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From truth to trust: the impact of blockchain traceability on trust in product authenticity

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FROM TRUTH TO TRUST: THE IMPACT OF BLOCKCHAIN TRACEABILITY ON TRUST IN PRODUCT AUTHENTICITY

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DEDICATION

I dedicate this dissertation to my family. First and foremost, I recognize my mother. She transcended her educational, financial, and social conditions to find a way to put me in the best schools and pursue my insatiable quests for knowledge and fixing/building things to help people.

I dedicate this dissertation to my children for their loving support. They inspire me every day and remind me that the true concept of self is both collective and relational - to each other and the sustainable cycle we call nature.

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VITA

Frank A. Betz was born in Nashua, New Hampshire. He grew up in Philadelphia, PA, where he attended the Mann School, the Haverford School, and Lamberton, where he graduated with honors in 1983. Frank attended the University of Pennsylvania as a member of the class of 1987, where he received a Bachelor of Arts in Philosophy. He received a Master of Arts degree in Global Business from Pepperdine University and the Institute de Gestion Sociale, Paris in 1995. He returned to Pepperdine University to complete his Doctor of Business Administration in 2021.

ABSTRACT

In the global marketplace, customers are increasingly unaware of the source, provenance, and authenticity of products. Early research has shown that the introduction of blockchain technology into the supply chain area can make it more transparent and trustworthy. As a platform that supports distributed, cryptographically secure, auditable transactions, blockchain has expanded from the domain of digital cryptocurrency into the domain of physical asset provenance and ownership tracking and tracing. This research examines blockchain support of trust in product authenticity adopting a two-paper dissertation format. In the first conceptual paper, I develop a conceptual framework on blockchain technology's unique features and characteristics and how it can boost trust in product authenticity. The second paper adopts the conceptual framework to test through a vignette experiment the effects of blockchain traceability, product identification, and the interaction between them on trust in product origin authenticity. Academics can use this research to develop new instruments to inform practice about how blockchain can boost trust in product authenticity. Results from this study can inform managers considering investments into blockchain solutions and unique product identification as a customer product authenticity, brand protection, or anti-counterfeiting strategy.

Keywords: blockchain traceability, product authenticity, unique product identification, trust, truth

CHAPTER 1: INTRODUCTION

Overview

In the global marketplace, customers are increasingly unaware of the source, provenance, integrity, and authenticity of products. Centralized supply chain management systems can sometimes add to the confusion by exposing the supply chain to corruption, fraud, and tampering (Azzi et al., 2019). Counterfeiting continues to grow in this global marketplace. Trends in trade in counterfeit and pirated goods puts the value of imported fake goods worldwide based on 2019 customs seizure data at $1.6 billion, up from $618 million in 2018 (USCBP, 2019). Customs seizures represent only a fraction of an estimated $1.7 trillion global counterfeit market (CSC, 2019). Fake goods not only affect trade but health as well. Worldwide, the percentage of counterfeit drugs can be as high as 10% (Abma, 2016), affecting millions of people every year, with more than 120,000 people dying in Africa alone from counterfeit malaria drugs (Bassat, 2016). Inefficient transactions, fraud, pilferage, and poorly performing supply chains lead to greater losses of trust, creating a need for better information sharing and verifiability (Saberi et al., 2019).

The relationship between proximity to production and trust in products has been evolving since the beginning of economic trade. Before global trade, trust in the safety and genuineness of products was secured by relationships with producers. By the time the East India Company rose to account for half of the world's trade in the 18th century, trust in various products and commodities was secured by the trading company acting as the central authority that collected and supplied goods globally. An increase in the physical distance between producers and consumers, combined with the growing complexity of the supply chain, introduced more challenges for customers to obtain reliable and verifiable product genuineness, quality, and safety information. As customers lose proximity to local producers, they use both traditional product information channels and new online tools such as customer product ratings, reviews, and feedback comments to glean information and increase their level of trust in products they purchase.

Trust in product authenticity secured by large brick-and-mortar retailers is being challenged by a consolidating retail marketplace. Online sales, the top source of counterfeiting (Boukis, 2019), are also at an all-time high of 13.4% in the U.S. (census.gov, 2021). Consumers who once relied on the legal and reputational accountability of retailers to back product brand claims and authenticity are losing those protections in the online environment. This occurs because global third-party companies are increasingly partnering with large e-commerce organizations to list, sell, and even fulfill orders from an expanding range of branded and non-branded product types. In 2020, Macy's, a traditional brick-and-mortar omnichannel fashion retailer in the U.S., reported more than 25,000 unique stock keeping units (SKUs). In contrast, Amazon reported more than 606 million unique SKUs, averaging 1.3 million new products per day. Just as technology companies have struggled to tackle misinformation on their platforms, Amazon has been unable to effectively police third-party sellers. Amazon exercises limited oversight over items listed by millions of third-party sellers, many of them are anonymous, many are located in China, and some offer scant information (Berzon et al, 2019).

The expansion in global trade has led to more complexity about the origin, processing, and journey of products, with an increase in the companies involved in production, processing, transportation, handling, and storage. Each change of custody in the supply chain represents a widening gap between the means of production and delivery of the final product to consumers.

This gap introduces potential fraud and counterfeiting opportunities for bad actors in the supply chain process (Yang et al., 2019). The t*rust gap* is defined as the perceived amount of trust in the origin, processing, and journey of a product that is widened or narrowed based on the physical distance or number of supply chain exchanges. It affects the confidence in the authenticity of products of value that are susceptible to counterfeiting or fraud. The trust gap manifests itself in the supply chain when manufacturers, producers, wholesalers, and other supply chain actors, who have a stake in the quality, safety, and genuineness of products, are potentially exposed to increasing product safety and fraud-related issues.

Problem Addressed

I am motivated to explore how blockchain technology can be applied to support trust in product authenticity and reduce the trust gap. Blockchain has been introduced into the supply chain area to make the area more transparent and trustworthy (Laaper et al., 2017). With its distributed, cryptographically secure, and auditable properties, blockchain distributed ledger technology has expanded into the domain of physical goods. It provides an unalterable record of transactions where all product and shipping information collected through different technologies are stored in a permanent, auditable record (Azzi et al., 2019; Ramamurthy, 2016). Information stored on the blockchain can be accessed to support product provenance assurances and integrity (Montecchi, 2019).

Research Question

To explore the phenomenon of how blockchain supports trust in product authenticity and to gain an understanding of the possible outcomes, I propose the following research question for this dissertation*:* "How can blockchain solutions impact trust in product authenticity?"

Significance of the Proposed Research

Currently, blockchain technology is starting to be applied to support supply chain trust in product authenticity. The application of blockchain technology has grown far beyond its use for cryptocurrency generation and transactions. It is being used to track and trace the ownership, location, and storage conditions for products such as endangered wood products, conflict diamonds, pharmaceuticals, food shipments, and luxury goods (Figorilli et al., 2018; Kshetri, 2017; Panarello, 2018). Any product that can be reliably identified and have its tracking and tracing conditions verified can benefit from the application of blockchain technology's digital tracking capability.

The ability of blockchain technology to support trust in product authenticity is influenced by product identification and verification technologies and practices. To represent a physical asset digitally, there must be trust that the digital asset truly represents the physical one. This research aims to explore blockchain technology to support trust in product authenticity and expand on existing blockchain trust theories to trust of authenticity of assets represented in the blockchain ecosystem, based on a product’s origin history. Blockchain has the potential to drive cost-saving efficiencies and enhance the consumer experience through traceability, transparency, and security. This research can lead to the development of new instruments to inform practice as to how blockchain can boost trust in product authenticity, provide a solution for brand protection and anti-counterfeiting efforts, and support the ownership tracing of physical assets via (non-fungible tokens) NFTs or other blockchain tokens.

CHAPTER 2: OVERVIEW OF THE RESEARCH AREA AND APPROACH

Introduction

In recent years, blockchain technology has grown in popularity and captured attention in the business community as an innovative method of storing and updating data within and between organizations. As a distributed ledger, the most notable features of the technology are immutability, resistance to censorship, decentralized maintenance, and disintermediation or the elimination of the need for a centralized trusted third party (Bencic et al., 2019). Distributed Ledger Technology (DLT) system transactions are different from centralized ledger systems, such as general ledgers found in enterprise resource planning (ERP) systems, in two ways. First, DLT information is distributed or stored on a network of machines with changes to the ledger reflected simultaneously for all holders of the ledger. Second, DLT transactions are authenticated by a cryptographic signature, which is an immutable tamperproof security feature. Together, these features provide a transparent and verifiable record of transactions.

One emergent specification of DLT is the blockchain data structure. The concept of blockchain was proposed in 2008 by an unknown author, known by the pseudonym of Nakamoto, in a paper about accomplishing non-reversible cash-like transactions without the involvement of a central authority or traditional bank (Nakamoto, 2008). The first application of blockchain technology was the cryptocurrency Bitcoin. With Bitcoin, when user A wants to transfer money to user B, the transaction is represented as a block of digital data transmitted to every node/user of the network. The users verify if this transaction is valid by solving a complicated math puzzle. This puzzle-solving procedure is known as mining, which incentivizes the first miner who finds the solution with a bitcoin reward. The transaction is complete when over half of the users approve the provided solution. Then, the transaction (block) is added to the cryptographically secured blockchain. The blockchain contains all the append-only blocks ever made and is visible to all other users (Garcia-Banuelos et al., 2017).

Blockchain represents a unique technology for supporting trust in digital transactions, as demonstrated by digital asset tracking ledgers such as Bitcoin. Modern cryptocurrencies exploit decentralized blockchains to record a public and unalterable history of transaction data which is generated mostly by blockchain protocols and programs known as smart contracts whose correct execution is automatically enforced without relying on a trusted authority. To support trust in the transaction, all agreements about the state of the ledger occur by consensus between distributed users instead of having to rely on a third-party. Users can append the ledger with digital assets such as records, acts, and states. The appended ledger is rendered immutable, transparent, and auditable, yet resistant to censorship and manipulation due to the cryptographic and distributed foundations of the technology (Maull et al., 2017). DLT has been recognized as an emerging digital technology that has the potential to usher in a new industrial revolution (Pastor & Veronesi, 2009).

Foundational Literature Review

The scope of the DLT covered in this paper is for applications of tracking and tracing supply chain products. Distributed ledgers for these applications are typically permissioned (restricted to users invited to join the network) and private within a given supply chain ecosystem. As a subset of DLT, blockchain technology is technically a public, permissionless, distributed ledger. Although DLT purists may reject the use of the term blockchain for private, permissioned systems, significant supply chain distributed ledger platforms like Everledger refer to their technology by its popular name blockchain (Austin, 2020). For simplicity, I will refer to DLT by its commonly recognized label blockchain.

Blockchain is creating new opportunities for value creation and value capture with fresh approaches to business transactions. Use cases of blockchain go well beyond peer-to-peer virtual currencies used in finance to some of the top industries, including banking, government, manufacturing, healthcare and life sciences, food, and new business applications such as neighborhood micro-grids, personal data, machine to machine transactions, smart cities, and digital medicine (Attaran & Gunasekaran, 2019). By linking physical assets to their digital representations on the blockchain, physical assets can be tracked digitally. One example of this occurred when Walmart successfully tested a blockchain solution for tracking pork from China to the United States (Kshetri, 2018). This demonstrated that the traceability and flexibility of various operations in the supply chain could be increased using blockchain technology. During a 2018 Escherichia coli (E. coli) scare, Walmart was forced to remove all romaine lettuce from its stores across the United States and halt the sale of its top-selling lettuce for several weeks. Walmart's (2019) internal research estimated that blockchain technology would allow the research time for tracing and removing contaminated food to the source could change from seven days to 2.2 seconds and save millions in potential losses that result from the lack of traceability.

Blockchain has the potential to revolutionize traditional supply chains for various commodities from food to pharmaceuticals, where health, safety, and corruption are a concern (Wang et al., 2019). With its unique features, blockchain technology offers a novel mechanism for storing, managing, and securing product traceability data that removes some of the business risks and operational issues imposed by centralized authorities (Rejeb et al., 2019). The scope of blockchain for tracking and tracing solutions covered in this research is for supporting proof of product origin. I use the terminology product origin in a broad sense of product history that includes the locations of production and subsequent product provenance information that can be traced back to a product's original production.

Trust

Trust is a broad and complex concept that has critical applications in a variety of fields for both individuals and organizations. Trust can be described as a psychological state comprised of the intention to accept vulnerability based on positive expectations of the intentions of another (Rousseau et al., 1998). In organizations, supply chain participants rely heavily on trust. In supply chain relationships, trust is a critical element to facilitate coordination and collaboration between trading partners. For exchange partners, trust exists when one party has confidence in the other partner's reliability and integrity (Morgan & Hunt, 1994). Trust has the potential to mitigate uncertainty, unscrupulous behavior, and other exchange hazards (Zhang & Huo, 2013).

Some research explores and tests the factors that tear down trust in interorganizational relationships and some research explores the factors that help to build or strengthen it. In interorganizational relationships, like those found in supply chain management, a partner's reputation in the market has a strong positive impact on the trust-building process, whereas a partner's perceived conflict creates a strong negative impact on trust (Kwon & Suh, 2004). The themes of commitment and integrity are pervasive throughout the literature, as is the common theme that interorganizational "trust exists when a firm believes its partner is honest and benevolent" (Kumar et al., 1995, p. XXX).

Digital technologies such as blockchain are providing new approaches to trust in supply chains. Historically, centralized authorities were assumed to be a source of power and trust among trading partners. The core assumption is that organizations provide a centralized source of legitimacy for the institution (Seidel, 2018). However, the recent emergence of distributed trust systems (i.e., blockchain) challenges these core tenets of organizational theory (Seidel & Greve, 2017). The concept of distributed trust is a shift in theoretical perspectives brought about by technologies such as blockchain where, upon first interacting with an unknown supply chain actor, firms could enter a trusted economic exchange without needing a third party to vouch for the unknown actor (Seidel, 2018). Blockchain is an immutable ledger of transactions that is not maintained by a centralized authority and provides proof of historical transactions that can be trusted without authentication by a central authority (Swan, 2015). Thus, for any type of ledger (e.g., a record of economic exchange, a reputation rating, a certificate of authenticity) a third party is no longer required to validate. This affects previous assumptions about the legitimacy and power benefits of central network positions that affect trust among trading partners.

Authenticity

The complexity of the authenticity construct is not new. Scholars grapple with the fundamental question of how authenticity should be defined. There is no consensus definition due in part to the diversity of contexts in which it is studied (Wang, 1999). Authenticity generally refers to the qualities of genuineness, truth, and reality (Beverland, 2009; Carrara, 2010; Grayson & Martinec, 2004; Lynch, 2000). It is a perception that affects individual judgment and behaviors across a wide variety of domains. It also plays a key role in the pleasure people derive from experiences or products, from dining to visiting museums to watching movies. Authenticity drives consumer preferences across several domains, including art, clothing, luxury goods, food, medicine, and everyday products (Newman, 2019).

Newman and Smith (2016) proposed three broad dimensions of authenticity: categorical, value, and historical. Categorical authenticity is viewed through the lens of an object's conformity to existing beliefs about a category of type. In the literature, this is also known as type authenticity and iconic authenticity (Newman, 2019). As an example, items such as Mexican food and UGG boots may be perceived as authentic if they conform to an observer's expectations about how they should taste, appear, or feel. Value authenticity is the lens whereby people evaluate authenticity as an assessment of values, specifically, the consistency between an entity's internal states and its external expressions or moral authenticity (Newman, 2019). Although this type of authenticity is more likely to arise in creative works, performances, or religious events than manufactured products, it is also related to the meaning of values associated with goods, such as consistency in process or certification. Historical authenticity is the way people evaluate authenticity based on history and associations with people, places, and events (Newman, 2019). It is the main lens of perception through which products are judged as genuine rather than fake or counterfeit.

For this paper, I focus on the concepts of historical and indexical authenticity, the specific types of authenticity viewed through the lens of a product's lifecycle. Central to this type of authenticity are the notions of indexical authenticity and origin assurance. Grayson and Martinec (2004) define indexical authenticity as people conceptualizing objects in terms of a spatiotemporal link that connects the object in the present day with some spatial/time point in the past. Indexical authenticity is based upon the idea of identifying a genuine, real object (e.g., a painting) from a copy or counterfeit. In the context of commodities, indexical authenticity represents the connection between a brand and a point of reference such as a place or an event (Fritz et al., 2017). It acts as an assurance of origin or as an assessment of several interconnected aspects linked to the place of brand origin and where products are made (Montecchi et al., 2019).

Blockchain and Product Authenticity

Blockchain technology is leading to a new way of thinking about the genuineness and authenticity of products. Counterfeit goods are reproduced copies that are often almost identical to the original, including packaging, labeling, and trademark (Bloch et al., 1993; Kay, 1990) and are a growing problem evident in a wide range of industries and supply chain echelons. As markets become more global, business competition is evolving from a "firm-versus-firm race to a supply chain-against-supply chain battle and a wrestling match between lawful manufacturers and counterfeiters" (Li, 2013, p. 169). Blockchain solutions provide trust and authenticity assurances to supply chain partners for tracking and tracing product origin and quality. With its tamperproof property of cryptographically signed historical transactions in a decentralized environment, blockchain is shown to help foster greater trust with auditable transactions by all parties (Kshetri, 2018).

Description of the Research Agenda

Currently, DLT is starting to be applied to track and trace the authenticity of physical goods. The ability of blockchain to secure records of transactions, as demonstrated by digital asset tracking ledgers such as Bitcoin, is being used to track physical assets in the real world. Blockchain technology renders transactions immutable, transparent, and resistant to censorship and manipulation. Although the data security enabled by blockchain can increase trust between organizations, additional measures are required to ensure the physical goods are accurately linked to their digital representation in the blockchain. Thus, blockchain technology has created new opportunities to support the verification of authenticity for physical goods represented by their digital identity on the blockchain. Use cases are emerging in the literature for blockchain technology to support anti-counterfeiting, safety, and sustainability efforts for physical asset domains such as restricted and endangered wood products, pharmaceutical supply chain exchanges and storage conditions, food shipments, and luxury goods authentication (Fernandez-Carames et al., 2018; Figorilli et al., 2018; Kshetri, 2017; Lu, 2018; Panarello, 2018).

The theoretical frameworks and concepts explored in this research represent an interplay between blockchain behavioral and technological solutions. Trust and authenticity theories and concepts address the behavioral side of the solution, whereas the properties and concepts of blockchain and supportive technologies address the technical side. Trust theory is considered an essential factor in all market transactions. Market freedoms would be inconceivable without a social order rooted in norms, including trust (Etzioni, 1988; Granovetter, 1985). Distributed trust is a new concept brought about by blockchain technology that will be explored in this dissertation. Blockchain's peer-to-peer distributed, cryptographically secure characteristics provide an environment where trust is replaced by facts and truth of historical transactions. A record of economic exchange or a certificate of authenticity no longer requires a trusted third party to validate (Seidel, 2018). Distributed trust adds an element of truth to belief in the validity of transactions due to the shared, distributed, and immutable nature of blockchain technology. Authenticity theories and concepts such as historical authenticity, the lens of perception through which consumers judge if products are genuine rather than fake or counterfeit (Newman, 2019), and indexical authenticity, the belief that an object is original or genuine (Barthel, 1996; Grayson & Martinec, 2004), address the behavioral side of blockchain technology and product authenticity. Blockchain and supportive technologies such as radio frequency identification (RFID) for unique product identification and data for anti-counterfeiting purposes (Staake et al., 2005), and internet of things and artificial intelligence technologies, to verify the authenticity of supply chain products (Kshetri, 2017), work together to address the technical side of the blockchain solution to support trust in product authenticity.

This dissertation research adopts a two papers format. The first paper develops a conceptual framework for exploring the ability of blockchain technology to support trust in the authenticity or genuineness of physical products. The findings from the first paper serve as a guide for the second paper, a quantitative paper, empirically testing specific hypotheses regarding the effects of blockchain traceability and product identification technologies on trust in product authenticity.

The research approach of the first paper consists of a three-step approach to explore blockchain's impact on trust in product authenticity. First, I review relevant literature involving theories, concepts, and frameworks. Next, I explore how technology can support trust in product authenticity and investigate how blockchain's ability to track and trace products compares with other techniques and methods. Finally, I create a conceptual framework by identifying commonalities between blockchain and previous successful technologies to determine the unique features of blockchain that affect trust in product authenticity. Insights from the first paper will allow me to answer a call for more quantitative blockchain trust research (Wong et al., 2020) and empirically test specific hypotheses regarding the effects of blockchain and unique product identification on trust in product authenticity.

The second paper is an empirical study examining one specific research gap identified in the conceptual paper. The second paper tests the effects of blockchain traceability, unique product identification, and their interaction to determine the most effective combination for building trust in product authenticity.

Justification of the Research Agenda and Approach

Blockchain technology usage for non-cryptocurrency business applications is growing, but research on its ability to track and trace physical assets is limited. With 40% of 1,000 companies surveyed reporting they would invest $5 million or more in blockchain in 2020, blockchain is gaining attention and investment as an important future technology (Deloitte, 2019). However, the current body of blockchain research is nascent. Specifically, research regarding the ability of blockchain technology to track and trace products is limited and even sparser regarding the technology to support trust in product authenticity. The state of the literature is mature for broad concepts trust and authenticity, but they have not been applied to verification technologies and practices for blockchain technology. This research builds on prior research for the use of blockchain to track and trace assets by expanding it with the role of verification to support established theories and frameworks of trust and authenticity.

Blockchain is a validation tool for digital assets like cryptocurrencies, but there are challenges relating to claims of authenticity for non-native, tangible assets represented on the blockchain. The anticipated outcome of this research is to elucidate the importance of the role of blockchain supported by identification and verification technologies to improve trust in the authenticity of physical. This research can lead to the development of new instruments to inform practice (i.e., product manufacturers, marketers, supply chain managers, government services, regulators) as to how blockchain traceability solutions can boost trust in product authenticity and reduce the trust gap.

CHAPTER 3: FROM TRUTH TO TRUST: CONCEPTUAL DEVELOPMENT AND FRAMEWORK ON THE IMPACT OF BLOCKCHAIN ON TRUST IN PRODUCT AUTHENTICITY

Introduction

In this paper, I examine the application of an emerging technology, blockchain, for product tracking and tracing in complex supply chains. By considering the features and capabilities of blockchain and the constructs of truth, trust, and authenticity, I develop a framework to explain how blockchain can impact customer trust in product authenticity.

This work is important because, in the global marketplace, customers are increasingly unaware of the source, provenance, and authenticity of products. Counterfeiting is a growing problem that is now widely considered one of the greatest threats to the world economy. The trade in counterfeit goods is extremely high, fueled in part by online spending that is at an all-time high (36% in 2021), up from 20% in 2020 (Lea, 2021). Despite global efforts to curb the proliferation of illegal goods, the trade of counterfeit and pirated goods continues to grow worldwide. Based on 2019 US Customs and Borders Protection seizure data, the value of imported fake goods increased from $1.4 billion in 2018 to $1.6 billion in 2019 (U.S. Customs and Borders Protection, 2019). According to CSC (2017), customs seizures represent only a fraction of an estimated $1.7 trillion global counterfeit market. These goods include fake versions of popular consumer products such as footwear, watches, handbags, consumer electronics, pharmaceuticals, medical products, and other high-value items.

With trade in counterfeit goods high, consumers are demanding proof of authenticity for products they buy (Francisco & Swanson, 2018). Brands are also seeking to protect the reputation, safety, and value of their products in response to these conditions. To protect brands and cater to consumer demand, trading and e-commerce platforms like e-Bay and Amazon increasingly offer 3rd party verification or product authenticity for most high-value items. Luxury good reselling platforms that cater to the growing $25 billion worldwide resale market, growing 8% faster than the luxury industry overall, now offer product authenticity verification with money-back guarantees to boost consumer trust in product authenticity (Bianchi et al., 2020).

One source of increased counterfeiting is the expansion of complex global supply chains that introduce challenges for customers to obtain trustworthy product information. Each change of custody in the supply chain represents a widening gap between the means of production and delivery of the final product to consumers. This gap introduces trust concerns in the authenticity of products, such as potential fraud and counterfeiting opportunities for bad actors in the supply chain (Yang et al., 2019). It manifests itself as manufacturers, producers, distributors, and other supply chain actors who have a stake in the truth of the originality and genuineness of products are exposed to fraud-related conditions. I refer to this phenomenon as the trust gap.

To increase trust in the origin of raw materials and components for the products they manufacture or sell, companies use product traceability systems to increase visibility into the supply chain (Abeyratne & Monfared, 2016). Traceability is a broad concept generally referring to the practice of identifying an object whereby information about it is accessible throughout its lifecycle (Schuitemaker & Xu, 2020). It refers to the combination of the ability to always know the possession of a product (tracking) and the ability to find the origin and ownership history utilizing recorded identifications (tracing). Effective tracing allows a user to establish a product’s provenance with confidence. It is widely accepted that a lack of supply chain transparency can lead to a loss of trust, creating a need for better information sharing and verifiability (Chang et al., 2020; Montecchi et al., 2019; Saberi et al., 2019). The complexity of modern global supply chains requires an approach that follows products throughout their entire lifecycle (Awaysheh & Klassen, 2010). Effective tracking can help suppliers minimize counterfeit products and manage services such as product recalls. Product traceability systems support supply chain trust and cater to the consumer requirements of visibility and quality assurance (Agrawal et al., 2012).

Although product traceability systems offer transparency, problems of trust can persist. These systems have evolved from paperwork to digital systems controlled by trusted central authority providers. Electronic Data Interchange (EDI) is a common system that companies use to transmit product information and electronic documents between proprietary computer systems (Chen & Williams, 1998). EDI is used by nearly 200,000 companies worldwide as part of e-business initiatives (Masudin et al., 2021). These systems rely on tagging, tracing, and sensing to store information in centralized databases that allow suppliers and buyers to obtain information about the originality, components, and location of products (Figorilli et al., 2018; Khalil et al., 2019; Masudin et al., 2021). They rely on a chain of trust among partners supported by technology solutions like RFID tags and barcodes to protect against counterfeiting. However, these systems fall short of protecting against counterfeit products caused by tampering activities such as tag removal, tag cloning, attacks against radio frequency communication, attacks against proprietary and loosely connected information technology systems, and forgery of product history and other documents (Lehtonen et al., 2007; Khalil et al., 2019).

Blockchain-based traceability systems are a promising technology suited to enhance trust in product authenticity with features that support transparency and security. Extant research and industry use-cases suggest that deploying the emerging technology of blockchain-based product traceability systems can enhance transparency and create trust among supply chain partners (Kshetri, 2018; Laaper et al., 2017; Min, 2019). Blockchain is a distributed ledger or database where transactions are bundled into validated blocks and added to a chain of previously validated blocks. The ability of blockchain technology to securely trace transactions back to their point of origin is an essential feature of a product traceability system (Jansson & Petersen, 2017). In an early use case, Maersk, the largest container shipper globally, participated in a supply chain traceability proof-of-concept to track a shipment of roses and avocados from East Africa to Europe (Chang et al., 2020). All supply chain exchanges, including customs documentation, were immediately uploaded with a cryptographically secure digital signature instantly available to everyone on the blockchain to help foster greater trust with auditable transactions by all parties (Kshetri, 2018).

Companies are investing money into blockchain technology, supportive product identification technologies like unclonable dot-matrix tags, and verification technologies and methods like the Internet of Things (IoT) sensors and artificial intelligence (AI). However, these investments are being made without understanding the essential features and capabilities of blockchain that actually increase trust or to what extent trust is increased. The aim of this paper is to build knowledge in this area that can be used by scholars studying blockchains and product authenticity. Further, this research can be used by managers to better direct their development and application efforts for blockchain and related technologies in tracking and tracing systems.

I examine the potential for blockchain technology as a traceability solution that can engender trust in product authenticity. Traceability solutions impact the perception that products exposed to complex supply chains or unknown origins are genuine and not fake or counterfeit (Matzembacher et al., 2018). This paper examines blockchain product traceability to maintain the factual identity and origin truths for genuine products, thereby affecting customer perceptions of authenticity and increasing their trust level (Figure 1).

Figure 1

Conceptual Causal Model

This paper contributes to the literature in several ways. First, the literature on the impact of blockchain on product authenticity is sparse. The few papers on blockchain and product authenticity are related to blockchain in relation to supply chain transparency and trust (Galvez et al., 2018; Pun et al., 2021; Westerkamp et al., 2020). The closest related work (Montecchi et al., 2019) focuses on blockchain provenance knowledge for establishing product authenticity, but it includes credence claims that are unverifiable, such as GMO and organic. This paper addresses product authenticity made possible by the phenomenon of a distributed trust technology for answers to questions such as "Is this a genuine product from the manufacturer and not fake or counterfeit?" without consideration of brand or credence claims that impact evaluations of authenticity based on associations to non-origin features and associations.

Second, I develop a new construct (product origin authenticity) which involves using blockchain to verify product authenticity using truths about the product's origin, building on authenticity constructs in the literature, including indexical, historical, and true-to-fact (TTF) brand authenticity (Grayson & Martinec, 2004; Newman, 2019; Moulard et al., 2020). This new construct is important because it advances the discussion on how blockchain can increase trust in product authenticity by relying solely on origin fact (truths) for confidence (trust) in the perception that products are original and not fake or counterfeit.

Third, I develop a conceptual framework that represents how the features and capabilities of blockchain can increase trust in product authenticity. This framework is important for evaluating trust in product origin authenticity based on truths supported by both blockchain and supplementary technologies and serves as a springboard for further theoretical development and empirical testing. My framework allows for the development of testable hypotheses so that researchers and managers can determine the effectiveness and relative importance of various framework components.

This paper is organized as follows. First, I review the basics of blockchain and the concepts related to product authenticity, truth, and trust. Next, I introduce a new construct of product origin authenticity made possible by the paradigm of smart contract driven blockchain technology. Subsequently, I develop a conceptual framework that shows how blockchain can lead to greater trust in product origin authenticity.

Research Questions

Product authenticity in this paper refers to the determination, based on signs, that a unique product represented on the blockchain is either genuine or fake. The focal phenomenon of this paper is the ability of blockchain technology to support trust in the product origin (e.g., date, time, manufacturer, and location) and identity (e.g., unique marking) that affect customer perceptions and judgments of authenticity. For exploring the ability of blockchain to impact trust in product origin authenticity, I propose the following research questions:

- What inherent characteristics of blockchain solutions for product traceability increase trust in product origin authenticity?
- What enhancements to blockchain solutions for product traceability can strengthen its ability to increase trust in product origin authenticity?

This paper aims to research the application of blockchain technology to support perceptions of trust in the origin and identity of physical products in the complex global supply chain. This research expands research on product authenticity considering new opportunities made possible by blockchain technology. The aim is to advance theory on the impact of blockchain on product authenticity. From a practical perspective, this paper provides insights for organizations that want to protect their products against counterfeiting and fraud, considering that end-customers increasingly seek assurances that products are genuine.

Literature Review

Blockchain

The concept of blockchain was proposed in a paper related to accomplishing non-reversible cash-like transactions without the involvement of a central authority or traditional bank (Nakamoto, 2008). This scheme, known as Bitcoin, is the first and most well-known utilization of the blockchain structure. Blockchain provides users with a peer-to-peer, distributed, transparent, immutable, and auditable mechanism that has grown in popularity and captured attention in the business community as an innovative method of storing and updating data within and between organizations.

Blockchain is the underlying technology for Bitcoin. With Bitcoin, when one user (node) wants to transfer funds to another user, the transaction is represented as a packet of data or a block that is transmitted to every node/user of the network. The nodes verify that transactions are valid by solving a complicated puzzle. This puzzle-solving procedure is known as mining. The first miner that finds the solution wins a Bitcoin reward. The transaction is complete when over half the users approve the provided solution. Then, the transaction (block) gets added to the cryptographically secured append-only record (chain). The blockchain contains all the append-only blocks ever made and is visible to all other users (Garcia-Banuelos et al., 2017).

The most notable features of blockchain technology that distinguish it from traditional databases are immutability, resistance to censorship, decentralized maintenance, and disintermediation by eliminating the need for a centralized trusted third-party intermediary (Bencic et al., 2019). Blockchain system transactions are different from centralized ledger systems, such as general ledgers found in enterprise resource planning (ERP) systems, in two ways. First, blockchain information is distributed or stored on a network of machines called nodes, with changes to the ledger reflected simultaneously for all nodes that hold a copy of the ledger. Second, blockchain transactions are authenticated by a cryptographic signature, which is an immutable tamper-proof security feature. Together, these features provide a transparent and verifiable record of transactions that differ from other technologies that have some characteristics of a decentralized system but are often controlled by a centralized authority or intermediary operator (DeFilippi and McMullen, 2018). As a distributed and immutable ledger of transactions with no central administrator, blockchain is an emerging technology that has the potential to usher in a new industrial revolution with its unique security and sharing features (Pastor & Veronesi, 2009).

Vitalik Buterin created the Ethereum platform to apply business logic (known as smart contracts) to the blockchain. The term smart contract is a computerized transaction protocol that executes the terms of a contract. A vital feature of a smart contract is its ability to automatically enforce or execute contract terms that were not technologically viable before blockchain (Reyna et al., 2018). For example, a smart contract might trigger automatic payment to a supplier after receiving a verified receipt of an item at a buyer's location. Smart contracts ushered in what is known as Blockchain 2.0. Popular platforms such as Ethereum and intra-company distributed ledger technology (DLT) such as Hyperledger Fabric opened up a wide range of economic opportunities (Cachin, 2016). Smart contracts extend blockchain beyond cryptocurrency to create a peer-to-peer economy without the need for a central authority to act as a trusted intermediary for supply chain traceability.

Blockchain has the potential to revolutionize traditional supply chains for various commodities from food to pharmaceuticals, where health, safety, and corruption are a concern. With its unique features, blockchain technology offers a novel mechanism for storing, managing, and securing product traceability data that removes some of the business risks and operational issues imposed by centralized authorities (Rejeb et al., 2019). The scope of blockchain traceability solutions covered in this paper is for supporting proof of product origin. I use the terminology product origin in a broad sense of product history that includes the locations of production and subsequent product provenance information that can be traced back to a product's original production.

In this paper, I assume blockchain traceability solutions are a form of chain of custody system. Blockchain's distributed, tamper-resistant features can be leveraged to provide a decentralized, secure chain of custody solution (Ahmad et al., 2020). With blockchain, chain of custody is achieved by defining a set of requirements and measures by smart contracts that provide the necessary controls on the movement of products and associated data from approved or certified businesses through each stage of the supply chain (Ahmad et al., 2020). Blockchain-based chain of custody systems enable information associated with a product and stored as metadata to be shared, stored, and audited among various organizations active in the chain of custody such as suppliers, processors, contractors, transportation and logistics companies, financial institutions, governmental organizations, end customers, and consumers.

Truth and Trust

Trust and truth are intertwined social constructs. Luhmann (1979) observed that trust is only possible where truth is possible. Carolan and Bell (2003) followed that truth comes from trust and trust comes from truth. I start with the concept of truth because it is the foundation of objective reality that can be captured with blockchain technology. Product-related facts (i.e., date and location of manufacturing) are objective truths. In the early 20th century, Bertrand Russell and George E. Moore conceptualized truth in the tradition of the correspondence theory of truth, which posits that truth is correspondence to or with fact (Stanford, 2013). It embraces the idea that truth consists in relation to reality as a relational property. In this paper, I evaluate statements such as "XYZ manufactured this ball at their factory in California" as correspondence to fact (CTF) truths (i.e., date and location of manufacturing) about the origin of the ball.

Like truth, trust is an elusive concept with many facets. Trust is generally understood to be a balance between confidence and vulnerability. For individuals, trust can be described as a psychological state comprised of the intention to accept vulnerability based on positive expectations of the intentions of another (Rousseau et al., 1998). In supply chain relationships, trust is a critical element for facilitating coordination and collaboration between trading partners. For interorganizational exchange partners, trust exists when one party has confidence in the other partner's reliability and integrity (Morgan & Hunt, 1994). Trust has the potential to mitigate uncertainty, unscrupulous behavior, and other exchange hazards (Zhang & Huo, 2013). In contrast, lack of trust can damage established relationships and can lead to anger, disappointment, and a loss of sales and competitive advantage (Castaldo et al., 2010). Trust in this paper is related to the degree of confidence customers have in the authenticity of a product.

Authenticity

Authenticity is a complex concept with no consensus on how to define it. It is a perception of an entity conforming to some phenomenological experience of fact, preexisting knowledge or expectation, or convention or habit that affects individual judgment and behaviors across a wide variety of domains (Moulard et al., 2020; Newman, 2019). It plays a vital role in the pleasure people derive from experiences or products, from dining to visiting museums.

The concept of authenticity is so broad and context-based that some have suggested it should be abandoned (Reisinger & Steiner, 2006). There is sharp scholarly disagreement on this issue. Marketing researchers have identified authenticity based on Peirce's (1883) semiotic framework (Beverland & Farrelly, 2010; Grayson & Martinec, 2004; Moulard, 2020; Newman, 2019). They adopt authenticity concepts for objects based on Peirce's philosophy of signs. The Peircean semiotic model takes a correspondence theory of truth approach where an object (e.g., product) determines the sign (e.g., brand logo), which in turn determines the interpretant or our understanding (e.g., perception of authenticity). The object-sign-interpretant framework is an object-based relationship of determination, not causation, between an object, a sign, and an interpretant. The nature of an object constrains the nature of its sign in terms of what makes it successful as a signifier. For example, the nature of a mole being a hole digger determines the sign of a mole’s hole as a signifier of a mole. The resulting interpretation of a sign is a similar mental state to the perception of the reality it represents (Peirce, 1883). Reisinger and Steiner (2006) argue that Peirce's (1883) concept of object-based authenticity should not be used. They suggest that if the concept of authenticity is so relative that only some can accept it, then it cannot be used for general research purposes.

Lau (2009) takes a social realist approach and suggests that authenticity be conceptualized only as object-based authenticity in that authenticity only makes sense when it corresponds to a physical object. Newman (2019) and Moulard et al. (2020) attempt to create overarching definitions of authenticity consistent with Peirce's (1883) characteristic of a sign as indexical, iconic, or symbolic. Peirce (1883) suggested that if a sign reflects qualitative features of an object (e.g., portrait or painting), it is an icon. If it reflects an existential or physical connection to objects, it would be considered indexical. Signs that reflect convention, habit, or social rule would be considered symbolic. In his later writings, Pierce suspected signs could not be completely isolated and that icons and indices were always part conventional or symbolic (Atkin, 2013). He also recognized that any single sign might display a combination of characteristics. To advance his concept of sign, he introduced the notion of a composite or chain of signs based on the logic that since signs determine interpretants that become signs, then an infinite number of signs becomes conceptually necessary (Atkin, 2013).

In this paper, I focus on the type of authenticity determined by existential facts that correspond to truth. Peirce (1883) referred to the signs for this type of authenticity as indexical and associated with the phenomenological experience of fact. Grayson and Martinec (2004) define indexical authenticity as people conceptualizing objects in terms of a spatiotemporal link that connects the object in the present day with some spatial or time point in the past. In the context of physical products, indexical authenticity represents the connection between a product and a point of reference, such as a place or an event (Fritz et al., 2017). It acts as an assurance of origin or assessment of interconnected aspects linked to the place of product origin and where products are made (Montecchi et al., 2019). Newman (2019) proposes historical authenticity as the main lens of perception through which consumers judge if products are genuine rather than fake or counterfeit (Newman, 2019). It combines indexical authenticity with the view of nominal authenticity as an object's history and connection to correct identification of the origin and provenance of an object (Dutton, 2003). Newman (2019) asserted that historical authenticity is often evaluated through physical connections with binary judgment (e.g., Did the item have contact with X or not?). For example, a Matisse painting could be considered historically authentic if its provenance could be traced back to Matisse himself.

Moulard et al. (2020) conducted an extensive literature review of marketing research on authenticity to offer clarity on how consumers perceive authenticity based on truth. They conceptualize a reference framework for authenticity that provides an overarching definition of authenticity based on the epistemic truths that correspond to appropriate facts (Moulard et al., 2020; Newman, 2019). They define TTF authenticity as a consumer's perception about the extent to which information about an entity corresponds to an actual situation, like "Apple publicly claims its products are designed in California yet assembled in China" (Moulard et al., 2020, p. 101). In this framework, terms for TTF authentic objects/products are honest, transparent, verifiable, unquestionable, and original (object/product); whereas, terms for TTF inauthenticity are deceptive, fraudulent, corrupt, and counterfeit (Moulard et al., 2020).

Conceptual Development

Product Origin Authenticity

Product authenticity based exclusively on objective truths about an object's origin history does not fall within current concepts of indexical or historical authenticity in marketing research (Beverland & Farrelly, 2010; Grayson & Martinec, 2004; Moulard et al., 2020; Newman, 2019).

In these marketing research forms of authenticity, the fact referent (e.g., manufacturing location(s) and the manufacturer) is communicated but unidentifiable. An accurate assessment is difficult and reliance is on seller and marketer claims (Moulard et al., 2020). Moreover, empirical research shows objective product knowledge has a positive influence on user perceptions of the authenticity of products and increases user willingness to buy (Mavlanova & Benbunan-Fich, 2010). Therefore, I introduce ‘product origin authenticity’ as a form of authenticity derived from identifiable and verifiable product origin and history facts considered to be truths. In evaluating product origin authenticity, an object would be perceived as authentic (original) or inauthentic (counterfeit) based on CTF truths like manufacturing location and date, chain of custody exchanges, and ownership information.

When using blockchain to determine product origin authenticity, the evaluation of origin authenticity is restricted to facts about the origin of the manufacturer that creates the blockchain record. It assumes that the initiator or minter of the digital token that represents the physical product is certified as the true company on the blockchain and is disincentivized to commit fraud that could lead to reputational damage or any legal, criminal, or financial liability. Any product that can be reliably identified, tracked, and traced back through the supply chain to its origin would be judged as product-origin authentic. If not, it would be perceived as product-origin inauthentic. This view of authenticity is consistent with existing theories and concepts that suggest authenticity should be conceptualized for physical objects based on corresponding facts related to their origins (Grayson & Martinec, 2004; Lau, 2009; Montecchi et al., 2019; Moulard et al., 2020; Newman, 2019). In this paper, I focus on truth and facts related to identifying the origin story of products.

Blockchain and Distributed Trust

Blockchain represents a unique technology for supporting trust in digital transactions, as demonstrated by digital asset tracking ledgers such as Bitcoin. However, it is the specific characteristics of the underlying distributed ledger technology (DLT) where uniqueness and disruptive potential lie. Removing the intervention of third parties tends to shift trust from humans to the system itself and the network behind it (Werbach, 2018). As an immutable ledger of digital transactions, blockchain provides proof of historical transactions that can be trusted without authentication by a central authority (Swan, 2015). Thus, for any type of ledger, record of economic exchange, reputation rating, or certificate of authenticity, a trusted third party is no longer required to validate.

Blockchain technology supports trust in digital assets in two main ways. First, it is distributed by nature, so an agreement about the state of the ledger is achieved by consensus of the network of distributed users instead of having to rely on trust in a third-party intermediary like a bank or clearinghouse (Swan, 2015). This disintermediation drastically affects previous assumptions about the legitimacy and power benefits of central network positions that affect trust among trading partners (Bencic, 2019). Second, users can append the ledger with digital assets such as records, acts, and states. The appended ledger is rendered immutable, transparent, auditable, and resistant to censorship and manipulation due to the cryptographic and distributed foundations of the technology (Maull et al., 2017). Because of this, blockchain can extend trust to previously unknown players in complex networks. Supply chain transactions broadcast by any single actor get verified by all other actors before auditing, making blockchain a promising solution to ensure the integrity of products in various supply chains (Tapscott & Tapscott, 2016).

The concept of distributed trust brought about by blockchain technology represents a shift in theoretical perspectives. Historically, centralized authorities were assumed to be a source of power and trust among trading partners. The core assumption of this position is that third-party organizations provide a centralized source of legitimacy for institutions (Seidel, 2018). However, the recent emergence of distributed trust systems, such as blockchain, challenges these core tenets of organizational theory (Seidel & Greve, 2017). Some have suggested there is no need for the traditional concept of trust between transacting parties due to the benefits of the transparent and immutable blockchain procedure for creating and storing transactions in a ledger (Elsden et al., 2018). Using blockchain, upon first interacting with an unknown supply chain actor, firms could enter into a trusted economic exchange without needing a third party to vouch for the unknown actor (Seidel, 2018). Peer-to-peer distributed systems enable trust through the involvement of participants (which could be upwards of several thousand) in the verification and acceptance of the data stored within the system (Green et al., 2018). As transactions processed by the blockchain are validated and verified within the system, the network can provide a new basis of trust (van den Hoven et al., 2019).

Trust literature suggests technology itself can transmit signals of trustworthiness and help the trustor (the person who trusts the other entity) form expectations of the trustee's (technology) behavior (Riegelsberger et al., 2005). McKnight et al. (2001) propose three signals for trust in technology: functionality, helpfulness, and reliability. These three signals were subsequently tested by Lankton et al. (2014). Functionality refers to the belief that a given technology can perform the required task (e.g., software that reports patient vital signs). Integrity refers to the idea that a trustee adheres to principles that are acceptable to the trustor. Reliability refers to the properties of a technology that make it dependable and accurate (e.g., software that operates smartphones). Functionality, helpfulness, and reliability contribute to a belief that technology is competent as a trustee and has skills that help the trustor achieve the desired function (Marella et al., 2020). As a platform that enables peer-to-peer sharing, blockchain technology attributes affect trust (Beck, 2018; Dann et al., 2020).

While there may be some genuine trust in the blockchain technology itself on an application level, trust in an IT artifact needs to be established. Zavolokina et al. (2020) find the trust-supporting design elements of blockchain technology represent single features or groups of features that positively influence trust. However, they confirm problems for blockchain identified in the literature, including that lack of understanding, knowledge, and experience with blockchain technology may lead to lower levels of trust (Zavolokina et al., 2020).

Blockchain traceability systems impact trust evaluations for supply chain partners by providing immutable knowledge of origin, custody, and integrity information. Blockchain can deliver traceability, certifiability, trackability, and verifiability of product information along the entire supply chain (Montecchi et al., 2019). It provides a verifiable record of provenance transactions, whereby all product and shipping information collected through different technologies are stored in a tamper-proof record and stakeholders can audit product history (Azzi et al., 2019; Ramamurthy, 2016). As a digital technology, blockchain can dematerialize or represent a physical asset with digital information or metadata and move that information across a digital infrastructure or network (Normann, 2001). Digitization is important because digital representations of assets can travel instantly across networks and be shared, stored, evaluated, and enhanced with other asset information. This process is known as tokenization. By linking physical assets to their digital representations or tokens on the blockchain by devices such as labels, barcodes, or RFID tags, physical assets can be tracked digitally in an immutable, distributed, and auditable system.

Greiner and Wang (2015) introduced the notion of blockchain as a trustless or trust-free system based on the technology's ability to create immutable, consensually agreed-on transactions governed by the system with no need for a central authority. Although trustless sounds negative, in this view, blockchain's peer-to-peer distributed sharing and automated features remove the requirement of third-party intermediaries to secure trust. Beck et al. (2016) expand on this idea of a trust-free environment by arguing that their prototype blockchain smart contract payment system creates a trustless environment that replaces traditional trust-based payment systems, ruling out malicious behavior and misunderstandings by people. Instead, a system automatically carries out a payment transaction based on a defined protocol in a transparent system with no invisible bias or malicious computing (Beck et al., 2016). Once this data gets recorded on the blockchain, it provides authenticity proof for products, eliminating the need for trusted physical or digital certificates that are subject to tampering and forging. Rather than relying on trust, customers have more direct access to truths. My observation is that blockchain helps shift product origin authenticity from truth to trust.

The literature suggests that although blockchain has many characteristics that are trust-enhancing, it does not render all forms of trust obsolete. As a socio-technical structure, blockchain realigns the trust relationship between organizations but does not eliminate it. Sas and Khairuddin (2017) found decentralization, deregulation, miner expertise, and transparency of transactions as blockchain social trust factors. However, blockchain technology itself is not enough to render social trust outside the closed blockchain ecosystem obsolete. From a behavioral perspective, blockchain trust includes trust in the platform's aspects and a network of agents represented as nodes of the blockchain network. Hawlitschek et al. (2017) suggest that a social system exists beyond the collection of any system's technological features enables trust from a behavioral perspective. In other words, blockchain has many trust-shifting and trust-enhancing characteristics, but it does not render social trust obsolete.

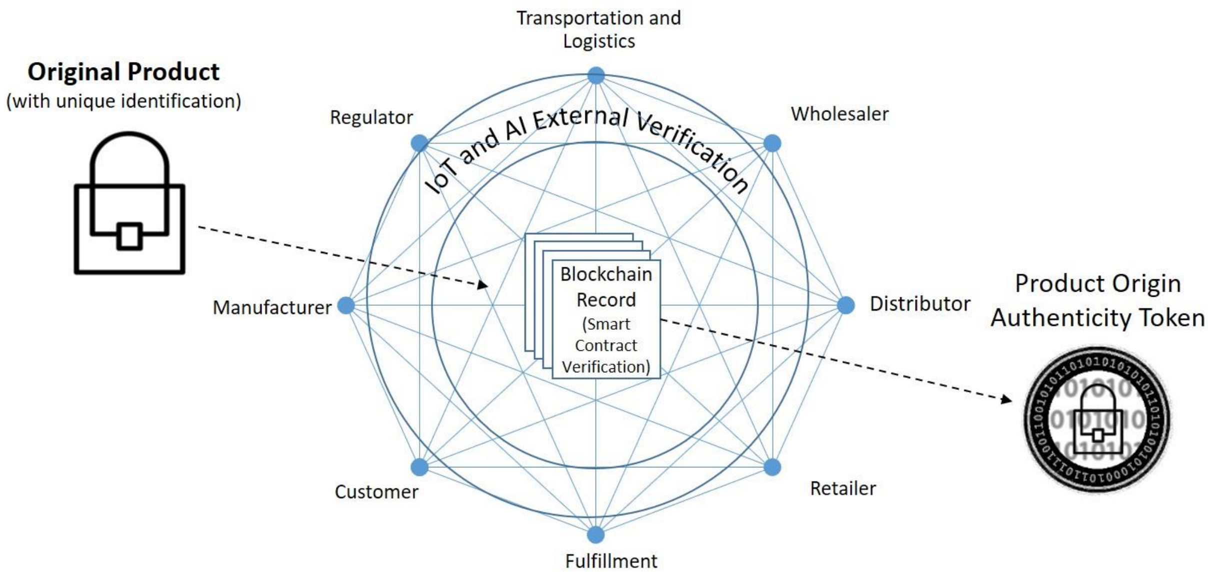
The concept of a trustless or trust-free blockchain environment that can eliminate the need for trust between human agents has been challenged as impossible. As a social construct, Maurer et al. (2013) argue that with blockchain systems like Bitcoin, trust is not obliterated but shifts from central authorities toward algorithms. Frowis and Bohme (2017) suggest that blockchains are not trust-free by definition. They find that algorithms are not immune to human trust, with 40% of blockchain smart contracts examined reported to violate non-manipulability conditions. Lustig and Nardi (2015) suggest algorithmic trust is not limited to the functioning of the algorithm but also includes socio-technical factors such as third-party services, legitimacy within the institutional environment, and the transparency and comprehensibility of the underlying algorithms. Al Khalil et al. (2017) suggest the algorithmic forms of trust found in smart contracts is actually trust in the correctness of a formal and legal social system.

Blockchain and Product Origin Authenticity

In this section, I present the role blockchain can play in generating product origin authenticity and discuss how it enhances trust. Effah (2017) suggests that when evaluating the authenticity of an object, like an electronic boarding pass, there exists a composite sign (e.g., flight, boarding permit, seat number) that acts to determine if the boarding pass is real or fake (Effah, 2017). In my model, identifiable and verifiable product origin history facts (e.g., location and date of manufacturing, supply chain of custody identity, traceability information) on the blockchain make up the composite sign to determine product origin authenticity. This composite sign acts as a memory of product origin information stored on the blockchain as a token. Using the ERC20 standard on the Ethereum blockchain platform (Vogelsteller & Buterin, 2015), it is possible to create a product origin token that includes product provenance and traceability information (Figure 2). Much like a nonfungible token (NFT) for physical asset history and ownership, the product origin authenticity token contains product origin metadata linked to the physical product via a unique identifier (e.g., serial number, barcode, RFID tag, or some verifiable chemical or physical property). The blockchain token acts as a composite sign to determine product origin authenticity.

Figure 2

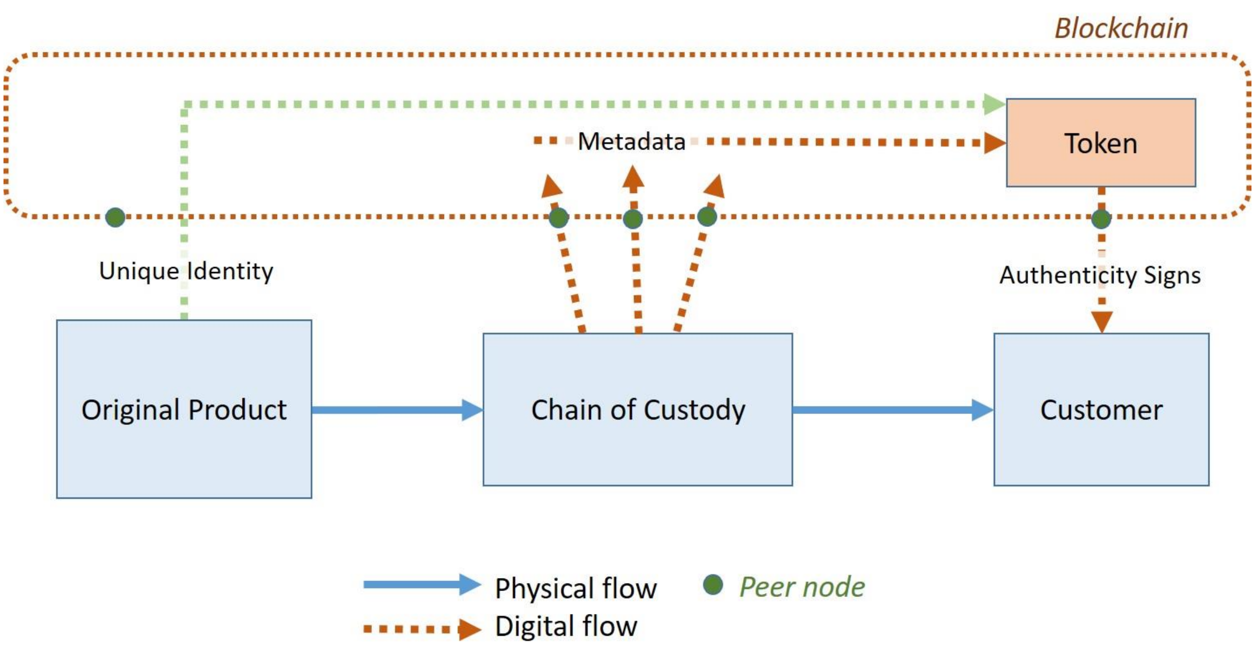
Blockchain Product Origin Authenticity Token



As a system to trace the origin and track the movement of products from the initial sourcing of raw materials to manufacturing, distribution, and consumption through a chain of custody network of operators, blockchain can be used to store, share, and audit product origin information. It can act as an assurance of product origin or as an assessment of several interconnected aspects linked to the place where products are manufactured (Montecchi et al., 2019). Assuming trusted facts that align with the needs of the users, blockchains can deliver information about the origination of a product and the stages from source to the point of consumption (Abeyratne & Monfared, 2016). Product origin authenticity combines CTF truth(s) with chain of custody origin history metadata tokenized on the blockchain that acts as signs of product authenticity (Figure 3).

Figure 3

Blockchain Product Origin Authenticity Foundation

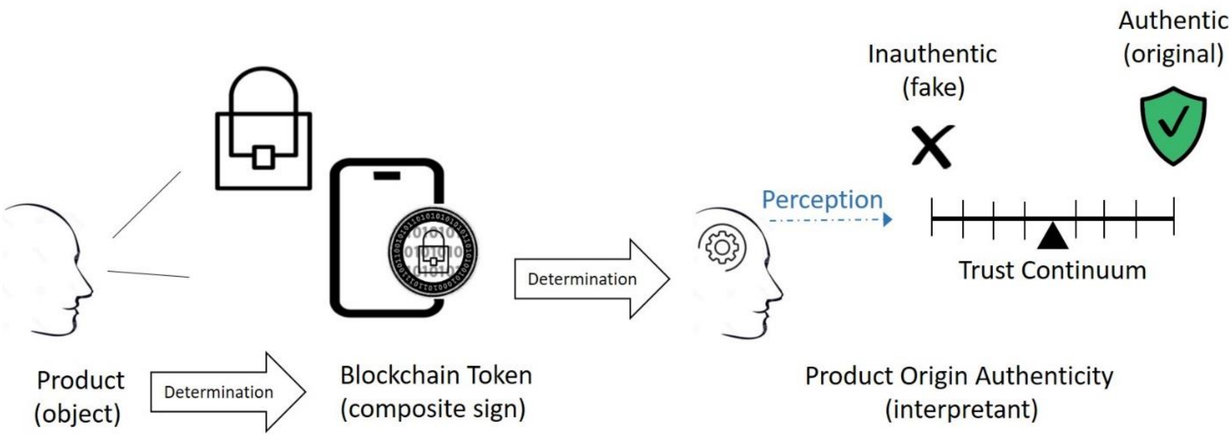


Blockchain and Trust in Product Origin Authenticity

I expect blockchain-enhanced history of a product's origin will boost trust in product authenticity. For any product that can be identified with its tokenized representation on the blockchain, this should boost the trust that products are not fake or counterfeit. Research has shown that blockchain-based traceability systems support trust and positively impact product purchase intentions (Nie & Luo, 2019). In an empirical study testing a trust-based B2C consumer decision-making model, Nie and Luo (2019) show that when the influencing factor of consumers' trust in blockchain traceability includes perceived information quality, they are more likely to buy. Their study supports trust in blockchain traceability, whereas I posit product authenticity based on origin facts. I conceptualize blockchain's role in enhancing trust in product origin authenticity as the degree of confidence consumers have that a product is original and genuine based on the digital product-blockchain composite sign (token) and its relationship with the physical product (Figure 4). The blockchain product origin token provides information in a secure distributed trust environment that allows consumers to expand their evaluations of a product as genuine or counterfeit and enhance trust that it is an authentic item from the manufacturer and not fake or counterfeit.

Figure 4

Blockchain and Trust in Product Origin Authenticity



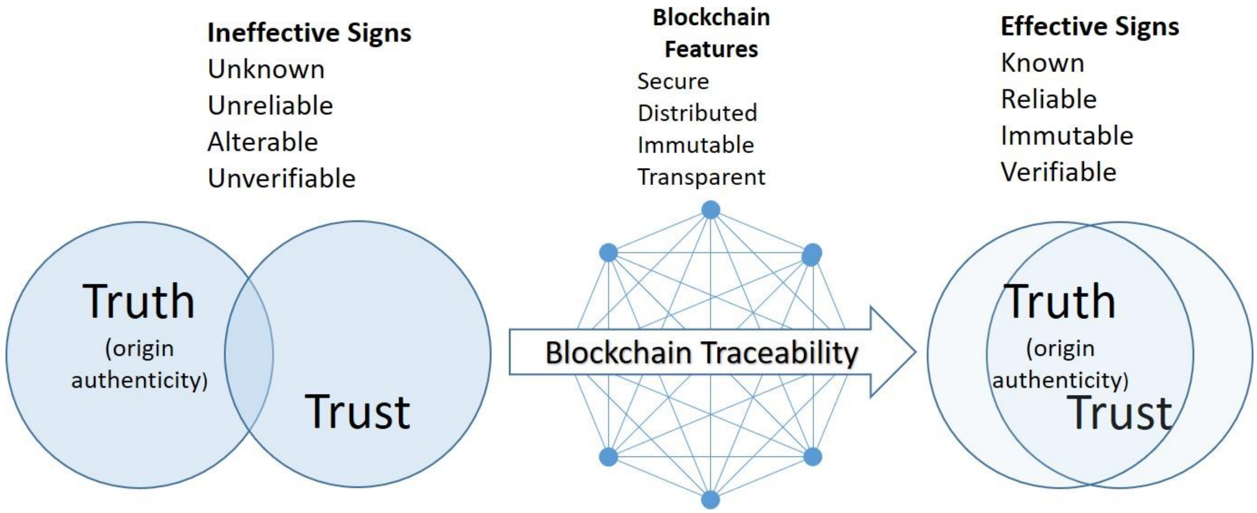
To understand the impact of blockchain technology on perceptions of trust in product origin authenticity, companies today are experimenting with blockchain to track and trace the provenance of goods as they travel through the supply chain to verify authenticity. In a wine industry case, a French wine producer implemented a blockchain traceability solution to track wines in conjunction with another organization. The wine system gave each bottle a unique digital identity with over 90 pieces of data related to ownership and storage history (Kshetri, 2019). The data included images and information from the label, capsule, cork, and glass. As the wine bottle with its label moved to different actors in the supply chain, digital data were updated to the blockchain with ownership and storage records. The authenticity of the wine was judged by verifying its provenance, whereby retailers, warehouses, auction houses, and other sales platforms linked the bottle to its digital identity on the blockchain (Kshetri, 2019).

Conceptual Framework

In this section, I provide a full account of the ability of blockchain to impact trust in product origin authenticity. With its secure and distributed trust memory of CTF origin signs of authenticity, blockchain is a technology that can assemble facts (truths) as agreed to by multiple parties and then prevent them from being altered (Figure 5). In traditional non-blockchain product traceability systems, data is assembled that may be true and untrue. It is not reviewed and approved by multiple parties and, even if it is, someone could later change the records. This paper assumes that the brand manufacturer who creates the blockchain record is a certified and verifiable legal entity and is disincentivized from creating a false product origin record on the blockchain because of potential regulatory, reputational, and financial penalties.

Figure 5

Relationship Between Blockchain and Trust in Product Origin Authenticity



Once the blockchain token has been created, supporting technologies can be used to bolster the integrity of the blockchain record during the chain of custody to the end consumer. This section discusses the role of identification and verification in blockchains for supporting product origin authenticity and outlines a conceptual model to illustrate it.

Identification and Verification Technologies for Supporting Product Origin Authenticity

The inherent capabilities of blockchain can enhance trust in product origin authenticity. Blockchain has been called a truth machine (Casey & Vigna, 2019). Despite the trust capabilities discussed, blockchain cannot assess the accuracy of claims or the truth of any physical, off-chain asset represented digitally on the blockchain. Although blockchain provides an immutable record of transactions, the potential still exists that the immutable data in the system is false since unethical supply chain actors might falsify data before entry. For example, identification numbers for genuine products could be duplicated and applied to counterfeit products, or records of required refrigeration temperatures could be falsified by an unscrupulous shipper and entered onto the blockchain. Thus, I next consider how blockchain technology can be enhanced by both product identification technologies and verification technologies.

Product Identification

Product identification technologies provide a critical knowledge component of a product's origin, processing, and supply chain conditions (Paunescu et al., 2016). Product identification plays a critical role in tracking, tracing, and linking physical objects to the information stored and represented digitally on the blockchain. Applications that gather knowledge about the location, route, or state of products rely on unique identification (Kärkkäinen & Ala-Risku, 2003). In any traceability system, the link between the product identification and tracking information is important, but is a potential vulnerability because it is the only link between the physical object and its virtual representation. Once a customer receives a product, its authenticity can be verified based on its unique product identity. Suhail et al. (2020) find that effective product identification helps resolves the problems of counterfeit products and helps to achieve customer trust.

Product identification technologies or identifiers used to support product origin authenticity can be categorized as either extrinsic or intrinsic. Extrinsic identifiers are tags or markers attached, embedded, etched, or affixed to a product. The most common product identifiers used in supply chain traceability systems are extrinsic. They are found on everyday products in the form of physical, non-native labels and tags like barcodes found on supermarket products. One common extrinsic identification technology, RFID, has been used to uniquely identify products for anti-counterfeiting purposes (Staake et al., 2005). RFID tags identify products using radio waves to store and transmit unique identification. RFIDs improve on barcodes because they do not require line of sight, have an increased range, and can be read quickly in batches, making them ideal for supply chain application for inventory tracking and loss prevention. Another unique extrinsic product identification technology, the Near Field Communication (NFC) chip, is an identifier that improves on Quick Response (QR) codes with increased security and added intelligence, making them ideal for product authentication. A NFC chip secured in the stitching of a handbag, for example, does not require line of sight and can be scanned using a mobile device. Since most extrinsic identifiers must be affixed or embedded in products, there is the possibility that even the most sophisticated identifiers could be duplicated or swapped.

Intrinsic identifiers are inherent to the product itself and cannot be duplicated or swapped. Intrinsic identifiers are the chemical, physical, electronic, or biological characteristic inherent to a product that allows it to be uniquely identified. In the electronics industry, physically unclonable functions (PUFs) would be considered intrinsic identifiers. A PUF is a physical object that, for a given input and conditions, provides a physically defined digital fingerprint output that serves as a unique identifier mostly used for semiconductor devices (Islam & Kundu, 2019). By running a current through an electronic device, a unique identity can be determined for an electronic component. Other inherent physical and optical properties of items, such as the natural graphical patterns in leather, wood, and paintings, would also be considered intrinsic identifiers. Chemical identifiers like flavonoids are used to support trust in food authenticity. Since the composition of chemical flavonoids is genetically determined, they create a relative quantitative fingerprint that can be traced to prove authenticity and discover frauds of food from plant origins (Zimmerman & Galensa, 2006).

Emerging extrinsic identification technologies based on scientific discoveries include nanoparticles, fluorescent dyes, and DNA to encode graphical, optical, and chemical tags, making extrinsic identification more like intrinsic identification (Masna et al., 2018). Although these extrinsic identifiers have intrinsic properties, most are still affixed in some way that does not prevent tampering. For example, removing an unclonable 3D dot matrix tag from a product may render it unmatchable with its blockchain token. As research continues into immutable physical and chemical markers that can be added to products for better security, I expect intrinsic identifiers and their converging extrinsic counterparts to be a more trustworthy way to identify authentic products.

Product Verification

The relationship between trust and verification is not a topic commonly explored in the academic literature. The phrase 'trust but verify' captures the anomalies of trust and its relationship to other strategies of governance within interdependent exchanges (Krass, 1985). Verification is a process that plays a key role in the dyadic relationship between trust and truth. It is the act of establishing truth. In engineering, trust is assigned incrementally through a process of truth verification (e.g., inspection, demonstration, analysis, and testing) to verify credence claims and confirm a product meets its previously agreed characteristics and performance. To verify product origin history, customers typically rely on product tracking provided by a carrier such as UPS or DHL. Tracking information provided by the carrier is a tool for verifying the partial history of a product based on the time and location of its package. Verification can be from manufacturer to consumer delivery. However, typical tracking systems are maintained solely by a single party (usually the carrier) without oversight or auditing by others.

Unlike conventional traceability systems, blockchain systems provide an origin-to-destination solution that inherently incorporates verification technologies. Internal verification within the blockchain provides trusted product origin and chain of custody information by monitoring, learning, deciding, and reporting on the conditions of identifiable products. Internal blockchain verification occurs as transactions are validated and verified within the system to ensure data integrity, which signals the completeness and accuracy of the information shared. Data transparency within blockchains helps prevent counterfeiting and dishonest behavior to boost trust. This is accomplished by reducing information asymmetry, increasing audit compliance, incorporating authentication to identify a person or piece of data, and enhancing data security to ensure that records issued to the network are tamper resistant. To summarize, there are four internal features commonly associated with Blockchain traceability trust features (e.g., mining consensus mechanisms, immutability, peer-to-peer sharing, and smart contracts) and four data features: security, authentication, integrity, and transparency (Glaser, 2017, Teng, 2021).

Beyond these inherent blockchain features, companies are enhancing and developing technologies external to the blockchain to increase its verification capabilities. The internet of things (IoT) is a network of objects and humans connected through unique address schemes that interact with each other and share information gained by objects such as their manufacture, transportation, consumption, and further details (Qu et al., 2018). IoT devices can sense supply chain processes, improving visibility, accuracy, traceability, interoperability, and collaborative decisions along supply chains (Reaidy et al., 2015). Such devices are an example of external verification technology whose data can be added to the blockchain. The automation possibilities of blockchain smart contracts combined with IoT data collection capabilities open new opportunities for enhancing product traceability with secure, transparent, reliable, and shared rules and data (Ahmed et al., 2020). Bahga and Madisetti (2016) argue that blockchain platforms with IoT scanners and sensing devices can enhance the decentralized and trustless peer-to-peer networks inherent to blockchains by expanding the network to include input from these impartial devices. They contend manufacturing product information such as the facility of origin, machine details, and parts data can be added by IoT devices and stored on the blockchain along with the manufacturing date (Bahga & Madisetti, 2016).

Using IoT verification technology, product origin data captured automatically with sensors and IoT devices are stored as metadata on the blockchain. I refer to this type of metadata as CTF product origin truths that constitute the blockchain product origin token. In one case, Figorilli et al. (2018) used infotracing as a method of integrating information related to product origin with traceability using IoT technology. The study showed how the entire forest wood supply chain could be captured from tree cutting to the sawmill process to final products by implementing IoT infotracing (Figorilli et al., 2018). Blockchain enhanced trust that final products did, in fact, come from wood that was traceable back to its source in the forest.

In another use case, Intel demonstrated how its technology could track seafood from catch to the table using blockchain smart contracts and IoT technology (Del Castillo, 2017). Working in conjunction with IoT monitors and sensors, the smart contract added verification aspects to the transaction validation features of blockchain technology. Blockchain transactions included supply chain location data captured automatically by GPS-enabled IoT devices where the fish were caught and tagged with RFID tags, along with the fishmonger's purchase details and the sale to the restaurant. Telemetry and temperature data were captured by IoT sensor devices and transmitted wirelessly to add trustworthy data to the blockchain. The blockchain-IoT technology created an immutable record of provenance and tracked food temperatures by smart contracts for compliance with safety conditions for physical goods as they made their way through a transparent and secure blockchain-enabled supply chain (Del Castillo, 2017).

Like IoT, artificial intelligence (AI) is an emerging verification technology that evaluates and supplies external data to the blockchain. The term AI used in this system refers to narrow artificial intelligence (e.g., Google searches, Siri, Alexa, and self-driving cars). It is all around us and is a successful realization of AI as it focuses on performing specific tasks. Narrow AI has experienced numerous breakthroughs in the last decade that have had significant societal benefits and have contributed to the nation's economic vitality (NSTC, 2016). Companies such as NetObjex are using AI combined with IoT-enabled blockchain for logistics tracking, real-time failure detection, and data and device authentication. In one case, peer-to-peer energy trading is conducted using AI, where data is collected from both consumer smart meters and energy company monitors. The ability of AI to detect fraud from patterns makes it a valuable partner for blockchain authenticity solutions and produces trusted product origin data.

I expect trust in product origin authenticity to be strengthened by combining the distributed trust and traceability features of blockchain technology with reliable product identification and verification to support physical products' historical authenticity and genuineness. The internal features of blockchain, such as cryptography, automatic smart contracts, and peer-to-peer sharing work together with product identification and verification technologies to support trust in the authenticity of products tracked and traced on the blockchain. By complementing reliable product identification technology such as RFID tags with data from external verification technologies such as IoT and AI, product origin history can be more reliably tracked and traced to impact trust in product authenticity.

I expect blockchain technology to have a direct effect on trust in product origin authenticity. I conceptualize that product identification technologies using blockchain that provide a critical link to physical products, together with verification technologies that provide historical origin and provenance data, can boost trust in product origin authenticity. Reliable product identification provides the critical link between a physical product and its token represented on the blockchain. Product verification technologies provide origin history information that acts as a chain of CTF signs to determine product origin authenticity.

The focal phenomenon of interest in this paper is the effect of blockchain product origin traceability solutions on the perceptions of products as either genuine or fake. Research conducted for this qualitative paper leads to the development of a conceptual model (Figure 6) that shows how identification and verification technologies can work together in a distributed trust blockchain environment to boost trust in product origin authenticity.

Figure 6

Conceptual Model for Blockchain Support of Trust in Product Origin Authenticity

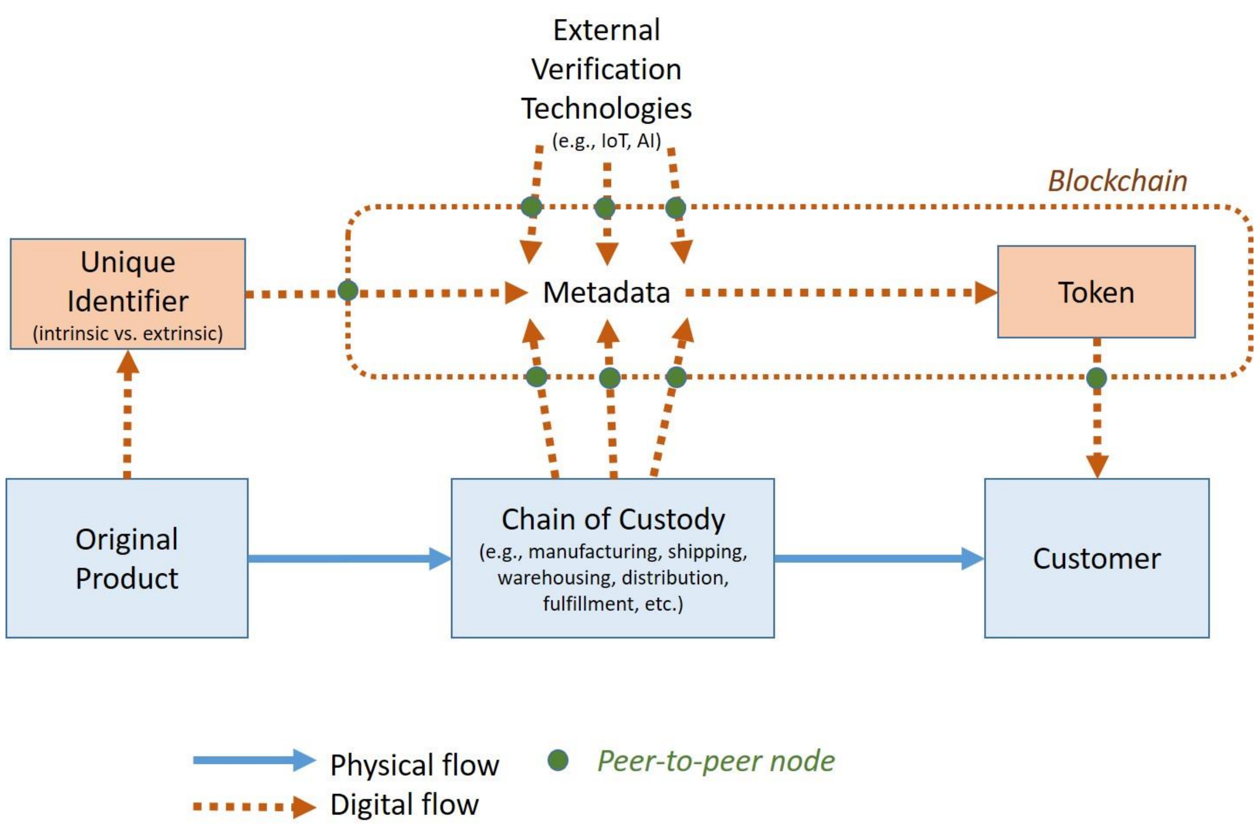


Figure 6 is helpful to our understanding of how these technologies work together. Companies are investing substantial amounts in blockchain traceability technology, unique identifier technologies, and external verification technologies, all with the expectation that it increases customer trust in product authenticity. What is not known is how much effect these technologies have in increasing trust and/or the relative magnitudes. This framework allows for the development of testable hypotheses to empirically examine the effect of a blockchain-based solution with different components on trust in product origin authenticity. For example, it could be that blockchain itself gives a significant boost to trust and that the supporting technologies are only incremental (or vice-versa).

Conclusion

The evolution of blockchain-enabled traceability systems has created a more trustworthy and secure network to support product authenticity. Blockchain traceability solutions can reduce the trust gap by mitigating the perceived risks of counterfeiting and fraud associated with intermediary interventions. With its ability to record historical product origin transactions in a secure, distributed, and auditable manner, blockchain technology, combined with reliable product identification and verification technologies, has significant potential to support trust in product origin authenticity.

In this paper, I developed a conceptual framework to explain how blockchain can impact customer trust in product authenticity. I introduced an authenticity construct, product origin authenticity, made possible by the characteristics and features of blockchain technologies to enhance trust and complemented by converging unique identification technologies and verification technologies. Product origin authenticity is conceptualized as the perception of a product as genuine or counterfeit based on CTF origin truths, supported by unique identification and verification technologies. Product origin authenticity is consistent with indexical, historical, and TTF product authenticity constructs that focus on existential truths to establish authenticity. It removes credence claims (e.g., sustainable and antique) from evaluations of authenticity and provides signals for authenticity based on origin facts tokenized by the product manufacturer. The concept of blockchain product origin authenticity may be unsatisfactory to evaluate whether a product is genuine or fake based on non-CTF origin truths. Blockchain product origin authenticity is concerned with questions like, "Is this product a genuine product manufactured by company X?" After establishing the concept of blockchain product origin authenticity, I presented the case for how it is uniquely positioned to impact trust in product authenticity.

This research supports existing theories and advances the literature on blockchain traceability for product authenticity. It complements authenticity research in marketing to include new possibilities thanks to blockchain technology. The conceptual framework can serve as a guide for companies exploring blockchain technology solutions for securing product authenticity information for supply chain partners, including end customers. It can serve as a basis for future research to empirically test the effects of blockchain identification and verification technologies on trust in product origin authenticity. These complementary technologies include converging graphical, optical, and chemical product identification technologies and verification technologies such as IoT and AI that give blockchain traceability systems the ability to more reliably provide confidence that the digital asset tokenized on the blockchain truly represents the genuine, original physical product. Findings from this research can lead to new insights to inform practice as to how blockchain can better boost trust in product authenticity and reduce the trust gap.

This paper contributes to the literature in several ways. First, the literature on blockchain product authenticity is sparse, despite being increasingly pursued in practice. The few blockchain product authenticity papers are related to blockchain supply chain transparency and trust. In this paper, I examined product authenticity through a distributed trust technology that answers questions such as “Is this a genuine product from the manufacturer and not fake or counterfeit?” without consideration of brand or credence claims. Second, I developed a new construct, product origin authenticity, that fills a gap in the literature for an adequate explanation of the phenomenon of product authenticity based on blockchain support of product origin truths. This is consistent with different literature's brand authenticity constructs, including indexical, historical, and TTF. This new construct is important because it includes the distributed trust, internal verification, and cryptographically secure memory of non-credence product origin facts (truths) for confidence (trust) in the perception that products are original and not fake or counterfeit. Finally, I developed a conceptual framework that related the features and capabilities of blockchain to increased trust in product authenticity. This framework is important to evaluate trust in product origin authenticity based on facts supported by both blockchain and supplementary technologies, and it serves as a springboard for further theoretical development and empirical testing. The framework allows the development of theory and practice around the framework’s components to determine their separate and joint impacts on trust in product authenticity.

CHAPTER 4: THE EFFECT OF BLOCKCHAIN TRACEABILITY AND UNIQUE PRODUCT IDENTIFICATION ON TRUST IN PRODUCT ORIGIN AUTHENTICITY: AN EMPIRICAL STUDY

Introduction

This paper examines the important relationships between two technologies, blockchain systems for product traceability and product identification methods, and how they affect trust in product authenticity. Blockchain applications for tracking and tracing products in supply chains are increasingly being highlighted for their role in combatting counterfeiting (Pun et al., 2021) and supporting customer trust that products are authentic (Montecchi et al., 2019). The trade of counterfeit and pirated goods in increasingly complex supply chains is high, estimated to be over $1.7 trillion globally (CSC, 2017). Concurrently, online sales, the top source of counterfeit products (Boukis, 2019), are at an all-time high of 13.4% in the US (census.gov, 2021). Companies are increasingly looking for ways to protect against illegal activity (Ertekin et al., 2018; Li, 2013). Since too many counterfeit products would discourage sellers from using their services, online sales platforms (e.g., Amazon, Alibaba, eBay) are encouraging manufacturers to consider blockchain traceability solutions as one means to reduce counterfeiting (Pun et al., 2021). Research suggests that wider adoption of blockchain would increase consumer trust by enhancing transparency and reducing counterfeit consumption (Boukis, 2019).

Consumers want to know they can trust label certifications and the authenticity claims made for products they purchase (Galvez et al., 2018). Due to counterfeiting concerns, consumers increasingly expect retailers to offer transparent product-related information throughout the entire supply chain (Busby, 2019; Gallo et al., 2021; Garaus, 2021). This shift in consumer preferences serves as a call for businesses to adopt new product traceability systems

(Islam & Cullen, 2021). Blockchain represents a promising application for addressing product authenticity concerns by ensuring product traceability (Clauson, 2018; Creydt & Fischer, 2019; Kshetri, 2019). Blockchain is a decentralized and distributed ledger in which supply chain product exchanges can be logged chronologically in a tamper-proof record (Treiblmaier, 2018). Blockchain-based solutions benefit manufacturers who seek a positive response to meet consumers' requirements for higher transparency in product traceability (Garaus, 2021).

A key component of traceability systems is product identification (Li, 2013). Since product information is recorded digitally and tracked and traced over networks, the information record and the product must be securely linked so customers can trust that the product they buy is the authentic item represented in its digital record. If the product identification is not reliable, the user might suspect that the received product differs from the information record. Item-level product identification like barcodes and RFID technologies provide a critical link for tracing product history and securing consumer trust in products after purchase (Lee et al., 2007). An empirical study found one unique product identifier, RFID, directly and positively impacted blockchain technology utilization, which positively and directly impacted supply chain transparency (Zelbst et al., 2019). As a full product traceability solution, businesses are implementing blockchain technology coupled with product identification technologies to provide product origin and chain of custody tracking and tracing to enhance trust in product authenticity (Clauson, 2018; Li, 2013; Montecchi et al., 2019).

The objective of this paper is to examine customer perceptions of product authenticity based on the product origin history captured by blockchain-based traceability systems. The concepts of blockchain traceability, product origin authenticity, and product identification are explained and hypotheses are developed about their relationship with perceived trust in product authenticity. To examine how blockchain traceability and unique product identification technologies interact to impact trust in product authenticity, the research questions are:

- Does the use of blockchain technology for product traceability increase trust in product authenticity?
- Does more reliable product identification technology increase trust in product authenticity?
- Is the combined effect of the two technologies (blockchain traceability and product identification) on trust in product authenticity additive or synergistic?

These questions are important because companies are investing in both technologies despite the lack of empirical evidence of their efficacy. Investment in product tracking and identification is skyrocketing as the demand for global track-and-trace solutions is projected to surpass $6 billion by 2027 (Research and Markets, 2021), and regulatory requirements like the US mandates for pharmaceutical tracking at the item level are required by 2023 (U.S. Food and Drug Administration, 2020). This study can help managers understand whether these technologies meaningfully enhance consumer trust in product authenticity and whether the purported benefits are worth the investments and implementation efforts.

This paper contributes to the literature in several ways. First, it answers a call for more quantitative research for companies seeking to use blockchain technology for business practices (Wong et al., 2020). I extend the work of Chapter 3 by empirically testing the proposed relationships between blockchain traceability, product identification technologies, and trust in product authenticity. The conceptual framework developed in Chapter 3 is important for understanding these relationships, but it has not been subject to empirical examination. The framework combines three streams of literature. The trust and authenticity literature provides the foundations for exploring how blockchain and product identification might affect trust in authenticity. Authenticity is a complex theoretical construct. In the context of determining if a product exposed to a complex supply chain is genuine and not counterfeit, authenticity constructs are based on spatial-temporal, historical, and factual signs (Grayson & Martinec, 2003; Moulard et al., 2020; Newman, 2019) are explored. They provide a foundation for the perception of a product as genuine based on origin history facts. A second literature stream focuses on how blockchain traceability can impact supply chain trust and transparency (Nie & Luo, 2019; Wang et al., 2019; Zelbst et al., 2019). Seidel (2019) describes how distributed, immutable, and auditable transactions processed and stored on blockchain distributed ledgers eliminate the need for a central authority like a bank to secure trust. Abeyratne and Monfared (2016) demonstrate that based on trusted facts that align with the users' needs, blockchains can deliver information about the origination of a product and the stages from source to the point of consumption. A third stream of literature focuses on product identification and verification technologies and methods to boost perceptions of product authenticity and trust (Azzi et al., 2019; Doukidis & Pramatari, 2007; Sun et al., 2021; Wallace & Manning, 2020). Mondal et al. (2019) propose a framework for a blockchain-inspired traceability system based on unique RFID product identification. These works separately support the importance of product identification technologies (unique identifiers) in establishing the critical link between a physical asset and its representation on the blockchain and the use of data stored on the blockchain to support trust in product quality and integrity. Synthesizing these three literature streams, I propose that blockchain traceability systems, together with associated technologies such as unique product identification, can boost customer trust that products are original and authentic rather than counterfeit.

A second contribution of this study is that it adapts existing indexical and historical authenticity scales to measure a new construct of authenticity, product origin authenticity.

Although the construct of product origin authenticity was proposed in Chapter 3, it has yet to be operationalized. Product origin authenticity is a perception of authenticity based on origin facts (e.g., manufacturing dates and locations) that act as signs or indicators that people use to determine what is genuine or fake. It provides a framework to answer the question that consumers who purchase products of unknown origins and complex supply chains want to know: "Is this a genuine, original product from the manufacturer?" I develop a scale based on product origin history that removes the influences, relationship to other entities, and credence claims that form the basis of most product authenticity constructs (Beverland & Farrelly, 2004; Grayson & Martinec, 2010; Moulard et al., 2020; Newman, 2019).

Third, I empirically test not only the effects of blockchain traceability and product identification on trust in product origin authenticity but also the interaction between them. This uncovers not only their individual effects but also potential synergies between them. If a synergistic relationship exists between the two technologies, it could inform and influence investment decisions.

A fourth contribution is my use of experimental vignette methodology to empirically investigate the relationships of interest. A vignette provides a short description of a situation with precise references to important decision-making factors intended to elicit opinions, values, and attitudes arising from unique situations that are sometimes difficult to define or articulate (Rungtusanatham et al., 2011). Since vignettes are multivalent representations of real-life situations, the related questions are more realistic and allow for the investigation of factors varied in an experiment (Steiner et al., 2016). Vignette experiments allow for the simultaneous investigation of factors varied in the experiment and their interactions (Gould, 1996). Although this methodology is well established in the literature for measuring perceptions (Atzmuller &

Stener, 2010; Cook, 1979; Dulmer, 2007), it has not been widely applied in general supply chain research or to specifically study the effects of blockchain technology on product authenticity.

The most closely related work to this paper is Montecchi et al. (2019) who developed a blockchain-based provenance knowledge framework from product origin, authenticity, custody, and integrity information that should help reduce perceptions of fake products. They presented a guide on implementing blockchain to establish provenance. My work differs in several ways. First, I consider product authenticity based on origin facts stored on the blockchain. Second, I include product identification as a critical knowledge component to reliably link a unique product to its representation on the blockchain. Third, I test blockchain's effects on trust in product authenticity. Last, I demonstrate how products represented on the blockchain are perceived as genuine to a greater extent than those tracked in a traditional manner.

The remainder of the paper is structured as follows. I summarize the relevant literature on product authenticity and trust and examines the potential roles of product identification and blockchain technologies in boosting trust. Next, I present the research design and methodology. I then report and discuss the findings. Finally, I conclude the paper with implications for research and practice, avenues for future research, and limitations.

Literature Review

Product Origin Authenticity and Trust

I cover four main concepts of authenticity central to the idea of product origin authenticity. First, Grayson and Martinec (2004) conceptualize indexical authenticity in terms of a spatiotemporal link that connects an object in the present day with some spatial/time point in the past. In the context of physical products, indexical authenticity represents the connection between a product and a point of reference, such as a place or an event (Fritz et al., 2017). It acts as an assurance of origin or assessment of interconnected aspects linked to the place where products are made (Montecchi et al., 2019). Second, nominal authenticity is expressed as an object's history and connection to correct identification of the origin and provenance of an object (Dutton, 2003). Third, historical authenticity is a combination of indexical and nominal authenticity. It acts as the main lens of perception through which consumers judge if products are genuine rather than fake or counterfeit based on evaluations of physical connections with binary judgment (e.g., Did the item have contact with X or not?) (Newman, 2019). For example, a Rembrandt painting would be considered historically authentic if its provenance could be traced back to Rembrandt through associations of ownership and events. Fourth, Moulard et al. (2020) conducted a literature review of marketing research on authenticity to clarify how consumers perceive authenticity based on truth. They conceptualize a reference framework for TTF authenticity that provides an overarching definition of authenticity based on the epistemic truths that correspond to appropriate facts (Moulard et al., 2020). TTF authenticity is a view of authenticity through the lens of a consumer's perception where information about an entity corresponds to an actual state of affairs like "Apple publicly claims its products are designed in California yet assembled in China" (Moulard et al., 2020, p.101).

In Chapter 3, I combined these four concepts of authenticity to propose a construct called product origin authenticity. Product origin authenticity is the perception of a product as original or genuine based on product origin history that corresponds to facts. Unlike historical or indexical authenticity constructs, product origin authenticity does not allow for credence claims (e.g., sustainable source, wild-caught) to establish if a product is authentic. It also does not consider external events or relationships (e.g., Victorian era, Gettysburg artifact). In assessing product origin authenticity, an object perceived as genuine/original (trust) would be considered authentic, whereas an object perceived as fake or counterfeit (lack of trust) would be considered inauthentic. Any product that can be reliably identified and traced back through the supply chain to its origin could be judged for product origin authenticity. This view of authenticity is consistent with existing theories, suggesting that authenticity should be conceptualized for physical objects based on corresponding facts related to their origins (Grayson & Martinec, 2004; Lau, 2009; Montecchi et al., 2019; Moulard et al., 2020; Newman, 2019).

Since product origin authenticity cannot typically be independently verified by customers, they must judge it based on information or authenticity cues available to them. Product origin history stored on the blockchain provides cues for customers to judge if they accept the vulnerability (trust) that a product is genuine and not fake or counterfeit (distrust). That is why I use the phrase "trust in product origin authenticity."

Blockchain-based Product Traceability

Blockchain technology in its most basic form is a digital ledger of shared transactions related to accomplishing trustworthy non-reversible cash-like transactions without the involvement of a central authority or traditional bank (Nakamoto, 2008). One blockchain platform, Ethereum, introduced programs stored on a blockchain that automatically run when predetermined conditions are met, known as smart contracts. Smart contracts used in blockchain traceability applications verify relevant information (e.g., originality, ingredients, and locations) and issue certificates enabling users to track and trace products for accountability and forensic information (Xu et al., 2018). Smart contracts enforce and execute business logic with complex programmable conditions that were not technologically viable before blockchain (Reyna et al., 2018). For example, a supply chain exchange smart contract for wine traceability could be deployed to automatically create a data record for each transaction, validate the transaction information, validate the signature of the user, and append the record to the blockchain (Yiu, 2021). Smart contracts ushered in what is known as Blockchain 2.0 and extended blockchain beyond cryptocurrencies, like Bitcoin, to product traceability applications that do not require a central authority to act as a trusted intermediary.

The literature suggests the ability of blockchain traceability platforms to leverage the distributed, secure, and immutable features and capabilities of blockchain to impact supply chain transparency and boost trust that products tracked and traced are not fake or counterfeit (Yiu, 2021; Zelbst et al., 2019). Using blockchain traceability, firms can enter trusted economic exchanges upon first interacting with an unknown supply chain actor without the need for a third party to vouch for the unknown actor (Seidel, 2018). Blockchain traceability systems provide a verifiable record of provenance transactions. All product and shipping information collected through different technologies are stored in a tamper-proof ledger where stakeholders can audit product history (Azzi et al., 2019; Ramamurthy, 2016). The appended ledger is rendered immutable and resistant to censorship and manipulation due to the cryptographic and distributed foundations of blockchain technology (Maull et al., 2017). Blockchain can extend trust to previously unknown and untrusted players in complex supply chains, making it a promising solution to ensure the trust and integrity of products in various supply chains (Tapscott & Tapscott, 2016).

Technology trust is important because using technology involves evaluating risks (Neumann, 1993). Conversely, if people do not trust the technology, they may not accept it as useful (Lee & Wan, 2010). Blockchain's ability to extend trust to product authenticity is enhanced by its role as a trusted high-technology solution. Wallbach et al. (2020) conducted a study and found that the blockchain features of immutability and traceability have a positive impact on it as a technology people trust.

Montecchi et al. (2019) establish a framework to explain how blockchain technology implemented in supply chains can enhance provenance knowledge and assurances based on origin, authenticity, custody, and integrity of products. They outline how transparent product traceability information shared on blockchain ledgers enhances product provenance transparency, chain-of-custody tracking, and product authenticity. Pun et al. (2021) discuss using blockchain technology as a supply chain solution for counterfeiting and suggest that manufacturers use blockchain data to support product authenticity when customers distrust products in the supply chain. Although Montecchi et al. (2019) and Pun et al. (2021) make convincing arguments, there is not yet any empirical evidence to support their claims.

Given research on the inherent trust-enhancing characteristics of blockchain traceability technology (e.g., distributed, immutable, auditable), I suspect that blockchain product traceability information (e.g., location and date of manufacturing) act as reliable signs or cues to boost customer trust that products are genuine and not fake or counterfeit. I hypothesize that:

H1: Blockchain product traceability increases trust in product origin authenticity.

Unique Product Identification

The role of product identification or identifiers in traceability systems is to connect or map a physical product to the true identity of an organization (Yiu, 2021). Product identification technologies provide a critical knowledge component required for securely binding the identity of a product to the traceability history stored on the blockchain (Islam & Kundu, 2019; Paunescu et al., 2016). RFID tags and unique biometric patterns found in leather and wood are a few examples of unique identifiers that provide a one-of-a-kind link between a physical product and its traceability information stored digitally as metadata on the blockchain. Suhail et al. (2020) find that effective product identification helps resolves the problems of counterfeit products and helps to achieve customer trust.

Product identification technologies or identifiers used to support product origin authenticity can be categorized as either extrinsic or intrinsic. The most common product identifiers used in supply chain traceability systems are extrinsic. Extrinsic identifiers are tags or markers attached, embedded, etched, or affixed to a product. They are found on everyday products in the form of physical, non-native labels and tags such as barcodes found on supermarket products. Although extrinsic identifiers like QR codes and RFID can provide reliable product identification, some industries are turning away from these technologies because they can be easily falsified and are not considered safe. Since most extrinsic identifiers must be affixed or embedded in products, it leaves the possibility that even the most sophisticated identifiers could be duplicated or swapped.

Unlike extrinsic identifiers, intrinsic identifiers are inherent to the product itself and cannot be duplicated, swapped, or falsified. Intrinsic identifiers are the chemical, physical, electronic, or biological characteristic inherent to a product that allows it to be uniquely identified (Islam & Kundu, 2019; Li, 2013; Sun et al., 2021). For example, in the electronics industry, a PUF would be considered an intrinsic identifier. A PUF is a physical object that, for a given input and conditions, provides a defined digital fingerprint output that serves as a unique identifier. PUFs created by the unique pattern of drying patterns in silicon and varnish are being used to combat the problem of copying and creating a fake traceability history which is a drawback of RFID and QR technologies (Hepp et al., 2018; Islam & Kundu, 2019). Other intrinsic identifiers being developed for unique product identification include inherent properties of items, such as the DNA and natural graphical patterns found in leather and wood. The wood products industry is one example where the intrinsic biometric features of wood texture create a fingerprint that can be used to distinguish individual wood products (Sun et al., 2021). Other industries like electronics, food, pharmaceutical, and luxury are also turning to intrinsic identification technologies (Arcenegui et al., 2021; Galvez et al., 2018; Sun et al., 2021).

Both extrinsic and intrinsic identifiers have been shown to support trust in product authenticity. Extrinsic identification technologies like RFID tags used to enhance supply chain management have been shown to support trust that products are not counterfeit (Lehtonen et al., 2007; Srivastava, 2010; Staake et al., 2005). Zelbst et al. (2019) find RFID directly and positively impacts blockchain technology utilization, which positively and directly impacts supply chain transparency, creating an environment that supports product authenticity. As an example of intrinsic product identification, Zimmerman and Galensa (2006) tested the use of intrinsic chemical flavonoids to provide proof of authenticity and tracing of foods. Flavonoids create a quantitative fingerprint that can be traced to verify product authenticity and discover food from plant origin fraud. They found support for using intrinsic product identification as a useful tool for food tracing, to prove authenticity and to discover frauds of food fraud from their origins (Zimmerman & Galensa, 2006). Based on the characteristics of unique product identification, I hypothesize that:

H2: Trust in product origin authenticity associated with intrinsic product identification is greater than that associated with extrinsic product identification.

In addition to the direct effects on trust that I hypothesize for blockchain traceability and the type of product identification, I consider whether the type of product identification (i.e., intrinsic vs.

extrinsic) moderates the relationship between blockchain traceability and trust in product origin authenticity. Customers must have confidence that the product identification is unique to the actual product. Without that confidence, even the most secure digital system (like blockchain) will not increase trust. Based on my argument for H2, I expect that people are less trusting of extrinsic product identification than intrinsic. Although Zelbst et al. (2019) propose that extrinsic identification technology works with blockchain to increase trust, Sun et al. (2014) argue that weaker extrinsic identifiers like barcode tags provide minimal protection against counterfeiting and can be more easily counterfeited by photocopying. Hepp et al. (2018) argue that extrinsic identifiers (e.g., RFID have a drawback in that they can be copied. It has been suggested that the lesser trust of extrinsic identification could lessen the effect of blockchain on trust. Therefore, I suspect the less reliable extrinsic product identification scheme could reduce or eliminate trust associated with blockchain-based traceability systems and trust in product origin authenticity.

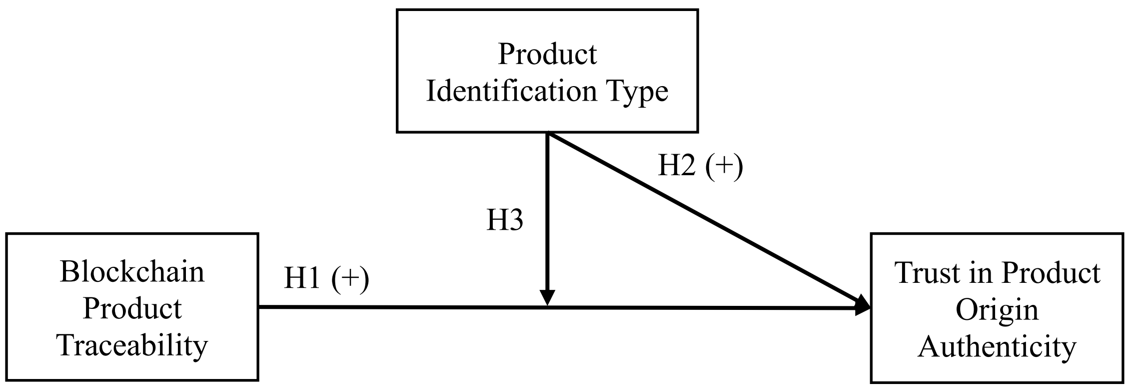
Intrinsic identification is essential to provide a trusted link to assets on the blockchain. It plays a crucial role in fighting counterfeit, trademark law enforcement, and organic product certification. They play an essential role (Hepp et al., 2018). Intrinsic product identification schemes share some of the same trust characteristics of blockchain technology. They have immutable properties that secure unique product identification. In the case of intrinsic identification, immutability is in the form of unclonable physical, chemical, or biological fingerprints. In the case of blockchain, cryptography secures the unalterable digital representation of unique physical products. Thus, it is reasonable to expect that a good product identification scheme (such as intrinsic) coupled with blockchain could have a synergistic effect on trust. In other words, intrinsic product identification could positively moderate the relationship between blockchain traceability systems and trust in product origin authenticity. This leads to the following hypothesis:

> H3: Product identification type moderates the relationship between blockchain product traceability and trust in product origin authenticity.

See Figure 7 for a conceptual model of my hypotheses.

Figure 7

Conceptual Model, Empirical Paper



Research Design and Approach

Vignette-based Experiment

To test the hypotheses, I conducted a vignette experiment. In survey research, vignette experiments typically consist of short, systematically varied descriptions of hypothetical situations used to elicit the attitudes or behaviors of respondents with respect to presented scenarios (Steiner et al., 2016). Vignette experiments are particularly appropriate when the dependent variable of interest is a perception (Aguinis & Bradley, 2014).

Given the role of blockchain traceability and product identification in affecting trust in product origin authenticity, a vignette experiment offers several advantages. A vignette experiment provides an opportunity to examine the effects of blockchain product traceability and product identification on trust in product origin authenticity in a potentially less aggressive and/or imposing format than that of direct questions. Vignettes do not necessarily require participants to have in-depth knowledge of the topic but can be used to elicit automatically generated meaning from the participants (Colllind & Brief, 1995). The information contained in the vignettes can be defined and standardized (Berk & Rossi, 1982) to enable all participants to respond to the same stimulus.

Development of the Vignettes

Classical experimental designs achieve their high internal validity from orthogonal design plans and an active mode of measurement enabled by the controlled intervention; however, single experiments typically have low external validity due mainly to their unrepresented and oversimplified setting (Atzmuller & Steiner, 2010). Vignette studies try to overcome this limitation by combining the traditional survey with an experiment where the availability of multifactorial designs reorient narrowly methodological concerns to broader substantive issues (Sniderman & Grob, 1996). Studies have adopted a similar methodology to elicit opinions, values, and attitudes arising from unique situations when the dependent variable is a perception (Rettinger et al., 2004). To test the hypotheses, I conducted a 2x2 full factorial between-subjects experiment with product identification type (intrinsic vs. extrinsic) as one independent variable and the use of blockchain for product traceability (yes vs. no) as the other independent variable. My dependent variable was trust in product origin authenticity.

I developed two vignettes for each independent variable, drawn from realistic product purchasing scenarios, which assigned the participant to the role of an online customer of a fictitious product. The vignettes were constructed to allow for the manipulation of two blockchain traceability levels (yes vs. no) and two product identification types (intrinsic vs. extrinsic), creating four scenarios. See Appendix B for complete verbiage of each scenario.

The vignettes used in this study were developed after a literature review and interviews with blockchain academics and business leaders to ensure the face validity of the scenarios. Preliminary vignettes were tested using manipulation checks with small groups of graduate students and refined until manipulation checks resulted in the desired differences in responses.

In each vignette, participants were asked to assume the role of a customer purchasing a popular air quality monitoring device from an online e-commerce website. The vignettes provided a realistic representation of a consumer product with antecedents to trust such as safety, manufacturer, brand, country of origin, and price (Kennedy et al., 2001; Witt, 1990; Yeung & Morris, 2006). An online air quality monitoring device was chosen because it addressed several product antecedents to trust. First, it represented a consumer product with health and safety concerns that could impact trust. Second, it was an unknown brand, so participants would have no pre-existing judgment that might bias their responses. Third, the air quality device was not cheap to be throw-away but not so expensive that consumers would go to extraordinary lengths to secure trust. Fourth, the product was manufactured in Vietnam, a country largely unknown to participants but could raise suspicions of counterfeit. Finally, the product contained an integrated circuit required for the intrinsic product identification test condition.

Each participant was given an identical description of the setting and their role. Participants were presented with the safety issue of failing counterfeit products discussed in the news to stimulate concerns of product authenticity. Each participant was then randomly assigned to one of the four scenarios and asked to rate their trust in the origin authenticity of the product. Analysis of the responses indicated that most participants took the survey seriously as only 22 failed the attention check. These responses were excluded from the analyses. The assignment of vignettes for each of the experimental conditions was done by a randomizer feature. In the end, 548 participant responses were obtained for the four vignette scenarios.

Study Population and Sampling

The study was conducted using a sample of online followers recruited from a Twitter social media lifestyle microblog (Table 1). Participants 18 years and older, exclusively from the United States, were recruited by asking for voluntary participation in a study on product authenticity. The overall survey took an average of 10 minutes to complete. 73% of the participants ranged in age from 25-44 and almost 59% were male. Over 44% of participants had at least a bachelor's degree, 82% had at least three years of work experience, and 49% reported having at least three years of supply chain work experience.

INSERT TABLE 1 ABOUT HERE

Careful consideration was given to the survey design to minimize the error between an estimate produced using survey data and the true value of the variables in the population (Dillman et al., 2014). Four types of errors were addressed in the design of the study. First, for coverage errors that exist when the sample members do not accurately represent the population, this study included screening questions to identify consumers who understand the properties of blockchain technology that make it possible to track and trace products from raw materials to sale. Moreover, although online followers of fashion and lifestyle social media platforms do not represent the entire population of consumers, they are a good representation of the consumer population with experience purchasing goods online from unknown suppliers. Even though most study participants were expected to have exposure to purchasing consumer products online, screening questions were added to identify their familiarity with online shopping. 91.8% of respondents reported they purchase consumer products online occasionally to very frequently. Second, to reduce the error that can occur when only a sample of the frame is surveyed, making the survey available online and leveraging the large follower base of a social media influencer enabled access to more study participants to reduce the sampling errors. Third, nonresponse error due to partial responses was addressed using a forced response to all key questions. Fourth, the vignettes presented background information and real-world scenarios to solicit more informed survey responses to reduce measurement error and minimize total survey error. To ensure that the vignettes were read and understood, an attention check was also included.

Ethical Considerations

This study was approved by the Graduate and Professional Schools Institutional Review Board (IRB) at Pepperdine University (Appendix A). Study participants received an explanation of the study aims, procedures, and information regarding their rights and the confidential handling of their data. After participants provided their informed consent, they completed a survey. To reduce sampling bias, participants were not incentivized or rewarded.

Independent Variables

The treatment to test the effect of blockchain traceability on trust in product origin authenticity consists of scenarios with and without the use of blockchain (yes vs. no). In the blockchain used scenarios, the participant was told product traceability information, such as time-stamped locations, are added to the blockchain throughout the entire supply chain from manufacturer to the end customer (the role played by the participant). Any deviation in package delivery or storage would result in package contents flagged as potentially counterfeit.

Conversely, in the blockchain not used scenarios, the participant was told that product packages are trackable from the seller's website from fulfillment centers to the end customer by traditional product tracking. In these scenarios, blockchain was not mentioned.

The treatment to test the effect of product identification (intrinsic vs. extrinsic) on trust in product origin authenticity also consisted of scenarios. In the intrinsic product identification treatment condition, the participant was told the product has a unique identity key based on the naturally occurring structure of silicon found in the device's internal electronic components that is impossible to clone or copy. When registering the device online, the unique identity key is verified, and the customer receives a notification of authenticity based on the unique identity key. In the extrinsic product identification treatment, the participant was told the product has a QR code tag containing a unique serial number. The QR code is attached to the device and could possibly be cloned, copied, or removed. When registering the device online, the QR code is verified, and the end customer receives a notification of authenticity based on the QR code match.

Dependent Variable

The dependent variable used was trust in product origin authenticity. Measurement items were drawn from the product authenticity literature. Four questions were derived from studies on indexical and historical authenticity. 2 captured indexical elements (e.g., indexically authentic because it was made in the 1800s) (Grayson & Martinec, 2004) and two of which captured historical elements (e.g., historically authentic Civil War uniform) (Newman, 2019) of product origin authenticity. The four questions represented the perception of a product as origin authentic based on correspondence-to-fact (CTF) origin history truths like date and location of manufacturing as captured by the manufacturer that creates the blockchain record.

After reading a vignette, participants rated their trust in product origin authenticity as if they were the consumer verifying the genuineness and originality of the product (e.g., "What is your level of trust that the device you received is genuine from the manufacturer and not fake or counterfeit?"). Participants rated their level of trust using a 7-point Likert scale (1= Extremely Low, 7 = Extremely High).

Control Variables

I chose control variables based on previous studies. The variables of age, gender, years of work experience, and frequency of purchasing consumer products online were drawn from the literature on factors that influence user perceptions of product authenticity (Baek et al., 2020; Mavlanova & Benbunan-Fich, 2014). I included education level based on studies that show lower educated participants experience more trust than higher educated participants (Charlebois et al., 2016). A measure of years of supply chain work experience was added based on studies that show that trust is an important factor for blockchain adoption in supply chain applications (Fosso et al., 2020).

I theorize that higher levels of technology literacy and blockchain comfort may also lead to more trust in blockchain traceability. My rationale is that people who understand blockchain technology, or who are more technologically savvy, may be more likely to value blockchain as a product traceability solution based on its ability to create a distributed, secure, and auditable record of traceability transactions.

Table 2 displays correlations among study variables. Most of the control variables correlated with the dependent variable and one other. Exceptions included age, gender, and years of supply chain work experience. A noteworthy finding was that the mean trust (4.84) was greater than a neutral average (4 on a 7-point scale) across all scenarios. This is most likely due to all scenarios containing product identifiers that are unique and all products were tracked. To avoid a potential bias that may have resulted from asking a respondent to choose between two scenarios in a 2x2 factorial design, participants were not permitted to choose between two product identification or tracking and tracing scenarios.

INSERT TABLE 2 ABOUT HERE

Manipulation Checks

During the initial pre-testing of the vignettes, two manipulation checks were performed to check the reliability of similar manipulations. To verify that there was a perceived difference between the types of blockchain traceability, each participant was asked how much shipping, warehousing, or distribution data they thought they could retrieve from the blockchain for this product. To verify that there was a perceived difference in the product identification type factors (intrinsic vs. extrinsic), each participant was asked how likely they thought a product's unique identification could be copied or altered by a counterfeiter. The results of a preliminary t-test confirmed the subjects perceived a difference between blockchain traceability methods, $t(2865) = 15.86$, $p < .001$, and product identification, $t(2865) = 14.56$, $p < .001$. The vignettes in the final study were created based on the preliminary study.

Data Analysis and Results

Internal Consistency of the Measures

The measure of product origin authenticity used was adapted from two authenticity constructs: indexical authenticity (Grayson & Martinec, 2004) and historical authenticity (Newman, 2019). Table 3 indicates the items used to measure trust in product origin authenticity and internal consistency. With all Cronbach's alpha values > 0.7 for the four items, the measurement of the product origin authenticity construct is deemed reliable for this study as it shows moderate to high internal consistency. Convergent validity was analyzed using Spearman rank correlation coefficient to determine the strength of the relationship between indexical and historical authenticity measures and product origin authenticity. The strength of correlation was interpreted as moderate (0.48 to 0.65) for all four items (Huber et al., 2004), supporting convergent validity for the construct.

INSERT TABLE 3 ABOUT HERE

The means and standard deviations of trust in product authenticity for the four treatment conditions are presented in Table 4. The overall rated trust level was greater than neutral *(M* = 4.85) across the four scenarios. This suggests that respondents tend to be trusting, even in the baseline scenario without blockchain or intrinsic identification. As a preliminary analysis, I performed an ANOVA for the two independent variables of interest without control variables (Table 5). The intercept was significant, indicating that the baseline rated trust level was high. I then included all control variables and analyzed the sample data using an ANCOVA (Table 6). The results for each of the three hypotheses are reported below.

INSERT TABLES 4, 5, AND 6 ABOUT HERE

Effects of Blockchain Product Traceability

H1 predicts that blockchain product traceability increases trust in product origin authenticity. As the comparison of the rows in Table 4 shows, it appears that trust in product origin authenticity is significantly greater when blockchain traceability is used (*M* = 4.99) than when it is not used ($M = 4.71$). The ANOVA results in Table 5 revealed significant main effects of blockchain traceability (used vs. not used) on participants' trust in product origin authenticity in the vignettes. Participants reported significantly greater trust in product origin authenticity when blockchain traceability is used ($F = 12.64$, $p < 0.001$).

Including all controls, an ANCOVA (Table 6) revealed significant main effects of blockchain traceability (used vs. not used). Participants reported significantly greater trust in product origin authenticity when blockchain traceability is used ($F = 15.31$, $p < 0.001$). The results for the effects of blockchain traceability in Tables 4, 5, and 6 are all consistent. These results provide support for H1 that blockchain product traceability increases trust in product origin authenticity.

Effects of Unique Product Identification Type

H2 predicts that intrinsic product identification increases trust in product origin authenticity to a greater extent than extrinsic product identification. As seen in Table 4, it appears that trust in product origin authenticity is greater for intrinsic product identification ($M = 4.98$) than for extrinsic product identification ($M = 4.72$). An ANOVA (Table 5) revealed significant main effects of product identification type (intrinsic vs. extrinsic) on trust in product origin authenticity in the vignettes. Participants reported significantly greater trust in product origin authenticity when intrinsic product identification is used ($F = 10.97$, $p < 0.001$). When controls were included, the ANCOVA results (Table 6) revealed significant main effects of product identification type (intrinsic vs. extrinsic) on participants' trust in product origin authenticity. Participants reported significantly greater trust in product origin authenticity when intrinsic product identification is used ($F = 14.30$, $p < 0.001$). The results for the effects of product identification in Tables 4, 5, and 6 are all consistent. These results provide support for

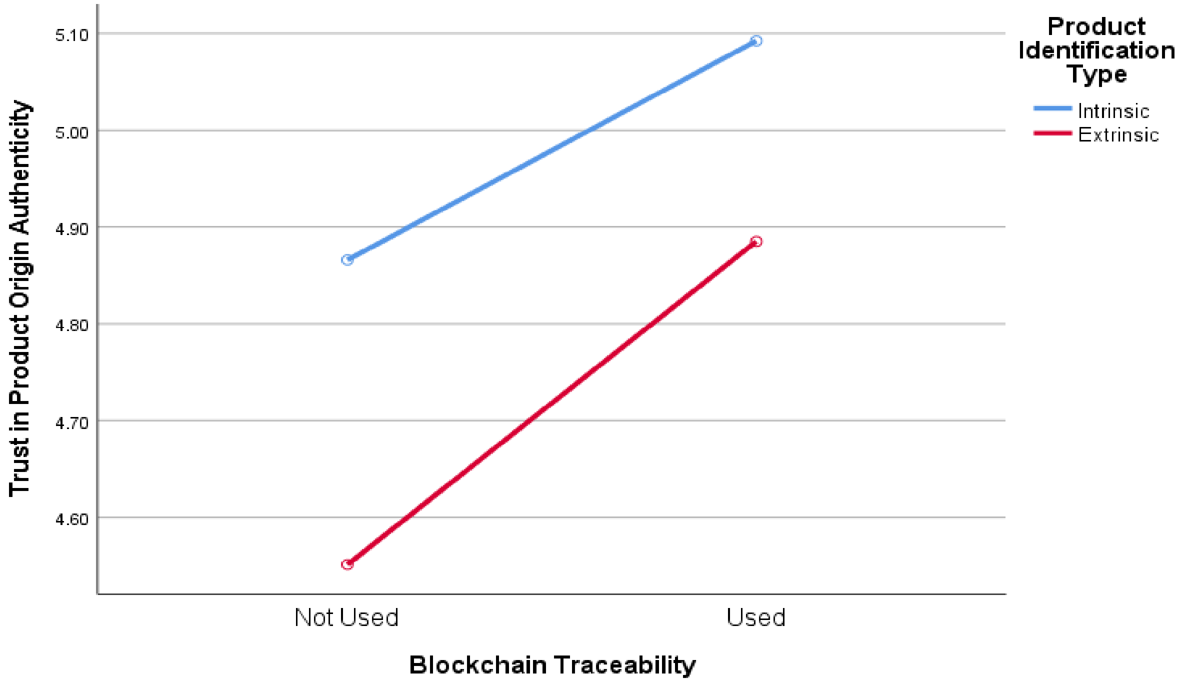
H2 that trust in product authenticity associated with intrinsic product identification is greater than the trust in product origin authenticity associated with extrinsic product identification.

Effects of Product Identification Type as a Moderator

H3 predicts that product identification type moderates the relationship between blockchain product traceability and trust in product origin authenticity. Figure 8 is a plot of the interaction between blockchain traceability and product identification, based on the mean results in Table 4. Although both blockchain traceability and product identification type clearly had direct effects, the parallel plots indicate a weak or non-significant interaction. Similarly, the ANOVA (Table 5) did not reveal a significant interaction effect between blockchain traceability (used vs. not used) and product identification (intrinsic vs. extrinsic) on participants' trust in product origin authenticity (F = 0.46, n.s.).

Figure 8

Interaction Between Blockchain Traceability and Product Identification



Including all controls, the ANCOVA (Table 6) revealed a non-significant interaction effect between blockchain traceability and product identification on participants' trust in product origin authenticity (F = 2.27, n.s.). Based on these results, H3 is rejected, suggesting that product identification type does not moderate the relationship between blockchain product traceability and trust in product origin authenticity.

Effects of Control Variables

After controlling for covariates using an ANCOVA (Table 6), the main results of the ANOVA analysis still hold that blockchain traceability (vs. no blockchain) and intrinsic product identification (vs. extrinsic identification) have positive and significant effects on trust in product authenticity. Conversely, the interaction effect is not significant when controlling for covariates.

Results from the ANCOVA revealed that gender was not significant, suggesting there is no significant difference for trust in product authenticity between genders. Years of work experience was also not significant, which indicates people's view of blockchain traceability and unique identification type does not depend on their work experience. Over 90% of respondents reported they at least occasionally purchase consumer products online. However, purchasing frequency had no effect on results. Age was significant as younger respondents trusted products to be genuine with blockchain traceability and intrinsic identification to a greater extent than older respondents. Education level was also significant in that more educated participants trusted more. Lastly, a participant's comfort levels with blockchain technology and level of tech-savviness had significant effects on the results. Participants who had more experience with blockchain applications or were more technologically savvy reported greater trust in product origin authenticity. Further consideration and testing of the covariate effects provides a good starting place for future research.

Discussion

In this study, blockchain-based product origin history signs demonstrated reliable effects on trust that products are original and not fake or counterfeit (H1). The results from the ANOVA and ANCOVA confirmed that blockchain traceability significantly increases trust in product origin authenticity. Respondents reported higher levels of trust with blockchain traceability than respondents without blockchain traceability. This finding is important because it is, as far as I know, the first empirical evidence that blockchain traceability demonstrably increases trust. Although others have proposed frameworks and argued for this positive linkage (Abeyratne & Monfared, 2016; Nie & Luo, 2019; Wang et al., 2019; Zelbst et al., 2019), this study provides significant empirical evidence of the positive effect.

The observed increase in trust, although statistically significant, is relatively modest. This calls into question whether the results have economic significance. Considering the hype around blockchain, the modest magnitude might be surprising to some. I conjecture that this modest result might be due to the high levels of trust by respondents to the baseline scenarios that did not include blockchain traceability. Considering the high starting point for trust, it is not surprising that the effect of blockchain traceability is modest. Future research could be conducted that attempts to establish a lesser baseline level of trust. This might be possible by employing a scenario where no product traceability information is available (rather than conventional product tracking) and/or by focusing on different product characteristics (e.g., greater safety implications, higher prices, product scarcity) that might influence the need for the higher level of traceability that blockchain can provide. If, in fact, a lesser baseline could be established, the resulting trust increase from blockchain traceability might be of greater magnitude, better justifying future investment decisions given the lower baseline scenario is realistic.

Like blockchain traceability, intrinsic product identification produced significant effects on trust in product origin authenticity to a greater extent than extrinsic identification (H2). Respondents reported higher levels of trust with intrinsic product identification than respondents with extrinsic product identification. Like H1, although the results were statistically significant, their economic significance is not evident from this study. This small magnitude is likely due to a high baseline for trust in product authenticity. Both product identification types (intrinsic and extrinsic) presented in the vignette scenarios were unique. Unlike model numbers that identify a product group, unique identifiers provide a one-of-a-kind reference to a product which I suspect is more trustworthy than non-unique product identification. Future research could establish a lesser baseline for trust, perhaps with a paper tag or even no unique identification. An alternative would be to focus on different intrinsic (e.g., DNA, biometric, chemical) or extrinsic (e.g., bar code, RFID) unique product identification features that might reveal a greater distinction for the increased trust intrinsic product identification can provide.

H3 concerning product identification type as a moderator between blockchain product traceability and trust in product origin authenticity was not supported. I conjecture the interaction effect was not significant because all four treatment conditions used in this study supported a relatively high level of trust. Over half of participants for each base treatment (intrinsic: 60.2%, extrinsic: 52.6%) had baseline conditions for product identification that were genuine and original. This was also the case for blockchain traceability (59.6%) and traditional tracking (53.1%). These results are consistent with previous studies that found general support for tracking and tracing as well as unique product identification. For example, Menozzi et al. (2015) found the intention to buy increases when product tracking and tracing is used, and unique product identification increases trust that products are authentic (Zelbst et al., 2019). Future research expanding on the characteristics and features of traceability and identification technologies is likely to increase the magnitude of the results.

Managerial Implications

Findings from this study can help companies considering integrating blockchain technology by addressing some of the concerns that users might have in adopting the technology. This research may be beneficial for managers exploring the use of blockchain technology and/or unique product identification as an anti-counterfeiting or brand protection strategy. If the lack of interaction is indeed true, managers can choose between either product identification or blockchain traceability, whichever is more cost-effective or easier to implement. However, if the objective is to substantially increase customer trust in product authenticity, the small magnitude of effects found in this study means more research is needed to assess the benefit from lower baselines. Given that blockchain traceability systems and intrinsic product identification technologies tend to be expensive, it is difficult to recommend their adoption based on these results. Results from this study should be interpreted with caution and deserve further research.

It is important to note that, aside from addressing customers' concerns about the authenticity of products, blockchain traceability systems may have the added benefit of discouraging supply chain partner companies from misconduct (e.g., counterfeiting data or low data accuracy) (Longo et al., 2019). Similarly, the use of intrinsic product identification might dissuade some counterfeiters from attempting to create false products. Despite the gains in customer trust and supply chain partner transparency, careful analysis is required for firms to understand stakeholders' reactions as closely monitoring customers, competitors, and other parties becomes possible (Montecchi et al., 2019).

Limitations

As with most empirical studies, the sample is not without limitations. The average respondent was skewed in the direction of a more blockchain knowledgeable, tech-savvy, educated consumer. Although this sample may not represent the current population, it is likely more representative of a younger generation of consumers. The survey respondents might more closely reflect the future demographic of an online shopper who is increasingly exposed to blockchain usage in supply chain applications.

Although much care was taken in the development of the vignettes, vignettes can be overly simple and subjective. The vignettes represented only a single, albeit realistic, scenario. Scenarios with different products, identifiers, origins, or monetary values might yield different results. Participants were asked to report their perception of trust in product authenticity based on potentially unfamiliar identification and blockchain traceability technologies which are prone to misinterpretation and invalid responses. Nevertheless, the vignette experimental design made it possible to present realistic scenarios to explain intrinsic identification and blockchain traceability using examples.

Respondent data was collected at a particular point in time. To the extent that temporal conditions affect general consumer understanding and attitudes toward blockchain, product identification, and counterfeiting, replications of this study at different points in time might find varying results.

Another limitation of this study is related to the generalizability of the findings. An extension of the work presented in this paper could be the inclusion of additional countries with a less US-centric approach to counterfeit goods (Hung, 2003). The concept of counterfeits and fakes differ, whereby consumers’ intention to purchase counterfeits in other cultures is driven by different motivations (Hung, 2003; Liu et al., 2015). Furthermore, research has shown that customer concerns about product authenticity vary for different products where health, safety, or value are greater (Sidali & Hemmerling, 2013). Therefore, one might expect potentially different results in other countries or regions and different products.

Conclusions and Future Research

Online shopping, counterfeiting, and global trade are all at an all-time high. Customers are demanding proof of authenticity for the products they purchase in an environment of increasingly complex supply chains. Research on blockchain technology solutions for supply chain traceability applications is expanding as use cases continue to grow. However, within this growing body of research on blockchain product traceability, there is little empirical research on the impact of blockchain coupled with unique product identification to address customers' demands for product authenticity. This primary goal of the current study was to test the effect of blockchain traceability and product identification on customer confidence that products are genuine and not counterfeit. Results from this study show that both blockchain traceability and intrinsic product identification boost trust in product authenticity. However, the lack of a significant interaction between them suggests that their effects are additive and independent rather than multiplicative.

The validated construct of product origin authenticity that is operationalized in this paper represents an important contribution because it considers authenticity based on CTF product origin history (e.g., date and location of manufacturing) as tokenized and verified on the blockchain. Product origin authenticity is intended to add clarity to customers evaluating the true source identity of products by setting aside credence claims and associations to other events and relationships found in other authenticity constructs such as indexical, historical, and TTF.

Product origin authenticity is intended to answer customer product authenticity concerns that products of unknown origin and/or complex supply chains are original from the manufacturer and not fake or counterfeit. In this study, blockchain traceability and intrinsic product identification were found to positively impact trust in product authenticity based on origin.

This study helps to lay the groundwork for future research on the roles of blockchain and product identification on trust in product authenticity. Insights gained from this research can be used to bolster efforts for anti-counterfeiting, brand protection, and asset ownership traceability. Further examination of specific mechanisms by which blockchain and its associated technologies can better identify and trace asset origin history can be used to boost trust in product authenticity and enhance the ability of firms to provide product truths to support customer trust.

This research answers the call for more quantitative research for companies seeking to use blockchain technology for business practices (Wong et al., 2020). Existing studies have either reported on blockchain-based product traceability models for supply chain trust or provenance knowledge but have not empirically tested them (Galvez et al., 2018; Montecchi et al., 2019). Thus, further studies are required to understand the impact of blockchain traceability on trust in product origin authenticity to better help organizations make adoption decisions. Few studies have extensively reported the use of blockchain technology for product authenticity, apart from a few prototype and feasibility studies (Agrawal et al., 2021; Sun et al., 2021). This scarcity further impedes this study from drawing on comparisons from similar works. Companies considering incorporating blockchain into their existing business models would require further consideration on the necessity of such technology (Queiroz et al., 2019). The amount of attention generated by blockchain technology solutions serves as a reminder that organizations need to plan for a technology that has the potential to radically transform operations and organizations.

CHAPTER 5: CONCLUSIONS AND IMPLICATIONS

Overview

Raelin (2007) describes a process called a practice epistemology. It combines reflective practice and introspection with conversations with colleagues in a participatory structure. Practice epistemology best describes my journey to encourage seamless transitions across theory and practice. My goal as a practitioner and scholar is to encourage an environment where practitioners and researchers become what Raelin (2007) refers to as a collaborative community of inquiry. This matches my own experiences in developing continuous adaptation to meet the needs of, and in consultation with, practitioners in organizations. As a former CEO of a transportation research and technology institute, I acquired a center for business and economic research to bring together academic researchers with practitioners to form a collaborative applied sciences organization. I am currently pursuing a similar path as a consultant connecting blockchain research with practical applications. The findings of this study have implications for advancing theory and practice, as well as highlighting productive future directions for research.

This doctoral thesis was born out of reflections on questions from over 25 years working in startups, SMEs, and large organizations where the question has always been how to identify and manage relationships with project stakeholders using technology solutions to ensure ongoing project success and to avoid unforeseen disruptions. As I gained exposure to the ability of blockchain technology to transcend the realm of cryptocurrency into practical business solutions, I began to wonder how I could contribute to bridging the gap between blockchain research-favoring rigor and practice-favoring relevance to provide business solutions. I found blockchain's distributed, cryptographic, verifiable, and auditable capabilities as a digital ledger of transactions relevant to brand protection and anti-counterfeiting but much research was needed to explore its potential. With online sales at an all-time high and supply chains becoming increasingly more complex in a $1.7 trillion global counterfeit market, I decided to base the research on the practical application of blockchain for impacting perceptions of product authenticity.

Implications for Advancing Theory

The framework of product origin authenticity developed in this research expands on the complex concept of authenticity by combining several authenticity constructs and expanding it into the area of blockchain traceability to support trust in product origin authenticity. Product origin authenticity is a lens through which customers can answer the "Is this a genuine product from the manufacturer?" Most product authenticity constructs are rooted in marketing and branding research (Beverland & Farrelly, 2008; Grayson & Martinec, 2004; Moulard et al., 2020; Newman, 2019). They are typically based on some form of semiotic theory (Pierce, 1883), where objects determine their signs that act as cues for authenticity by displaying some combination of iconic, indexical, and symbolic characteristics (Atkin, 2013). Product origin authenticity is relevant because it attempts to focus the perception of authenticity through a practical lens and avoid mixing authenticity constructs to address product authenticity based on origin history facts (Atkin, 2013; Moulard et al., 2020). One example of this is the distinction between perceiving a fake Louis Vuitton bag as authentic because it appears to be from the same vintage period (historical) or authentic because it can be traced back to a specific location (indexical). Product origin authenticity evaluates trust that the bag is genuine or fake based on correspondent to fact origin facts added to the blockchain and linked by unique product identification. Before blockchain, product origin facts did not have the support of cryptographically secure, distribute, and auditable product metadata that act as cues for trust that a product is genuine or original from the manufacturer.

The empirical study conducted for this dissertation contributes to the literature by empirically testing the proposed relationships between blockchain traceability, product identification technologies, and trust in product authenticity. The conceptual framework developed is important for understanding these relationships, but it has not been subject to empirical examination.

Authenticity is a complex theoretical construct. In the context of determining if a product exposed to a complex supply chain is genuine and not fake or counterfeit, illumination from authenticity constructs based on spatial-temporal, historical, and factual signs (Grayson & Martinec, 2003; Moulard et al., 2020; Newman, 2019), explored in this research. They provide a foundation for the perception of a product as genuine based on origin history facts. A separate body of research focuses on how blockchain traceability frameworks impact supply chain trust and transparency (Nie & Luo, 2019; Wang et al., 2019; Zelbst et al., 2019). Abeyratne and Monfared (2016) demonstrate that based on trusted facts that align with the users' needs, blockchains can deliver information about the origination of a product and the stages from source to the point of consumption. Another body of research focuses on product identification and verification technologies and methods to boost perceptions of product authenticity and trust (Azzi et al., 2019; Doukidis & Pramatari, 2007; Sun et al., 2021; Walllace & Manning, 2020). Mondal et al. (2019) propose a framework for a blockchain-inspired traceability system based on unique RFID product identification. These works separately support the importance of product identification technologies (unique identifiers) in establishing the critical link between a physical asset and its representation on the blockchain and the use of data stored on the blockchain to support trust in product quality and integrity.

Researchers can adopt product origin authenticity when focusing on product authenticity in the context of physical assets traced using the unique capabilities of blockchain. Empirical findings from this research reveal that product origin history facts (e.g., manufacturing date and location, unique identifier) processed and stored on the blockchain act as signs that products exposed to complex supply chains are genuine and not fake. Researchers studying blockchain technology for anti-counterfeiting, brand management, customer product authenticity trust, or physical asset ownership tracing may be particularly interested in the product origin authenticity framework. The scale created for this research can be used to measure the construct of product origin authenticity that provides a framework for answering a question consumers purchasing products of unknown origins and complex supply chains want to know, "Is this a genuine, original product from the manufacturer?"

Another implication for research is that this study may act as a guide for using an experimental vignette methodology to investigate the relationships of interest empirically. Since vignettes are multivalent representations of real-life situations, the related questions are more realistic and allow for investigating factors varied in an experiment (Steiner et al., 2016). Although this methodology is well established in the literature for measuring perceptions (Atzmuller & Stener, 2010; Cook, 1979; Dulmer, 2007), it has not been widely applied in research on the effects of blockchain technology product authenticity.

Implications for Business Practice

Insights from this study's results have important managerial implications. Findings from this research can assist firms in exploring the use of blockchain technology and unique product identification as an anti-counterfeiting or brand protection strategy. The results suggest product origin history provided by the blockchain has a significantly positive effect on trust that products exposed to a complex supply chain and online retailer are genuine and not fake or counterfeit. Likewise, unique intrinsic product identification, such as biometric patterns found in leather or silicon IC chips, is found to have a greater impact on trust in product origin authenticity than extrinsic product identification (e.g., QR code, barcode, and RFID technologies), which is much easier to copy, clone, or spoof. This research gives firms considering integrating blockchain technology as a product authenticity and traceability solution empirical evidence for addressing the concerns in adopting the technology. However, the small magnitude of effects found in this study may call into question whether substantial investments are warranted. Results from this study should be interpreted with caution and deserve further research. If a lack of interaction is true, managers can choose between either product identification or blockchain traceability, whichever is more cost-effective.

Further, addressing customers' concerns about the authenticity of products may have the added benefit of discouraging contract manufacturers from producing product overruns. Overruns are authentic products, but the brand manufacturer does not authorize them. In that way, they are counterfeit products. When a factory has a contract to make 10,000 units with a brand, they are not allowed to use that brand to sell any number of overruns past that. Blockchain product origin authenticity creates accountability for contract manufacturers. When customers register a product or verify its authenticity online, any discrepancy in production allotment would result in the product being flagged as counterfeit. This would discourage the contract manufacturer from overruns as their products would not be verified as authentic to the customer, and the brand manufacturer would receive notification of the fraudulent activity, further discouraging contract manufacturers from the practice.

Although this research finds that blockchain technology can boost trust that products are genuine from the manufacturer and not counterfeit, there is still a lot of work to be done to educate supply chain partners and the public about the capabilities of the technology. For customers to recognize the full ability of blockchain traceability and unique intrinsic product identifiers to provide product authenticity assurances, firms should market the capabilities of these technologies. One helpful strategy could be to encourage affiliates to promote the benefits of the technologies for providing product authenticity assurances, and another could be to encourage customers to mention blockchain-enabled product authenticity in their reviews.

Recommendations for Future Research

Although this research reveals the importance of concurrent AI and IoT sensors and devices for supporting blockchain trust in product authenticity, this work does not deeply examine the role verification plays on trust in product origin authenticity. Due to the complexity of some of the emerging technologies referred to in this research and the results of an exploratory study, I abandoned my initial plan to empirically test the impact of blockchain internal and external verification technologies on trust in product authenticity. I decided to focus on establishing whether blockchain technology and its critical link to a physical product could influence trust that a product is genuine. After achieving positive results that blockchain traceability knowledge has a significant and positive effect on trust in product origin authenticity, I plan to follow up by examining the role that verification plays on trust.

Another area for future research uncovered is examining the impact of regulatory agencies as nodes on product traceability blockchains to boost product trust and protection. U.S. consumer protection laws and agencies were created as a public good to protect the public. In an environment of expanding global trade, consumers are losing some of the protections in part due to increasingly complex supply chains where online sales are at an all-time high and online sellers are not being held accountable. This research could help secure greater partner accountability and boost consumer trust in product, food, and pharmaceutical authenticity and safety by providing additional assurances that products are genuine and safe.

This research has led me to realize the power of blockchain for securing product origin trust lies in its distributed, immutable, and auditable capabilities that act to verify product origin history. I started this research journey exploring truth-to-trust: how product origin history facts stored on a distributed, cryptographically secure, and auditable blockchain ledger could support trust in product authenticity. I plan to follow up with truth but verify: an examination of the impact of blockchain, unique product identification, verification technology, and the interaction between them on product authenticity or the perception that products are genuine and not fake.

This study lays the groundwork for future research on the roles of blockchain and product identification on trust in product authenticity. Insights gained from this research can be used to bolster efforts for anti-counterfeiting, brand protection, and asset ownership traceability. Further examination of specific mechanisms by which blockchain and its associated technologies can better identify and trace asset origin history can boost trust in product authenticity and enhance the ability of firms to provide product origin truths to support customer trust.

Conclusion

The evolution of blockchain-enabled traceability systems has created a more trustworthy and secure network for supporting product authenticity. Results show blockchain traceability solutions can reduce the trust gap by mitigating the perceived risks of counterfeiting and fraud associated with intermediary interventions. With its ability to record historical product origin transactions in a secure, distributed, and auditable manner, blockchain technology is shown to have a significant and positive effect on trust in product authenticity. Concurrently, intrinsic product identification has a greater impact on trust than extrinsic product identification technologies.

In this work, I developed a framework to explain how blockchain can impact customer trust in product authenticity. I introduced an authenticity construct, product origin authenticity, made possible by the characteristics and features of blockchain technologies to enhance trust, complemented by converging unique identification technologies and verification technologies. Product origin authenticity is conceptualized as the perception of a product exposed to supply chain conditions as either genuine or counterfeit based on correspondent to fact origin truths, supported by unique identification and verification technologies. Product origin authenticity is consistent with indexical, historical, and TTF product authenticity constructs that focus on existential truths to establish authenticity. However, it removes credence claims (e.g., sustainable and antique) from evaluations of authenticity and provides signals for authenticity based on origin facts tokenized by the product manufacturer that mint the product origin authenticity token. Product origin authenticity is concerned with questions such as, "Is this product a genuine product manufactured by company X?" The concept of blockchain product origin authenticity may be unsatisfactory for evaluating whether a product is genuine or fake based on false product origin history added to the blockchain by the manufacturer or representative that initiates the blockchain record. The assumption is that brands would be legally or reputationally disincentivized to commit fraud. After establishing the concept of blockchain product origin authenticity, I presented the case for how it is uniquely positioned to impact trust in product authenticity.

This research supports existing theories and advances the literature on blockchain traceability for product authenticity. It complements authenticity research in marketing and branding to include new concepts and paradigms made possible by blockchain technology. The conceptual framework can guide companies in exploring blockchain technology solutions for securing product authenticity information for supply chain partners and end customers. It can also serve as a basis for future research to empirically test the effects of blockchain identification and verification technologies on trust in product origin authenticity. These supportive technologies include converging graphical, optical, biometric, and chemical product identification technologies and verification technologies such as IoT and AI that give blockchain traceability systems the ability to more reliably support confidence that a digital asset, tokenized on the blockchain, truly represents the genuine, original physical product. Findings from this research can lead to new insights to inform practice how blockchain can better boost trust in product authenticity and reduce the trust gap.

This paper contributes to different streams of literature. First, the literature on blockchain product authenticity is sparse, despite being increasingly pursued in practice. In this paper, I addressed product authenticity made possible by the phenomenon of a distributed trust technology that answers questions like "Is this a genuine product from the manufacturer and not fake or counterfeit?" without consideration of brand or credence claims. Second, I developed a new construct, product origin authenticity, that fills a gap in the literature for an adequate explanation of the phenomenon of product authenticity based on blockchain support of product origin facts. Product origin authenticity is consistent with marketing and branding authenticity constructs, including indexical, historical, and TTF. This new construct is important because it removes credence claims and associations with other authenticity constructs for evaluations of authenticity based on product origin history provided by blockchain technology. Finally, I developed a framework that relates the features and capabilities of blockchain to increased trust in product authenticity. This framework is important for evaluating trust in product origin authenticity based on truths supported by both blockchain and supplementary technologies and it serves as a springboard for further theoretical development and empirical testing. My framework allows the development of theories and practices around the framework's components to determine their separate and joint impacts on trust in product authenticity.

Today, with online shopping, counterfeiting, and global trade at an all-time high, customers are demanding proof of authenticity for the products they purchase in an environment of increasingly complex supply chains. Research on blockchain technology solutions for supply chain traceability applications is expanding as use cases continue to grow. However, within this growing body of research on blockchain product traceability, there is little research on the impact of blockchain coupled with unique product identification and verification technologies to address customers' demands for product authenticity. This research journey started exploring how blockchain technology could support trust in product authenticity. Results from this research show that both blockchain traceability and intrinsic product identification boost trust in product authenticity. However, the lack of a significant interaction between them suggests that their effects are additive and independent rather than multiplicative.

The construct of product origin authenticity operationalized in this paper is important because it is the first work to assesses authenticity based on correspondence to fact product origin history (e.g., date and location of manufacturing) tokenized and verified on the blockchain. Product origin authenticity is intended to add clarity to customers evaluating the true source identity of products by setting aside credence claims and associations to other events and relationships found in other authenticity constructs. Product origin authenticity is intended to answer customer authenticity concerns that products of unknown origins and/or complex supply chains are original from the manufacturer and not fake or counterfeit. In this research, blockchain product origin history facts acting as truths were found to significantly and positively impact trust in product authenticity. Trust to truth serves as a starting point for research examining the phenomenon of blockchain trust in product origin authenticity. Much research is left to do better understand how this unique technology can bridge the virtual and physical worlds as a product authenticity solution.

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TABLES

Table 1

Demographic Profile and Control Variables

Measure	Item	Count	Percent
Age	18-24	84	15.3%
	25-34	253	46.2%
	35-44	149	27.2%
	45-54	48	8.8%
	>54	14	2.6%
Gender	Female	220	40.1%
	Male	322	58.8%
	Other	6	1.1%
Education	High school equivalent or below	23	4.2%
	Some college	59	10.8%
	Trade/technical /vocational	48	8.8%
	Associate degree	177	32.3%
	Bachelor's degree	168	30.7%
	Master's degree or above	73	13.3%
Years of work experience	0	7	1.3%
	1-2	89	16.2%
	3-5	278	50.7%
	6-10	137	25.0%
	> 10 years	37	6.8%
Years of supply chain work experience	0	66	12.0%
	1-2	216	39.4%
	3-5	193	35.2%
	6-10	63	11.5%
	> 10 years	10	1.8%
Frequency of purchasing consumer products online	Very rarely	3	0.5%
	Rarely	48	8.8%
	Occasionally	196	35.8%
	Frequently	227	41.4%
	Very frequently	74	13.5%
Number of blockchain-related courses	0	79	14.4%
	1	210	38.3%
	2	200	36.5%
	>2	59	10.8%
Blockchain comfort level	Low	23	4.2%
	Medium	400	73.0%
	High	125	22.8%
Tech-savvy level	Low	18	3.2%
	Medium	366	66.9%
	High	164	29.9%

Table 2

Correlations and Descriptive Statistics

	Mean (SD)	1	2	3	4	5	6	7	8	9	10
1. Trust in product origin authenticity	4.84 (9.94)	1.000									
2. Blockchain		**.115****	1.000								
3. Identification		**-.125****	-0.004	1.000							
4. Age	3.36 (0.98)	-0.004	-0.027	0.049	1.000						
5. Gender	1.61 (0.51)	-0.016	0.051	-0.015	**.221****	1.000					
6. Education level	4.19 (1.39)	**.287****	0.075	0.004	**.214****	0.055	1.000				
7. Years of work experience	3.20 (0.83)	**.156****	0.009	-0.024	**.507****	**.118****	**.239****	1.000			
8. Years of supply chain experience	2.52 (0.91)	0.053	-0.024	0.015	**.452****	**.201****	**.225****	**.542****	1.000		
9. Purchasing frequency	3.59 (0.85)	**.259****	0.033	0.012	**.109***	-0.015	**.306****	**.225****	**.127****	1.000	
10. BC comfort	4.72 (1.14)	**.454****	-0.026	-0.032	**.228****	**.131****	**.254****	**.290****	**.323****	**.271****	1.000
11. Tech-savvy level	4.90 (1.16)	**.491****	0.027	0.009	**.116****	-0.026	**.315****	**.247****	**.170****	**.327****	**.475****

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 3

Product Origin Authenticity, Items and Validity Correlation Matrix

Product Origin Authenticity Variables and Items			Alpha if deleted
Cronbach's alpha = 0.85			
Indexical Authenticity	IA1	What is your level of trust that the device you received is genuine from the manufacturer and not fake or counterfeit?	0.82
	IA2	What is your level of trust that the device you received is genuine based on the product's tracking history?	0.79
Historical Authenticity	HA1	What is your level of trust that the device you received is an original product from the manufacturer's plant in Vietnam?	0.81
	HA2	What is your level of trust that the device you received is not counterfeit based on traceable origin and provenance data?	0.82

	IA1	IA2	HA1	HA2
IA1	1			
IA2	0.566**	1		
HA1	0.645**	0.599**	1	
HA2	0.481**	0.575**	0.649**	1

**. Correlation is significant at the 0.01 level

Table 4

Means of Trust in Product Origin Authenticity Scores

	Intrinsic Identification		**Extrinsic Identification**		***Totals***	
	N	***M (SD)***	***N***	***M (SD)***	***N***	***M (SD)***
Blockchain Used	138	5.09 (0.80)	137	4.89 (0.81)	275	4.99 (0.81)
Blockchain Not Used	136	4.87 (0.91)	137	4.55 (1.14)	273	4.71 (1.04)
Totals	274	4.98 (0.86)	274	4.72 (1.00)	548	4.85 (0.94)

Table 5

ANOVA Results

Dependent Variable: Trust in Product Origin Authenticity

Source	Sum of Squares	*df*	Mean[2]	*F*	Sig.
Corrected Model	20.550[a]	3	6.850	8.048	0.000
Intercept	12882.455	1	12882.455	15135.627	0.000
Blockchain	10.761	1	10.761	12.643	0.000
Identification	9.335	1	9.335	10.967	0.001
Blockchain * Identification	0.395	1	0.395	0.464	0.496
Error	463.017	544	0.851		
Total	13368.563	548			
Corrected Total	483.567	547			

R^2 = 42.0% (Adjusted R^2 = 36.8%)

Table 6

ANCOVA Results

Dependent Variable: Trust in Product Origin Authenticity

Variable	*df*	Mean[2]	*F*	Sig.
Blockchain (H1)	1	8.485	15.306	0.000
Identification (H2)	1	7.928	14.300	0.000
Blockchain * Identification (H3)	1	1.257	2.268	0.133
Gender	1	0.675	1.218	0.270
Year of work experience	1	1.663	3.000	0.084
Purchasing frequency	1	2.724	4.914	0.027
Age	1	3.916	7.063	0.008
Education level	1	4.629	8.350	0.004
Blockchain comfort	1	33.238	59.959	0.000
Tech-savvy	1	28.072	50.638	0.000
Total	548			

R^2 = 38.6% (Adjusted R^2 = 37.3%)

APPENDIX A: IRB APPROVAL LETTER

PEPPERDINE

Pepperdine University
24255 Pacific Coast Highway
Malibu, CA 90263
TEL: 310-506-4000

NOTICE OF APPROVAL FOR HUMAN RESEARCH

Date: September 22, 2020

Protocol Investigator Name: Frank Betz

Protocol #: 20-07-1405

Project Title: Blockchain trust in product authenticity

School: Graziadio School of Business and Management

Dear Frank Betz:

Thank you for submitting your application for exempt review to Pepperdine University's Institutional Review Board (IRB). We appreciate the work you have done on your proposal. The IRB has reviewed your submitted IRB application and all ancillary materials. Upon review, the IRB has determined that the above entitled project meets the requirements for exemption under the federal regulations 45 CFR 46.101 that govern the protections of human subjects.

Your research must be conducted according to the proposal that was submitted to the IRB. If changes to the approved protocol occur, a revised protocol must be reviewed and approved by the IRB before implementation. For any proposed changes in your research protocol, please submit an amendment to the IRB. Since your study falls under exemption, there is no requirement for continuing IRB review of your project. Please be aware that changes to your protocol may prevent the research from qualifying for exemption from 45 CFR 46.101 and require submission of a new IRB application or other materials to the IRB.

A goal of the IRB is to prevent negative occurrences during any research study. However, despite the best intent, unforeseen circumstances or events may arise during the research. If an unexpected situation or adverse event happens during your investigation, please notify the IRB as soon as possible. We will ask for a complete written explanation of the event and your written response. Other actions also may be required depending on the nature of the event. Details regarding the timeframe in which adverse events must be reported to the IRB and documenting the adverse event can be found in the *Pepperdine University Protection of Human Participants in Research: Policies and Procedures Manual* at community.pepperdine.edu/irb.

Please refer to the protocol number denoted above in all communication or correspondence related to your application and this approval. Should you have additional questions or require clarification of the contents of this letter, please contact the IRB Office. On behalf of the IRB, I wish you success in this scholarly pursuit.

Sincerely,

Judy Ho, Ph.D., IRB Chair

cc: Mrs. Katy Carr, Assistant Provost for Research

APPENDIX B: RESEARCH INSTRUMENTS

Qualtrics Online Survey

Trust in Product Authenticity

Background

MOTH is an American company that sells a popular air quality device that sends out mobile alerts when it detects dangerous conditions in the home such as smoke, gas, or high carbon monoxide levels. MOTH has been a target of recent counterfeiting, now affecting 15% of all electronic products.

MOTH products are manufactured in Vietnam. As a consumer, you purchase a MOTH device from a popular e-commerce website. Safety is essential to you, and you want to be 100% sure the device is not one of the failing counterfeits you heard about in the news. The information you receive about the product is as follows:

Vignette II/BN

MOTH generates a unique identity key for each air quality device during manufacturing. The unique identity key is based on the naturally occurring structure of silicon found in the device's internal electronic components and is impossible to clone or copy.

After you place your order online, the device ships from a fulfillment center. Timestamped package tracking data captured by the shipper are available on the seller's website. No other carrier, warehousing, or distribution transaction data is available to you or shared with supply chain partners.

Upon receiving your MOTH device in the mail, you connect your device to the MOTH website via Bluetooth to register it. The unique identity key is verified, and you receive a notification of authenticity based on the unique identity key.

Please answer the following questions based on the previous scenario:

○ I'm ready to start!

Vignette II/BU

Blockchain technology is gaining popularity as an anti-counterfeiting solution for storing and sharing information about the creation, exchange, and ownership of products. As a decentralized database of cryptographically secure transaction records, blockchain makes it easy for participants to track the custody and trace the origin of products as they move between countries, factories, distribution, and sales.

MOTH generates a unique identity key for each air quality device during manufacturing. The unique identity key is based on the naturally occurring structure of silicon found in the device's internal electronic components and is impossible to clone or copy.

As devices ship from the manufacturer, timestamped locations and product details are recorded on the blockchain. All chain of custody information is available to you on the MOTH website and shared with all supply chain partners. Any deviation in package delivery or storage would result in package contents flagged as potentially counterfeit.

Upon receiving your MOTH device in the mail, you connect your device to the MOTH website via Bluetooth to register it. The unique identity key is verified, and you receive a notification of authenticity based on the unique identity key.

Please answer the following questions based on the previous scenario:

○ I'm ready to start!

Vignette EI/BN

MOTH attaches a QR code tag containing a unique serial number to each air quality device during manufacturing. The QR code is external to the device and could possibly be cloned, copied, or removed.

After you place your order online, the device ships from a fulfillment center. Timestamped package tracking data captured by the shipper are available on the seller's website. No other carrier, warehousing, or distribution transaction data is available to you or shared with supply chain partners.

Upon receiving your MOTH device in the mail, you scan the QR code via your phone to register it on the MOTH website. The manufacturer verifies the QR code information, and you receive a notification of authenticity based on the QR code match.

Please answer the following questions based on the previous scenario:

○ I'm ready to start!

Vignette EI/BU

Blockchain technology is gaining popularity as an anticounterfeiting solution for storing and sharing information about the creation, exchange, and ownership of products. As a decentralized database of cryptographically secure transaction records, blockchain makes it easy for participants to track the custody and trace the origin of products as they move between countries, factories, distribution, and sales.

MOTH attaches a QR code tag containing a unique serial number to each air quality device during manufacturing. The QR code is external to the device and could possibly be cloned, copied, or removed.

As devices ship from the manufacturer, timestamped locations and product details are recorded on the blockchain. All chain of custody information is available to you on the MOTH website and shared with all supply chain partners. Any deviation in package delivery or storage would result in package contents flagged as potentially counterfeit.

Upon receiving your MOTH device in the mail, you scan the QR code via your phone to register it on the MOTH website. The manufacturer verifies the QR code information, and you receive a notification of authenticity based on the QR code match.

Please answer the following questions based on the previous scenario:

○ I'm ready to start!

Manipulation checks

The product’s unique identification can be copied, cloned, or altered?

- ○ Strongly Agree
- ○ Agree
- ○ Somewhat Agree
- ○ Neither Agree nor Disagree
- ○ Somewhat Disagree
- ○ Disagree
- ○ Strongly Disagree

The product’s tracking provides thorough product traceability information.

- ○ Strongly Agree
- ○ Agree
- ○ Somewhat Agree
- ○ Neither Agree nor Disagree
- ○ Somewhat Disagree
- ○ Disagree
- ○ Strongly Disagree

Control Variables

What is your level of trust that the device you received is genuine from the manufacturer and not fake or counterfeit?

- ○ Extremely low
- ○ Low
- ○ Moderately low
- ○ Neither high nor low
- ○ Moderately high
- ○ High
- ○ Extremely high

What is your level of trust that the device you received is genuine based on the product's tracking history?

- ○ Extremely low
- ○ Low
- ○ Moderately low
- ○ Neither high nor low
- ○ Moderately high
- ○ High
- ○ Extremely high

What is your level of trust that the device you received is an original product from the manufacturer’s plant in Vietnam?

- ◯ Extremely low
- ◯ Low
- ◯ Moderately low
- ◯ Neither high nor low
- ◯ Moderately high
- ◯ High
- ◯ Extremely high

What is your level of trust that the device you received is not counterfeit based on traceable origin and provenance data?

- ◯ Extremely low
- ◯ Low
- ◯ Moderately low
- ◯ Neither high nor low
- ◯ Moderately high
- ◯ High
- ◯ Extremely high

How would you rate yourself as technologically savvy?

- ○ Extremely low
- ○ Low
- ○ Moderately low
- ○ Neither high nor low
- ○ Moderately high
- ○ High
- ○ Extremely high

How often do you purchase consumer products online?

- ○ Very rarely
- ○ Rarely
- ○ Occasionally
- ○ Frequently
- ○ Very frequently

What is your comfort level with blockchain technology applications?

- ○ Extremely low
- ○ Low
- ○ Moderately low
- ○ Neither high nor low
- ○ Moderately high
- ○ High
- ○ Extremely high

How many total years of work experience do you have?

- ○ 0
- ○ 1-2
- ○ 3-5
- ○ 6-10
- ○ More than 10 years

How many total years of supply chain work experience do you have?

- ○ 0
- ○ 1-2
- ○ 3-5
- ○ 6-10
- ○ More than 10 years

What is the sum of 3+3?

- ○ 1
- ○ 3
- ○ 6
- ○ 8
- ○ 11

What is the highest degree or level of school you have completed? If currently enrolled, highest degree received.

- ○ High school graduate, diploma or the equivalent
- ○ Some college credit, no degree
- ○ Trade/technical/vocational training
- ○ Associate degree
- ○ Bachelor’s degree
- ○ Master’s degree
- ○ Professional degree
- ○ Doctorate

How many blockchain-related courses have you taken?

- ○ 0
- ○ 1
- ○ 2
- ○ More than 2

What is your gender?

- ○ Female
- ○ Male
- ○ [ ] Other

What is your age?

- ○ Under 21
- ○ 21-24
- ○ 25-34
- ○ 35-44
- ○ 45-54
- ○ 55-64
- ○ Above 65

Closing Statement

Thank you very much for your participation in this study. Please feel free to add any comments below: