exploratory nature of theory building, specifically the partial least squares (PLS) method (Gefen & Straub, 2005; Gefen et al., 2000). Item loadings were first examined to determine convergent validity for the measures used. One item was dropped, after which loadings for all remaining items satisfied the criteria for a PLS model, i.e. the average loading for each construct is greater than .707 (Bagozzi & Yi, 1988; Gefen & Straub, 2005) and scores for the average variance extracted (AVE) each exceed .05 (Chin, 1998) (see Table 6.2). Discriminant validity was also supported using the (Fornell & Larcker, 1981) method, as the square root of AVE of each latent variable is greater than correlations among the latent variables, the results of this are displayed in Table 6.1. Reliability was supported as each construct satisfies the required threshold for composite reliability >.707 (Bagozzi & Yi, 1988). Lastly, a Harmon's single factor test suggested common method variance was unproblematic at 39.6% (Podsakoff & Organ, 1986).

Once measures were validated, comparative tests were run to compare scores for constructs in the *Creative Ancestry* and control groups. Tests used the average scores for included indicators for each construct. Comparisons included standard two-tailed t-test assuming equal variances and non-parametric two-sided Mann-Whitney tests. The results are presented in Table 6.3.

The results show mixed support for the utility of the system. Descriptively, the *Creative Ancestry*-enabled system scores more highly for each construct. Non-parametric tests suggest each of these differences is statistically significant at a probability level <.001.

However, t-tests do not demonstrate statistical significance at the .05 level for collaboration or *interactional justice*, suggesting further exploration of the structural model is needed.

PLS was used to analyse the structural model. Results are presented in Table 6.4 (inner model) and Table 6.5 (model with moderating variables)for a bootstrap test with 300 samples.