THE INTERSECTION OF ACCOUNTING AND BLOCKCHAIN TECHNOLOGY: AN ANALYSIS OF CURRENT AND FUTURE IMPLICATIONS

by

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Today we are undergoing an unprecedented era of innovation in the business world. Emerging technologies are impacting nearly every organization, with blockchain becoming one of the most widely discussed. It is important to understand that there is far more to blockchain than cryptocurrency, as it can impact many business processes, notably accounting functions. The goal of this piece of research is to provide a holistic survey of the implications of blockchain technology for the accounting profession, which demands an analysis of both current and future implications.

Short term, blockchain has the potential to aid many of the most cumbersome tasks associated with accounting today. Three areas that blockchain has implications for are improving the transfer pricing process, enhancing financial reporting in supply chains, and accounting for cryptocurrency. Looking into the future, blockchain can help drive advancement in the financial statement audit and increase the automation of repetitive tasks through smart contracts. Each of these processes will have to overcome technical and regulatory hurdles, which must be considered as well. Blockchain is well equipped to impact these processes due to its immutability, security, and ability to build trust between organizations, motivating a thorough analysis of the topic.

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Chapter 1: Background

Chapter 1.1: Introduction

Blockchain has emerged over the past decade as a technology that has the potential to create improved record keeping systems that promote efficiency, trustworthiness, and transparency across the business community. The technology presents an opportunity to not only increase the profitability of firms that commit to implementing blockchain in an effective manner, but also to increase the trust and confidence of stakeholders in our economy. Blockchain's astounding, although largely unproven, potential has created a necessity for the technology to be explored across a wide variety of disciplines if we are to be on the forefront of the "blockchain revolution." While the discussion of blockchain often centers around the topic of cryptocurrencies, such as **Bitcoin**, this is merely the tip of the iceberg when it comes to the applications of the technology, as blockchain is already impacting our society in consequential ways.

As accounting professionals understand, one of the most exciting parts of this field of study is the ever-evolving nature of our roles. This is not a new phenomenon, but rather a continuation of the intersection between accounting and technology that has occurred over the course of history. Early computing innovations, such as the abacus and punch card, are examples of the heavily intertwined nature of technology and the accounting profession, as both served the central purpose of making record keeping more efficient and effective. Other innovations such as the mechanization of tax assessments and collections, use of automation in the late 19th century, and the rise of computers being used to perform accounting tasks show that innovation is fundamental to the accounting profession. While accountants have become adept at evolving to meet the demands of policy changes and the dynamic nature of the modern economy, we are also beginning to reap the rewards of investments in modern emerging technologies. Innovations in **artificial intelligence**, data analytics and information sharing are starting to fundamentally alter the accounting profession yet again, and blockchain presents an opportunity to build on many of these past innovations.

Blockchain technology presents a clear business imperative for public accounting firms because it has the potential to be considered a disruptive technology. Inherently, a disruptive technology must either cater to the low-end of an existing market, that is ignored by the industry's major firms, or it must be able to satisfy the needs of new consumers not being served currently by existing firms (Christensen, Raynor, McDonald, 2015). Blockchain could be disruptive as it has the potential to make accounting processes more efficient, accurate and cost effective, leading to many of the traditional barriers to entry for new market entrants in the public accounting industry being greatly reduced. This particularly applies to the big-4 accounting firms as some of their greatest assets are their superior resources, experience, and technology that they can deploy to serve the needs of their clients. Blockchain is an opportunity for smaller firms as it can reduce the number of required resources to perform accounting tasks, lessen the experience gap between them and the big-4, and allow them to serve larger clients than currently possible. This paints a picture of the nature of blockchain as a disruptive technology, leading to this being an area that must be explored by the big-4 accounting firms if they want to protect themselves from this risk. Additionally, blockchain is a chance for the major accounting firms to differentiate themselves relative to existing competitors, which is essential to their long-term success due to the similar nature of the services provided by each of the major accounting firms. In addition, these larger accounting firms also have more resources they can employ to better understand and implement blockchain technology, potentially giving them an advantage relative to smaller firms. There is a clear business case for the further exploration of the intersection of blockchain and accounting, for both large and small firms.

Put simply, blockchain is about building trust in the transactions an organization engages in, which in my view is a fundamental role of the accounting profession. This congruence of objectives mandates that blockchain be explored in an in-depth manner. I hope my research will provide a foundation from which blockchain can be used to improve the accounting profession and fulfill our fundamental role of building trust in society.

Chapter 1.2: Research Question and Methodology

The primary focus of my research is on gaining a deeper understanding of how blockchain is likely to impact the accounting profession both in the short term and long term. Crucially, this is an extraordinarily theoretical and forward-looking topic, meaning that my primary goal is not to prove that blockchain will in fact become synonymous with accounting in the future, but rather to provide a comprehensive guide from which specialists in particular areas relevant to blockchain and accounting can investigate more deeply. My research is centered around engaging a wide variety of sources to answer the fundamental, yet complex question of "how is blockchain relevant to the accounting profession today? And how could this evolve in the future?" It is impossible to definitively answer this question, but I nonetheless feel that it is incredibly critical that we as accounting professionals deeply consider the potential that blockchain has to alter the accounting profession.

Typically, accounting research involves a detailed analysis of data regarding financial information to engage with a research question. Due to the nature of the project that I have undertaken, the totality of my research has been qualitative in nature. While this is clearly a limitation to my research, it has allowed me to engage a wide variety of perspectives that relate to the ever-evolving topic that is accounting and blockchain technology. Notably, I have drawn my research from academic accounting research, blockchain focused papers, and reports published by accounting organizations. What this variety of sources has helped create is what I feel is a holistic survey that engages the intersection of accounting and blockchain from multiple angles, considering the wide variety of perspectives present in the ongoing discussion we are amid. Additionally, while each of these categories of sources come together to form a comprehensive survey of the implications of blockchain on the accounting profession, they also each contribute in their own distinct ways to this piece of research.

Resources centrally focused on blockchain were pivotal to the research in this project as they not only taught me a considerable amount about the technology, but also provided an excellent roadmap that would eventually lead me to direct connections to accounting. By understanding both the theoretical and present-day applications of blockchain technology, I was able to narrow my research scope to target accounting processes that fit the specific criteria for successful blockchain implementations. The central traits that I decided to focus my accounting applications on were processes that require a large amount of data, incorporate many components of a business, and can be automated further. After applying this framework, I was able to pinpoint areas of accounting that likely could have blockchain applied to them, allowing me to dive deeper into the finer details of the accounting surrounding the areas.

The primary area of impact for the academic accounting research that was used for this project, was in identifying the magnitude and difficulty of specific accounting process. This had a substantial influence over the discussions of blockchain driven transfer pricing, the need for reform to how cryptocurrency is accounted for, and the highly regulated environment that accounting professionals operate within. It was essential to leverage these resources as it was important that any consideration of the implementation of blockchain technology in accounting operations was rooted in a fundamental understanding of the process it was being applied to. Without utilizing the wide array of accounting research that exists on each of these topics, it would not have been possible to understand the true implication that blockchain can potentially have on the accounting profession.

Engaging with reports published by notable accounting organizations, such as public accounting firms, provided excellent insight into where the industry sees the potential for blockchain technology. This proved to be critical as it helped to steer my research towards focusing on areas that will truly drive value for both public accounting firms and their clients. Additionally, I found that this area of research did a good job of bridging the gap between the accounting focused and blockchain centric research that I spent most of my time engaging with. This helped to drive much of the structure of this piece, and served as a model of how to consider the needs and knowledge bases of both accounting professionals and blockchain enthusiasts.

Chapter 1.3: Literature Review

I would describe the current collection of literature in the field of accounting and blockchain as sparse and fragmented, but continuing to grow. The literature is fragmented in that it is very difficult to find papers that include both a detailed description of blockchain technology and a clear illustration of how the technology can impact the accounting profession in a comprehensive manner. I believe that this has been one of the reasons it has been difficult for the field to gain widespread recognition within the broader community of accounting research, as many of the current resources paint an incomplete picture that calls into doubt the applicability of blockchain to accounting. On the other hand, it is relatively easy to find literature that explores the general topic of blockchain in detail, providing a foundation upon which I feel accounting researchers can engage in work that paves the way for new innovations in the accounting industry. My goal is to provide a relatively comprehensive guide to both blockchain and how it will impact the accounting profession, both today and in the future. Hopefully this guide will be useful for other researchers and the accounting profession so they can engage in meaningful work that can expand our understanding of the largely unexplored area of accounting and blockchain.

My perspective on the overall state of accounting and blockchain research does not mean that there are not excellent researchers who have done a tremendous amount of work to help us reach the point we are at today. A notable, and influential member of this community is Jana Schmitz, who began exploring the topic while she was a Ph.D. student in Australia. In many ways I have attempted to model my work after Schmitz's, as the paper "Accounting and Auditing at the time of Blockchain Technology: A research agenda" gets close to accomplishing what I feel is the goal of this research (Schmitz & Leoni, 2019).

A unique feature of research regarding accounting and blockchain is that much of it has originated not from academics, but from accounting firms and blockchain focused organizations looking to explore new business opportunities. While much of this research has been incredibly impactful in the field, it is my hope that academia will begin to engage in the discussion in a more substantial manner, as I feel that academics are uniquely qualified to explore this field. My hope is that by providing a comprehensive overview of the topic, other researchers will have an accessible entry point to blockchain and accounting, in turn contributing to building a strong academic community around the topic.

Chapter 2: What is a Blockchain?

Blockchain is a record storage technology that enables data to be stored in a decentralized, trustworthy, and secure manner. While blockchain grew out of the cryptocurrency revolution, it has expanded far beyond the realm of digital assets, becoming a disruptive technology with a wide array of applications. Presently, the storage of most records in the business world is highly centralized (Figure 1), meaning that if a record is to be accessed it is likely to only be accessible by going through a specific storage mechanism. This single point of storage can take on a multitude of forms, whether on site or in the cloud, but the majority are centralized in nature. At its core, blockchain aims to solve many of the problems that are pervasive in record keeping technologies today, such as:

- What happens if the single point of storage fails?
- What do we do if we discover that the records have been tampered with?
- How do we fix inconsistencies across different sets of records?
- How do we prevent the double spending problem of digital assets?

These topics are addressed through the three general categories of blockchain implementations: **public**, **consortium**, and **permissioned blockchains** (Figure 2).

Chapter 2.1: Types of Blockchains

Chapter 2.1.1: Public Blockchains

A public blockchain is the "purest" form of a blockchain, as no single person or group can control the network. This decentralization makes it nearly impossible in large scale blockchains, such as the one used in Bitcoin, for a single user to gain control over the majority of the network, preventing what is known as a **51% attack**. Additionally, public blockchains promote transparency by allowing any user to join, assuming they have access to the necessary computing power. Public blockchains are not without their flaws as they are often incredibly resource intensive and have substantial performance limitations, making them impractical for business implementations. Additionally, the business community is uncomfortable with public blockchains allowing their data to be accessible to the public, even though the data is anonymized. These are substantial drawbacks, leading to the conclusion that public blockchains are not yet suitable for most business applications.

Chapter 2.1.2: Permissioned Blockchains

Permissioned blockchains conform to the same general structure as public blockchains, with the distinction that they restrict who can be a part of the network. In restricting who can join the network, permissioned blockchains do not achieve true decentralization. This undermines key features of the technology, such as transparency, in favor of greater performance, privacy, security and cost savings. They also allow different access levels for the nodes in the network, a feature that is crucial for modern businesses. Multiple access levels are a potential gateway to permissioned blockchain adoption in business settings as it appeases security concerns while reaping many of the benefits of public blockchains. The few drawbacks and wide array of benefits, especially for large corporations, makes permissioned blockchains an excellent option for firms looking to step into blockchain based record keeping.

Chapter 2.1.3: Consortium Blockchains

Consortium blockchains are a hybrid between public and permissioned blockchains. They maintain many traits of permissioned blockchains with the added feature of nodes not being bound to a single organization. The implications of this are tremendous as consortium blockchains can increase efficiency amongst firms that interact with each other. An inherent challenge that they pose is that they require cooperation and trust amongst companies that are members of the blockchain. Consortium blockchains are incredibly useful for specific business use cases involving multiple organizations and should considered a key building block of blockchain in the future.

Chapter 2.2: Process Description

As an illustration of the core concepts of blockchain technology, it is useful to understand at a high level how data is added to a blockchain network. The process to add a new block, no matter the specific choice in blockchain type, can be defined broadly by the following stages:

1. <u>A transaction is requested:</u> Transaction information is provided to the network to generate the information necessary to add data to a block.
2. <u>A block is created:</u> A block is created that stores the transaction information.
3. <u>The requested transaction is broadcast, and a node is given the right to add:</u> The new block becomes available for each of the nodes to view. A node is then chosen to add the new block using a systemic process known as a consensus algorithm.

4. Nodes ensure that the transaction was added correctly: The nodes in the network leverage a consensus algorithm to check that the problem was solved, and the transaction was added correctly.
5. Block is added: If the necessary number of nodes in the network agree that the problem was solved correctly, and that the transactions are valid, the block is then added to the blockchain. The blocks on the blockchain are then linked together with hashes.

While the different implementations of blockchains carry out these tasks in slightly different manners, every blockchain follows these five steps broadly to carry out its purpose of storing data in a secure, efficient, and decentralized form. To understand this process more completely, it is critical to consider the components that make up a blockchain.

Chapter 2.3: Node Networks

The most fundamental level of a blockchain system is the network of nodes that comprise it. A node is any computer that is allowed to join a blockchain network and performs the core functions of adding, verifying and maintaining blocks of data that are stored on a blockchain. It is impossible to build a blockchain network without leveraging a set of network nodes to perform the core operations of the network. The crucial nature of nodes leads to another important distinction, and correction of a prevalent misconception, that there is no single "the blockchain." Instead, different communities of network nodes come together to form a wide array of diverse blockchains. For example, the blockchain that powers Bitcoin has a massive network of nodes, at one point utilizing over 100,000 unique nodes that can be joined by anyone with sufficient technology. This contrasts with the consortium blockchain that Walmart has used to track resources in their supply chain, which is restricted to only nodes that are owned by Walmart and their suppliers (Hyperledger, 2019). The wide variety of nodes allowed to participate in different blockchain networks is the central distinguishing attribute that exists between public, consortium and private blockchains.

Chapter 2.4: The Block

One of the most misunderstood elements of blockchain technology is how data is stored and secured within a blockchain. Network transactions are not stored directly on a blockchain, rather they are embedded within blocks that house many transactions. Blocks are what is stored on the blockchain and contain information that is used to retrieve transaction records. The size of individual blocks varies greatly, but mature public blockchains, can hold up to around 2,500 transactions in a single block. After transactions are consolidated into a single block, blocks are then linked together through one-way **hashing** to connect individual blocks. The process of hashing involves generating a secure sequence of values that can be used to identify a resource. For example, if we are attempting to add a block to the blockchain and the previous block generated a hash of 4qr7 (this is far simpler than hash values but is used for simplicity in this example) we would include 4qr7 in our block header to connect our block to the last block. This forms a process of chaining blocks together that is the basis for the name blockchain (Figure 3). For more information regarding how a block works, a discussion of the two main components of a block, the block header and block body, is included in the Appendix.

Chapter 2.5: Merkle Trees

Merkle Trees have become synonymous with blockchain technology as they are leveraged by arguably the two most famous blockchains, Bitcoin and Ethereum, as a way to secure transactions in an efficient manner within a block. Merkle Trees serve as a means by which the verification of data can be achieved efficiently within large scale data systems. A Merkle Tree is a data structure that leverages hash functions to generate unique identifiers and continuously pairs transactions until a single Merkle Tree root hash is generated. A Merkle Tree follows a very systemic process, take for example a set of eight transactions identified as: a,b,c,d,e,f,g, and h (Figure 4). During the first stage of creating the Merkle Tree, the nodes will be combined into pairs using a hash function, leaving us with ab hash, cd hash, ef hash, and gh hash. During the next step the pairs abcd hash and efgh hash will be generated, eventually leading to the creation of a final hash value that represents abcdefgh hash. Without Merkle Trees, blockchains would be too memory intensive for widespread adoption, would be incredibly inefficient to retrieve data from, and would reduce the immutability of blockchain systems. These benefits are discussed within the Appendix.

Chapter 2.6: Consensus Algorithms

Consensus algorithms are the processes by which blocks are added and verified by other network nodes in order to be added to a blockchain network. Consensus algorithms are one of the key building blocks of blockchain technology as they are one of the major components to building the trust-based networks that have come to define why blockchain is seen as a disruptive technology. Importantly, consensus algorithms are not a one-size fits all model, but rather specific implementations that are chosen to serve the purpose of the blockchain within which they will reside. This diversity of algorithms is one of the main reasons that consensus algorithms have become one of the defining traits between public, private, and consortium blockchains. The Appendix includes an in-depth description of the two most prominent consensus algorithms today, proof of work and proof of stake.

Chapter 2.7: Smart Contracts

One of the promising areas of innovation right now in blockchain technology is that of **smart contracts**, which allow blockchains to execute commands when a set of criteria is fulfilled. In simpler terms, a smart contract is very similar to a physical contract, when certain conditions are met an action is executed. The true impact of this is that smart contracts can make blockchains take on many of the functionalities performed by non-blockchain based pieces of software. This has opened up a wide array of possibilities for the evolution of blockchain as now not only is blockchain highly customizable and automated, but it also has the potential to be combined with other innovative technologies. Notably, blockchain has begun to leverage smart contracts to integrate artificial intelligence into major blockchains, such as Ethereum. The breakthrough of smart contracts has created a new era for blockchain, often referred to as blockchain 2.0, that will allow blockchain to expand into industries and uses cases that it has traditionally not served.

Chapter 3: Current Applications

While blockchain is an innovation that will impact the future of both the accounting profession and business community, it is important to recognize how the technology is relevant today. As is the case with many emerging technologies, we have only begun to scratch the surface of the use cases for blockchain. Notably, blockchain can aid accountants and organizations in reducing the burden that comes from transfer pricing and enhancing the record keeping of global supply chains. The first of these topics that will be discussed is transfer pricing, as it illustrates the multi-dimensional benefits that blockchain can provide for accounting professionals. In enhancing the ease of performing transfer pricing operations and providing greater transparency for regulators, blockchain can deliver value for accounting professionals on multiple dimensions. Processes, such as transfer pricing, that fit the technical capabilities of blockchain and are cumbersome to accountants, will be essential to further adoption of the technology, demanding that these processes by analyzed thoroughly.

Chapter 3.1: Reducing the Burden of Transfer Pricing

One of the most pressing issues for many organizations that operate globally is transfer pricing, which is the process that companies use to determine the price that they will sell goods between **subsidiaries** for. While this is a challenge for any large corporation, it is especially difficult for large firms that operate in a multinational environment. The primary reason that transfer pricing is an essential function for multinational organizations is the impact it can have on the tax liabilities incurred by corporations. The jurisdictions under which transactions occur alter the applicable tax rates, incentivizing companies to consider tax ramifications when undertaking

intercompany transactions. This motivation is the driving force behind transfer pricing. In fact, transfer pricing has become such a point of emphasis for multinational organizations that the Organisation for Economic Co-operation and Development, which is an intergovernmental group that contains many of the largest economies in the world, has outlined five specific methods that firms can leverage to undertake transfer pricing, which can be located on their website.

As illustrated by the diversity of approaches organizations can take in transfer pricing, it is not only an important function, but also a highly complex and technical one. Beyond just the calculation of transfer prices, individual governments have chosen to take up the issue through enhanced regulation, such as the United States' **Base Erosion and Anti-Avoidance Tax** (PwC, 2018). A major challenge imposed by transfer pricing, is the wide variety of stakeholders and departments that it engages across organizations. Not only do finance, tax, accounting, and supply chain professionals have to work together, but different global divisions also must collaborate. Despite substantial improvements in communication and record keeping technologies, transfer pricing puts substantial stress on organizations. Due to the need for information transparency, accuracy, and automation in transfer pricing, blockchain is well equipped to help aid in the following problems (PwC, 2018):

- The separate records maintained by different entities of a multinational organization
- The need for regulators to have access to a record of intercompany transactions
- The burden of manually calculating transfer prices

While blockchain's trait of being an immutable and trustworthy ledger empowers it to work towards solving these problems, it is important to look into how blockchain systems can be implemented.

While there are arguments for either private or consortium blockchains to be leveraged to aid transfer pricing, consortium blockchains are better equipped to solve the three major problems outlined earlier. While private blockchains can be implemented to solve the essential problems of synchronizing records within an organization and enabling the automation of transfer pricing, they do not allow for regulators to have access to the firm's records. This is due to the restriction that private blockchains place on node membership, while consortium blockchains enable the sharing of data between organizations in a non-public manner. Not only can implementing consortium blockchain based transfer pricing solutions enhance efficiency for regulators, but it can also allow organizations to allocate fewer resources towards government audits of transfer pricing. This feature will free up professionals within firms under audit to focus on higher value areas, which will be especially valuable as transfer pricing likely continues to be under greater government scrutiny in the future. The enhanced communication enabled by consortium blockchains between companies and regulators also has wide implications within large firms.

One of the core problems posed by transfer pricing is the manner in which the accounting records of organizations are often not synchronized, even when they are within the same organization. Not only does this often occur across departments in an organization, but between entities within the same company. For example, if a multinational organization has operations in both the United States and the United

Kingdom, it is likely that these two entities will maintain separate accounting records. While this may seem to be a trivial issue, it can have substantial tax implications as the incorrect accounting of assets and transactions can lead to an increased tax liability, and numerous issues during audits by regulators and public accounting firms. Blockchain can solve this problem by serving as a "single source of truth" for the organization that is trustworthy and accessible. The concept of blockchain being a "single source of truth" is primarily derived from its unique immutability and security, serving as one of the core components of why it can be useful in a business setting. While on face value the maintenance of a shared blockchain based accounting system may not seem to be all that different than the systems leveraged today, it is unique in that it reduces the risk of tampering, establishes a moderation tool for disputes amongst entities, and shields organizations from the risks associated with the single point of failure issue. These benefits establish both a regulatory and financial incentive to undertake a blockchain based approach to resolve intercompany accounting record inconsistencies.

Another prevalent issue in the world of transfer pricing is the labor demanded of organizations to set the transfer price of goods. While the approach varies from organization to organization, transfer pricing is one of the most complex and intense operations performed by many accounting departments. A core feature of modern blockchains is the use of smart contracts that allow code to be deployed onto blockchains. A key area that has been pointed out as an area of application for smart contracts is performing many of the transfer pricing functions undertaken by firms. From calculating the optimal number of goods to transfer, to testing the most beneficial transfer price, or automating the process to trigger the actual movement of resources, code for smart contracts can substantially reduce the labor needed to perform these difficult tasks. This illustrates one of the great benefits for accounting regarding blockchain technologies, as blockchain alone cannot replace accountants, rather it is an opportunity to ease the burden of many tasks unpopular within the profession.

From the perspective of the modern accountant, blockchain's usefulness in transfer pricing is a continuation of a technological revolution we have seen undertake the profession over recent years. Today, more than ever before, innovations in fields such as digital record storage and data analytics have empowered accounting professionals to focus on high value add areas for clients and employers. This increased focus on critical thinking, data analysis, and strategic thinking within the organization is what will be demanded of accountants in blockchain-based transfer pricing. In putting professionals in charge of consortium-based blockchain systems, and the smart contracts that will likely be deployed on them, accountants can craft a new era of transfer pricing that benefits both stakeholders and organizations. In increasing the ability of auditors to analyze transfer pricing operations, reducing the burden on accountants regarding manually performing transfer pricing, and synchronizing record keeping systems for organizations, blockchain provides an excellent means to improve transfer pricing.

Chapter 3.2: Improving Record Keeping in Supply Chains

A pertinent issue for many large organizations is the complexity of global **supply chains**. Today, organizations are increasing the length of their supply chains to meet the demand by consumers for quality products at the lowest possible prices. A motivator for the increased premium that is being placed on global supply chains, is the enhanced efficiency of transport, and reduction in the perishability of many products that has occurred over recent years (Shih, 2020). This has helped create an environment in which firms have looked to supply chain optimization to gain a competitive advantage in the minds of consumers. Additionally, as firms have turned to global business partners to meet their manufacturing demands, these same suppliers are often increasing the scope of their own global supply chains (Shih, 2018). This has cultivated an environment between purchasers and suppliers that is highly complex, difficult to track resources within, and ripe for distrust between organizations (Figure 5). While these are clear drawbacks to global supply chains, and we still cannot be sure what lingering impacts the COVID-19 pandemic will have on the international movement of goods, we will likely see even greater downward pressure on consumer prices, increasing the incentive to manufacture goods at a low cost internationally.

A solution to address the challenges of global supply chains is the use of blockchain technology. As an innovation that is fundamentally designed to allow parties to transact with each other in a trustworthy manner, blockchain has the potential to mitigate the ever-growing record keeping risks associated with the growth of highly complex global supply chains. We have seen early proof of concepts show tremendous promise for the application of blockchains in enhancing the ability of organizations to maintain accurate records of their resources, as they move across suppliers. A notable example of this was the pilot program that Walmart deployed to track their produce in 2016. Walmart forged a partnership with IBM to leverage their consortium blockchain platform, Hyperledger Fabric, to enable them to diagnose deficiencies in their produce more efficiently and accurately. The results of the pilot produced great results for Walmart, as they were able to cut their time required to trace a mango through their entire supply chain from 7 days to 2.2 seconds (Hyperledger, 2019). Since completing the test program, Walmart is now mandating that all of their leafy greens suppliers join their consortium blockchain, illustrating the substantial gains in record keeping ability that blockchain can provide within the context of large, globalized, supply chains. With the world's largest retailer behind the technology, it is crucial that accounting professionals consider how blockchain technology will impact their roles.

Most often, blockchain and its applications for supply chains are discussed within the context of performance optimization, with less attention given to the accounting implications that the technology will likely have. Despite blockchain powered global supply chains garnering little attention from the accounting research community, it is very likely the technology will fundamentally alter the way many organizations track their assets across the globe. This has clear implications for accountants, and I believe that it is imperative that the topic be explored. The focus of this section will be on the accounting implications both from an internal and external perspective, meaning that consideration will be given to the perspectives of a wide variety of stakeholders such as:

- Creditors
- Corporate Accountants
- Auditors
- Shareholders
- Regulators

It is critical to consider each of these groups as they all have different demands for the accounting systems of firms that engage in global supply chains. While not exhaustive, some of the likely questions that these stakeholders will have regarding the intersection of blockchain and accounting in global supply chains are:

- How can creditors gain more trust in global supply chains in a cost-efficient manner?
- Will blockchain be able to bridge the gaps in legacy **ERP systems**?

Both of these questions can be answered with blockchain technologies, helping to craft supply chains that not only optimize performance, but also ease the accounting burden of ever-growing supply chains.

Prior to engaging the specific problems that blockchain can alleviate, it is important to understand how the technology can be applied. As is the case in most business implementations, the most suitable form of blockchain is either private or consortium. The choice between private and consortium blockchain should be largely firm dependent, as there is no definitive answer that is applicable to all organizations. In most circumstances though, organizations that are not highly **vertically integrated**, should choose consortium blockchains, since they allow interactions with suppliers that maintain their own distinct ERP systems. This is essential as it is not realistic or efficient for large firms to demand that their suppliers, who often have fewer technological resources to deploy, reinvent their already functioning systems. Rather, consortium blockchains can be thought of as a way to expand existing ERP systems to promote enhanced interactions between the stakeholders in a supply chain. Organizations that should consider private blockchains, where node membership is restricted to a single organization, are those that are vertically integrated and maintain a set of accounting records that is accessible by the owner of the blockchain. This is a very specific set of conditions, and it should be emphasized that restricting the nodes to a single organization has the potential to limit who can be transacted with or demand a consortium-based system be put into place at a future date. While it is important to know how blockchain is broadly applicable, it is crucial to analyze how it can deliver value for stakeholders who rely on the accounting records of supply chains.

A problem that has come to the forefront over recent years, and is likely to grow in the future, is the need for creditors to have access to accurate accounting information in supply chains. One of the core reasons for this problem is how different flows of data can become disjointed or lost within the context of a global supply chain (Gaur & Gaiha, 2020). Simply put, the accounting records may not truly reflect the status of the supply chain. This disconnect between data flows can impact many different accounts, depending on how the organization is structured, but an example of an account that can be impacted are inventory related accounts. Whether it be inaccurate valuation of finished goods, incorrect unit counts, or misallocation of direct labor and overhead, inventory accounts are highly susceptible to error in the context of global supply chains. The challenge of coordinating the information flows in the supply chain can make it very difficult for creditors to accurately assess the financial statements of organizations, often leading to costly audits needing to be performed by public accounting firms. These audits required by creditors, while they are necessary today, are a cost of doing business that can be greatly reduced with blockchain technology.

One of the primary ways that blockchain technology can aid accounting professionals who interact with supply chains, is by providing a means for the accounting discrepancies between organizations to be resolved. In established record keeping systems, it is easy for organizations who transact with each other to disagree on the details of a transaction, since the companies do not share accounting details with each other. Often this proves to be **immaterial**, meaning that the disagreement is not significant enough to warrant further scrutiny, but in extreme cases it can create significant challenges for companies, auditors, and creditors. Once a discrepancy is discovered, the challenge is to determine who is correct? And where did the accounting go wrong? In traditional ERP systems this is very difficult since transactions are not linked together in a traceable sequence and there is no moderator to determine what the true details of the transaction were without undertaking costly procedures. By implementing a consortium blockchain approach, that is shared with suppliers, firms can almost instantly trace back where accounting discrepancies arise from and customize a method for determining agreement on transaction details through consensus protocols. A key feature of consensus protocols is their ability to be customized, which means that owners of consortium blockchains can mandate agreement on transaction details between parties as a condition for the transaction to be added to the blockchain. In this way, blockchains can mediate disputes between entities while creating an easy method to identify accounting missteps. Not only can this enhance the financial reporting of organizations who participate in global supply chains, and aid shareholders, but it also helps creditors by providing a way for them to easily gain reasonable assurance of the accuracy of accounts that depend on accurate reporting from supply chains. In this manner blockchain can benefit firms by enhancing the accuracy of their accounting and aid stakeholders by increasing their confidence in financial reports.

A challenge that has been arising as supply chains become more and more advanced, is the demand for ERP systems to be able to scale with them. While there has without a doubt been a tremendous amount of innovation in the ERP space recently, there is still a significant amount of legacy software that is powering large organizations today. In fact, Vishal Gaur and Abhinav Gaiha found in their piece "Building a transparent supply chain" that "One large company told us it had 17 ledgers in separate ERP systems associated with a single activity—trucking—and its suppliers and distributors had their own ledgers and ERP systems." As any computer programmer can attest to, bad architecture is exposed when systems hit scale, not initially, demanding that we consider the scalability of the systems that power global supply chains. This is not only incredibly operationally inefficient, but also difficult for the accounting professionals of the organization to work with, as it adds an unnecessary layer of complexity to their jobs. Accounting is difficult enough, even when technology is not a barrier. In the case of the organization mentioned, they could turn to a private blockchain to streamline their accounting records. As blockchain networks are independent of ERP systems, they can serve as a coordinating layer on top of business management systems that can mend together the fragmentation that exists in many organizations (Figure 6 outlines a consortium-based solution). In the case of organizations, such as the one mentioned previously, that are finding their fragmented ERP systems lacking scalability, a permissioned blockchain is likely the best option. The reason they are superior in this case is that they can achieve the highest performance of any blockchain implementation, due to node restrictions, and they do not need to share information to other organizations.

Blockchain systems can solve many of the shortcomings of legacy ERP's and in turn reduce the administrative burden on accountants.

Chapter 3.3: Revisions in Accounting for Cryptocurrency

A topic that has become a hot button issue for individuals, regulators, and corporations is the rise of cryptocurrency. Notably, we have seen corporations begin to make strategic investments in cryptocurrencies that have thrust their accounting treatment into the spotlight. As we move into the future, especially in a post COVID-19 economy, it is unlikely that there will be a reduction in strategic investments in cryptocurrency, mandating greater attention being paid to how digital assets are accounted for. While this piece of research is primarily focused on the intersection of accounting and blockchain from a record keeping and technology point of view, I would be remised if I did not address some of the unique accounting challenges posed by cryptocurrency. The purpose of this is not to lay out a concrete solution for the specific accounting hurdles around the topic, but rather to point out areas that demand further research and clarity.

The central issue around accounting for cryptocurrency is the ambiguity around the subject. As of the writing of this piece, the **Federal Accounting Standards Board (FASB)** has declined to provide specific guidance on the topic, leaving a substantial void in **Generally Accepted Accounting Principles, aka GAAP** (Chandrasekera, 2020). A decade ago, this would not have been a major problem, as cryptocurrency had not become a significant consideration for corporations, but the same cannot be said today. Recently influential organizations that span from financial leader J.P Morgan Chase to technology titan Tesla have recognized the potential upside of investments in digital assets. As more organizations follow the lead of these two industry leaders, the magnitude of the void created by the lack of guidance from the FASB will only become larger and more detrimental to both shareholders and companies. Additionally, the monetary and fiscal policies undertaken by the U.S during the COVID-19 pandemic has increased the use of cryptocurrency, as many firms see it as a hedge against the U.S dollar, which has debatable merits but is nonetheless an increasingly held opinion (Tully, 2021). Even though the FASB has been largely silent on this issue, other groups have begun to take up the matter.

The most notable attempt by an accounting body to provide guidance on accounting for cryptocurrency has come from the **American Institute of Certified Public Accountants**, who commissioned a task force that produced a report in December 2019 to address the matter. While the AICPA does not set GAAP, they are one of the influential accounting organizations in the United States and help shape the direction of the accounting profession. In their opinion, which is what today most organizations follow, cryptocurrency is accounted for as an **indefinite life intangible asset**. The impact of this is that as the prices of cryptocurrency fluctuate, no gains in their value are allowed to be recognized while the asset is held. Crucially though, if the price falls at the end an accounting period, an **impairment** must be recorded to the asset, leading to a loss being recognized on the **income statement**. This has been a controversial decision as while it is defensible from the perspective that cryptocurrency is a non-physical resource that never expires, it also has the potential to distort both the earnings and asset positions of firms.

A notable organization that has been impacted by the AICPA's decision on how to classify cryptocurrency is Tesla, who recently purchased $1.50 billion in Bitcoin (Powell, 2021). Due to their large position, fluctuations in the price of Bitcoin can have a substantial impact on how investors evaluate the financial health of Tesla. Over the course of 2020, the price of Bitcoin rose by over 300%, meaning that if Tesla would have held their position for all of 2020 their real asset position would have increased by $4.5 billion and not been reflected in their financial reports. When it is considered that the total value of Tesla's asset holding as of their 2020 annual financial report was $52.148 billion, and their net income was $721 million, it becomes clear how significant of an issue this method of accounting for cryptocurrency is. While the way digital currencies are treated under the AICPA's guidance does not reflect their true nature, I believe that they were in a difficult position due to the FASB's reluctance to provide specific standards.

It is easy to criticize the AICPA for the decision that they made, personally I believe that cryptocurrency most closely mirrors financial assets, but I feel that they were put in a very difficult situation by the FASB. This is due to the fact that there does not exist an asset classification under GAAP today that clearly reflects the nature of cryptocurrency. Rather the AICPA was left to choose from asset classifications that do not adequately address the issue: cash, financial assets, and indefinite life intangibles. While some of these classifications align more closely with the nature of digital currencies than others, they are all insufficient in one way or another. The implication here is that despite the best efforts of the AICPA's well qualified task force, they were being asked to achieve an almost impossible mission. As an illustration, consider the following discussion of the strengths and weaknesses of each of these classifications.

An asset classification that is similar, but not identical, to cryptocurrency, is that of cash and cash equivalents. Over recent years, we have seen increasing adoption of digital currencies, Bitcoin in particular, as a medium of exchange. The payment ecosystem involving Bitcoin has evolved from humble beginnings to today where it can be used to make purchases from the Xbox store, Home Depot, and Whole Foods. While the ease of these transactions varies from company to company, and can be dependent on third parties, we are also seeing the largest payment processors in the world get behind the currency. During 2020, both PayPal and Square announced that they would be adding Bitcoin integration to their systems (Moyer, 2020), removing another major hurdle to the adoption of cryptocurrency as a mainstream medium of exchange. PayPal has stated that their initiative will make "cryptocurrency more mainstream by making it available for use at 26 million merchants around the world." Despite the areas of parallel as a medium exchange between cryptocurrency and standard currency, there are many areas where they do not mirror each other. The first way is that they do not share similar volatility natures, as cryptocurrency is highly volatile while the majority of well-established national currencies are fairly stable. This would render it difficult to classify the fluctuations in the price of digital currencies, since they would likely distort the traditional meanings of accounts used for fluctuations in the values of currencies. A crucial area of distinction as well is the lack of government backing of cryptocurrencies. Due to their lack of support from national governments, the asset class does not enjoy the same stability or ease of regulation that traditional currency does, creating a clear barrier to them being classified legally in the same manner as traditional currencies. The classification of cryptocurrency as cash or cash equivalents is insufficient as while they both can act as a medium of exchange, the do not have similar risk or legal profiles.

The asset classification that I feel most closely monitors the true nature of cryptocurrency is that of financial assets. One of the defining features that aligns cryptocurrencies to financial assets is that of their **liquidity**. While not being completely liquid, both **equity shares** in public companies and holdings in digital currency represent two investments that are easily convertible to cash. The ease of converting cryptocurrency to cash has increased rapidly with recent innovations in consumer facing platforms, such as Coinbase, that now have brought down the barrier to trading them much in the same way that online brokerage platforms opened up equity investing for the masses. Another key point of connection is that both financial assets and digital currencies are susceptible to fluctuations in price and represent a strategic decision by organizations. While the volatility of Bitcoin has outpaced most of the **S&P 500**, investment firm Van Eck Global found that it actually was more stable than between 22% to 29% of the firms that comprise the group during 2020. It would be foolish to definitively assume that this will continue, as 2020 was a year with substantial stock market volatility, but it is nonetheless significant. Primarily the reason this is so important is that one of the main arguments against allowing fluctuations in the price of cryptocurrency to impact income is the volatility of the investment. What this shows is that while cryptocurrency is without a doubt volatile, often times so are the equity shares that are currently allowed to impact income. Regarding differences, the central distinction between cryptocurrency and financial assets is that digital currencies are almost entirely speculative investments, while financial assets can take on many investment forms. Embedded within this distinction is the concept of rights to future cash flows inherent in owning shares of a public company, which is often cited as a line of demarcation between equity shares and cryptocurrencies. The key takeaway from this difference is that while both represent a strategic investment with future economic value in mind, the manner in which they derive this future value is very different. While financial assets are very similar to cryptocurrency, they still do not fully capture the unique nature of digital currencies.

Intangible assets with an indefinite life are the standard for how cryptocurrency is accounted for today, but it mirrors very little of the substance of cryptocurrencies. The reasoning that the AICPA provided for their decision to classify cryptocurrency as intangible assets largely hinged on the fact that they are assets that “lack physical substance.” Of course, this is completely true, but it fails to analyze the underlying nature and behavior of the asset. Common examples of intangible assets are purchased patents, trademarks, and goodwill, all of which share the common trait of providing economic value through use by an organization. This is very different than cryptocurrency which is held inherently to be sold at a future date. While cryptocurrency without a doubt generates economic benefits, it derives value from markets of exchange rather than usefulness in business functions. In the case of standard intangible assets, it makes sense to record them at purchase price and test for impairment since they bring value to businesses and do not have an easily identifiable market price. This is a very different situation than cryptocurrency which is highly liquid and always has an easily identifiable market price, showing that the only connective tissue between intangible assets and digital currencies is their lack of physical substance. In my view, the other attributes of cryptocurrency are more important than its physical substance regarding how it should be accounted for.

There currently does not exist an asset classification that is proper for cryptocurrency. Today this is already an issue for public companies, and it will likely continue to grow in concern as more organizations purchase and accept digital currencies. This should motivate the FASB to provide specific guidance that addresses the unique nature of cryptocurrency, such as how they have with equity investments, so that organizations and shareholders can analyze financial statements that represent the true nature of these investments. The FASB has begun to have discussions surrounding this topic, but they have yet to add it to their project agenda. The purpose of this discussion has not been to propose a new framework for cryptocurrency, but rather to illustrate that the current method is insufficient and motivate action from the FASB. Accountants will have to continue to stay up to date on this subject as it will continue coming under scrutiny from organizations that own cryptocurrency, potentially putting pressure on a change in accounting standards.

Chapter 4: Current Limitations

As a new technology that breaks the traditional paradigm of record keeping that has existed for many decades, there are presently challenges to implementing blockchain to aid in accounting functions. This does not mean that the applications of the technology are impractical, instead it indicates that it is important to be conscious of the limits of the technology. Often regarding innovations, it is just as important to understand what they cannot do as what they can do. When considering a topic as essential, regulated, and unique as accounting, it is especially important to gain a thorough understanding of the challenges embedded in blockchain based solutions. Crucially, two of the major obstacles that stand in the way of blockchain becoming mainstream in the business world are security concerns from organizations and the highly specialized and regulated nature of accounting. Both of these legitimate hurdles will likely slow down the adoption of blockchain in the accounting profession, but they both can be overcome.

Chapter 4.1: Accounting is Highly Specialized

One of the major talking points surrounding the intersection of technology and the accounting profession is the ability of accounting functions to be automated. There is no disputing the fact that automation will, and has already, alter the manner in which accountants perform their roles, but this does not mean all accounting tasks can be automated. In fact, the majority of operations performed by accountants today cannot be automated by technology that is currently widely accessible. An important distinction regarding the automation of accounting and blockchain technology is the difference between where we are today and where we may be in the future. As of this piece of research, there does not exist the technology to replace the roles of many accountants, specifically those who hold a CPA designation and perform tasks that require significant judgement. While blockchain can aid in the increased effectiveness of accounting departments, its ability to automate the role of accountants is largely dependent on other technologies. The most notable technologies relating to this topic are smart contracts and artificial intelligence, which work together to create blockchains that are equipped to engage in complex decision making. AI has evolved over recent years to the point that it can closely mimic human behavior, but it still lacks the contextual tools to replace human judgment in many cases. This is particularly true in a profession like accounting that often requires a substantial amount of critical thinking to solve problems with unclear solutions. The significance of this is that while it is not unthinkable that AI could advance to the point where it is able to leverage context to perform the functions of the majority of accountants, it is not there today. Additionally, it will be critical to the continued growth of blockchain that its integration with other technologies continue to advance. Despite advancements in AI and machine learning integration over recent years within major blockchains, such as Hyperledger and Ethereum, many smart contracts are still relatively simple. In this way, we are very much in the early stages of seeing technologies such as blockchain and artificial intelligence together in a manner that has widespread business applications.

Chapter 4.2: Accounting is Regulated

A unique trait of the accounting profession, relative to other industries, is the high degree of regulation that exists. This is especially true for publicly traded organizations and public accounting firms, who have to comply with guidelines from multiple regulatory bodies. What this means is that in analyzing the implications of blockchain based record keeping systems, it must be considered the degree to which successful implementation is dependent on evolutions in regulations. One of the main concerns that publicly held companies are likely to have when considering blockchain is the implications that it may have on their audits of internal controls. Not only will this be a large concern, but it will also be widely held since the **Sarbanes-Oxley Act** mandates that the majority of public companies have an audit of their internal controls. While there will be many aspects of SOX audits that blockchain will be able to enhance, consideration will have to be given to how this new technology functions and impacts other internal controls. Likely the greatest hurdle though from a regulatory perspective is the slow manner in which accounting standards setters adopt new regulations. A prime example of the slow nature of accounting standard setting, is the process that was undertaken to enact revenue recognition reform, ASC 606, in 2014. The process to bring about this substantial reform to the manner in which revenue from contracts is recognized, took over twelve years, illustrating the lag that often exists regarding accounting standard setting. This delay in regulations is particularly relevant for cryptocurrency as there is still not a clear answer to how markets will respond to reform to cryptocurrency accounting and digital currencies were largely immaterial for organizations prior to the last few years. When considering the fundamental nature of revenue recognition regarding accounting, it is highly unlikely that blockchain standards will be set in the near future.

Blockchain faces a unique set of challenges to be implemented in the highly regulated and specialized field of accounting. Both of these hurdles can be overcome, but they still nonetheless illustrate that blockchain integration will likely be limited in scope of applications for the next few years. This can without a doubt change over time, but it is important to acknowledge the reality of the situation today.

Chapter 4.3: Security Concerns

A substantial, and understandable concern that many leaders in the business world have is the safety and integrity of their organization's data. Notably, in regard to the implementation of blockchain, they are uncomfortable with sharing their data with organizations that they have not engaged in previous data sharing relationships with. Compounding this concern is the fact that due to blockchain's immutable nature, security breaches can have devastating impacts as they are irreversible. While blockchain is secure on a technical level, as illustrated by the finance and healthcare industries increasing willingness to embrace the technology, this is in many ways less essential to the technology's adoption than the narrative that surrounds it. It is important to acknowledge as well that the discussion being had about the security of data is a positive step for the business community. Today, as the threat of cybercrime is ever increasing, it is crucial that organizations understand the security implications of the record keeping systems that they decide to employ.

The first major consideration when analyzing the security of blockchain networks is to understand the manner in which architecture can profoundly impact security concerns. Primarily, the main factors that drive the difference in security risks between forms of blockchains are the restrictions on node membership imposed, the consensus protocol leveraged, and the centralization of the network. For example, consider the possible risks from a 51% attack within the contexts of public and consortium blockchains. In the case of a large public blockchain that powers a cryptocurrency, such as Bitcoin, the implications of a 51% attack would be potentially catastrophic as malicious users would be able to gain control of many functions of the network, potentially blocking new transactions from occurring and exploiting their control for their own benefit. On the other hand, in the case of a consortium blockchain between business partners, the risk of a 51% attack is much lower. This is because it is known who members of the blockchain are, making it relatively easy to identify which member acted maliciously. This would enable the other members of the consortium network to take appropriate action against the guilty party, making the idea of executing a 51% attack a very poor one in blockchains with restricted node membership. What this means is that many of the concerns being raised by corporate leaders can be answered by choosing the blockchain implementation that best balances functionality and security for their specific needs. While not exhaustive, some of the major technical considerations that business leaders need to consider, beyond those mentioned previously, when designing the architecture of their blockchain networks are:

- How does the network handle nodes not being online?
- Are the included parties in the network trustworthy?
- How important are performance, decentralization, and cost?

Each of these questions can have a substantial impact on the decisions that organizations will make when implementing blockchain networks. Beyond these few questions, it is important to understand some of the common security vulnerabilities in blockchain networks.

One of the most impactful security flaws in many blockchains is the manner in which they interact with non-blockchain based software. For example, despite the fact that cryptocurrency blockchains are typically secure, often the digital wallets that users interact with are not (Deloitte, 2017). This has caused many of the cryptocurrency hacks that we have seen over the past few years (Lamesh, 2021). Unfortunately, blockchain technology is often blamed for vulnerabilities in systems that do not actually utilize blockchain, such as a digital wallet. While this distinction is clearly significant, it also raises important security implications for the ability of blockchain to integrate with non-blockchain based systems. This illustrates that while blockchains are secure, the same security standards are often not present in software that must interact with blockchains. From the perspectives of businesses, this means that blockchain should not be looked at as a technology capable of solving the cyber security problems of existing software that it is integrated with. Within the context of consortium and private blockchains, where members of the network are not anonymous, this is especially critical as vulnerabilities in one node can potentially expose sensitive information. Due to this fact, it is important that organizations who join private and consortium blockchains trust, and understand, the securities protocols taken by their business partners.

Another crucial area of consideration when implementing blockchains is their susceptibility to human induced vulnerabilities. Similar to the case of software with security flaws integrating with blockchain, this is not strictly a problem with blockchain from a technical perspective. It nonetheless is critical though to thoroughly consider, as it is one of the primary means by which cybercriminals can use mainstream methods of attack against blockchains. This can be done in a multitude of ways, but the simplest case to consider is that of stolen login credentials in consortium blockchain. If a hacker were to be able to obtain the login information necessary to access the blockchain through a conventional computer, they would be able to access the information stored on the blockchain much in the same manner they could traditional record keeping systems. For this reason, it is critical that organizations who decide to invest in blockchain based systems train their workforce on what the technology specifically does and does not do. Otherwise, blockchain can create a false sense of security within organizations that exposes them to the same security risks they have already been dealing with.

As a final note, it is important to consider what the future of security vulnerabilities in blockchain will look like over the next few years, specifically relating to smart contracts. As one of the most popular areas of growth in blockchain, smart contracts introduce a whole host of opportunities for the technology by allowing software developers to build fully functional decentralized applications. With this new field of innovation though has come substantial security concerns. Currently, the largest blockchain for smart contract usage is Ethereum, as the founder of the blockchain Vitalik Buterin has been at the forefront of the movement. Unfortunately though, a study performed in 2018 found that 34,200 smart contracts on Ethereum currently have security vulnerabilities (Pearson, 2018). This is especially dangerous considering the manner in which smart contracts can facilitate the movement of assets. The greatest strength and weakness of smart contracts is their ability to close the gap between blockchain and conventional computer programming, opening up a world of opportunities and security concerns alike.

Chapter 5: Future Applications

Blockchain is an evolving technology that will have a distinct set of implications in the future that have not yet been realized today. For the accounting profession this is especially relevant as the field must be responsive to changes in the business world broadly, while also looking to continuously differentiate themselves within the highly competitive accounting industry. Due to this, it is essential that accounting professionals be forward looking in order to embrace the opportunities that blockchain will provide for them to deliver greater value for clients and enhance their own experience in their roles. Notably, accountants must consider the implications of blockchain for the financial statement audit and the evolution of smart contracts. These areas must be thoroughly considered by accountants, corporations, and accounting firms as they have the potential to unlock a new era of innovation within the accounting field. This section provides a high-level overview of how these areas can theoretically impact accountants in the future.

Chapter 5.1: Blockchain Based Audits

One of the most often cited potential use cases for blockchain with regard to accounting is the ability for auditors to leverage the technology. Over recent years there has been a tremendous push by public accounting organizations to further integrate advanced data analysis tools into their audits. In fact, deriving new and novel insights from data has become central to the auditing industry, illustrated by the fact that each of the big-4 accounting firms has created their own data analysis platform (Kokina & Davenport, 2017). These platforms integrate unique tools, advanced data processing power, and artificial intelligence to deliver value for clients. This provides a tremendous opportunity for blockchain technologies to be leveraged alongside these platforms to craft an audit that is more efficient, reliable, and simple for not only auditors, but also those who rely on the financial statements of organizations.

The element of blockchain-based auditing that has garnered the most discussion is that of real time auditing. Currently, there is a substantial delay that exists between when the transactions being recorded occurred and when financial statements are released to the public. While information that took place in the past without a doubt is useful, there are limitations to the utility of information that occurred months prior to the user of the financial statement finding out. A core barrier in auditing, that has contributed to this substantial delay for stakeholders, is the volume of data that auditors must analyze over a relatively short period of time. This not conducive to promoting the highest theoretical standards of audit quality, nor does it provide auditors with the best experience when auditing. Today, auditors often undergo what is known in the profession as busy season, which demands that they work far beyond their standard hours, often leading to an erosion in their overall health and satisfaction in their roles. With blockchain, there is a strong likelihood that this burden can be reduced by allowing public accounting firms to be members of accounting focused consortium blockchains with their clients. Crucially, this would allow for public accounting firms to be able to see in real time the information that they would have to wait months for today, allowing them spread out the work of an audit over the course of an entire reporting period, rather than a few select months. This benefits the end user of the financial statement as well since by evening out the audit work over the course of an entire period, the wait for financial statements to be issued can be reduced. Beyond easing the considerable toll busy season takes on accountants, the existing capabilities of public accounting firms can help drive a better audit using blockchain.

Due to the previously mentioned investments in data analysis that public accounting firms have made, they are well positioned to utilize the full potential of blockchain in their audits. Auditors can engage sophisticated tools in data processing, automation, and artificial intelligence to in real time be alerted to potential problems in the accounting of their audit clients. Consider the case of a public accounting firm that has the ability to analyze the risk profile of a client's **journal entries** using artificial intelligence to compare them to prior journal entries, which is a capability that exists for public accounting firms today. If the client posts a journal entry that is deemed to be abnormal, the auditor can be altered either by real time monitoring software, or during a regularly scheduled review of the client's recent accounting activity. The benefits of this near real time alert of potential audit issues become even more valuable when it is considered with the auditable trail that is created by blockchains. In creating an easily auditable trail, auditors can easily derive the cause of the alert, analyze the transaction, and perform the necessary follow up with the client. This process promotes better audits while at the same time allowing auditors to perform their roles in a more time efficient manner.

Chapter 5.2: Evolutions in smart contracts

A key area that demands further study is how smart contracts can be leveraged to perform many accounting tasks. One of the areas that I feel is a prime candidate for future exploration is the ability of smart contracts to aid in account reconciliations, which is an accounting process to ensure that account balances are correct at the end of a period. This is a cumbersome process for every accounting department and can become quite the challenge when account balances do not agree with each other, prompting further exploration into the discrepancy. A common complaint, that I can attest to from personal experience, is that it can be extraordinarily difficult to pinpoint the journal entries that created the problem in the accounting. As discussed previously, blockchain technology creates an easy-to-follow trail for accounting professionals, potentially reducing the labor demanded to perform account reconciliations by a substantial amount. This alone would be a considerable gain for accountants, but it can be further extended through the use of smart contracts to automate many human driven tasks. Theoretically, smart contracts written in consultation with accounting professionals can automate many of the rudimentary tasks involved in account reconciliations. They can achieve this by utilizing the records stored on the blockchain to test that account balances are correct and are matched to their corresponding accounts. Additionally, there is the potential for documents traditionally used in account reconciliations to become less important in a blockchain based system that leverages smart contracts. For example, cash reconciliations typically rely on comparing bank statements to journal entries and searching for issues. In a consortium blockchain system that includes banks, it can be argued that bank statements would no longer be as important since the bank would have already agreed to the correct recording of each cash transaction through the consensus protocol. Account reconciliations are a crucial aspect of corporate accounting, but they also provide a tremendous opportunity for smart contracts to aid accounting professionals.

Today, smart contracts are typically limited to relatively systemic tasks, but this will likely not be the case in the future. As discussed earlier, smart contracts are currently undertaking an era of innovation that is going to expand their use cases. Notably, the ability of smart contracts to be used in conjunction with emerging technologies, such as artificial intelligence and **internet of things** (IoT). Put simply, blockchain and smart contracts record and execute transactions, artificial intelligence makes software be able to reason, and the internet of things connects assets to the internet. These three technologies are well equipped to combine to create revolutionary accounting systems because they compensate for their respective deficiencies. If combined in the correct manner, these three technologies can be merged to form accounting systems that are highly connected, trustworthy, and intelligent. As an illustration of the merits of such a system, consider its ability to deliver value for a company that ships good to customers where ownership transfers when the inventory arrives. By implementing a combination of blockchain, smart contracts, artificial intelligence, and IoT they can:

- Track the flow of the inventory in real time
- Agree on the completion of a transaction with their customer
- Generate the corresponding journal entries

These benefits can be derived by undertaking the following process:

1. Creating a consortium blockchain that customers can be added to
2. Training an AI model to generate journal entries
3. Attaching a sensor to each shipment that is connected with IoT
4. Recording the shipment leaving facility on the blockchain
5. Recording when the goods arrive at the client on the blockchain

6. Leveraging a smart contract to check that the terms are satisfied
7. If the terms are satisfied, use the AI model to generate journal entries for both parties

This process represents an evolution in the future of accounting that is based in what cutting edge organizations are already doing. A prime example of this is RoadLaunch, a logistics company that is focused on emerging technologies (Skinner, 2018). They have been able to institute a global blockchain network for themselves and their customers that allows for the real time updating of smart contracts, constant tracking of assets, and an auditable trail of transactions. The CEO of RoadLaunch, Cory Skinner, has cited the combination of blockchain, IoT, and AI as the driving force behind why they have been able to substantially reduce the overhead of many of their customers. The only component of the process that I have outlined that they have not engaged in is the use of AI to generate journal entries. While this will definitely require further research to reach the point where AI is reliably generating journal entries from blockchains that can accurately record highly subjective areas of accounting, there is reason to think that this will happen in the future.

Chapter 6: Future Limitations

As blockchain becomes more prevalent within the global business community, the challenges the technology will face are likely to evolve as well. It is critical to pay attention to how the increased adoption of blockchain can compound with many of the problems that the technology faces today to produce real limitations to its use cases. The reason it is essential to consider these challenges is that implementations of blockchain in the future must be thoughtful, especially in an industry that demands a high attention to detail in the manner that accounting does. The two most essential limitations to be considered regarding the future adoption of blockchain in accounting is the limited scalability of many blockchain implementations and the issues that blockchains have in communicating with each other.

Chapter 6.1: Scalability

A common argument that is used to justify the applications of blockchain for the business community is blockchain's ability to enhance the trustworthiness of how business transact with their stakeholders. For the most fervent supporters of blockchain in business, they often advocate building large scale public blockchains where users can participate in a manner that is similar to how users engage cryptocurrency blockchains today. Putting aside the security and organizational concerns, this is not currently technically feasible due to the performance requirements that is demanded by companies today. As has been discussed previously, public blockchains still are not very efficient when compared to more centralized forms of storage. To put this gap in perspective, Ethereum, which has become a dominant player in distributed application development, can only handle 15 transactions per second (Tapscott, 2020) while other storage options, such as Microsoft's SQL Azure platform, can handle 75,000 transactions per second. Ethereum is currently working on increasing this transaction limit, which Vitalik Buterin has claimed will increase the platform's transactions per second to up to 3,000 (Wuckert, 2020), but there is still a substantial performance gap that exists. There is little doubt that blockchains will become higher performing in the future, but it is abundantly clear that they are not well suited for situations that demand excellent performance. Additionally, as blockchain becomes integrated with other emerging technologies, performance of blockchain systems will be impacted and further optimization will need to be performed, posing another technical hurdle. As a remedy for these issues, consortium and private blockchains are often proposed as potential solutions. This is a relevant point, but consortium and private blockchains must be deployed in a thoughtful manner since they are far from the solution to all the problems with blockchain.

A common flaw in how consortium and private blockchains are viewed is that they fail to consider the scalability limitations of them. Hyperledger Fabric by IBM is one of the most widely used consortium blockchains implementations, as it has shown substantial promise in both testing and real-world applications. Currently though, Hyperledger Fabric is only equipped to handle 3,500 transactions per second and much of its testing has been in environments that only used up to 128 nodes (IBM Research Editorial Staff, 2019). This is plenty of nodes for many of the business processes that have been discussed previously, such as transfer pricing, real time auditing and making supply chains more transparent, but is not currently suited to achieve some of the more ambitious goals that have been proposed. From an accounting perspective, the most ambitious goal that has been set forth is to allow shareholders to be a part of the blockchain networks of public companies in order for them to be able to analyze financial performance as it occurs. Often consortium blockchains are cited as a way to achieve this, but they are currently unproven operating at the scale that would be necessary to implement such a system. This leads to the conclusion that for blockchain to achieve many of its substantial potential use cases in the future, that there will need to be many separate blockchains maintained, which introduces a whole other set of problems.

Chapter 6.2: Lack of Interoperability

A common issue that is faced by innovative technologies is that they are often fragmented over their early years. What this means is that adoption of innovative technologies is often hindered by its inability to be bundled together in a way that drives value for users. A prominent example of this phenomenon is the early years of the internet, as private networks that did not communicate well with each dominated the space in the beginning (Tapscott, 2020). The internet was only able to reach its full potential once networks were able to easily communicate with each other and exchange information in the manner that we know today. The origin of the internet is similar to the stage that blockchain is in today, as the **interoperability** of blockchains is still lacking. Critically, this illustrates that currently different blockchains are not well equipped to communicate with each other in a consequential manner, a problem that is only more likely to grow in the future. Some organizations have begun to work on solving this issue, such as Cosmos, IBM, and Ethereum, but there is still a large amount of progress that needs to be made.

From an accounting perspective a lack of interoperability in blockchains can have substantial negative ramifications for the adoption of the technology, as many of the future applications will demand that organizations share data that is stored on separate blockchains. In the case of real time auditing, if public accounting firms maintain a shared consortium blockchain with their clients, and either the accounting firm or client maintains their own blockchain that is relevant to the audit, they will need to communicate with each other. If the blockchains cannot interact with each other in a productive manner, many of the benefits of blockchain are lost as technologies such as smart contracts become much more difficult to employ. The negative ramifications of such a scenario are also compounded by its ability to limit innovation in blockchains. One of the core areas of intersection between AI and blockchain that has been pointed to as being particularly useful in the future, is the ability of blockchains to be used to share training data for AI and track the process by which it makes decisions (Cuomo, 2020). This is substantially diminished if organizations cannot share data from their own blockchains with others because it is difficult to pinpoint the precise cause of decision making for some forms of AI. Additionally, other applications of blockchain will likely be limited, such as the example provided earlier regarding the hypothetical company that uses smart contracts, AI, and IoT to automate the recording of a shipment of inventory. If both organizations make the decision to leverage their own permissioned blockchains for their accounting, their shared consortium blockchain would need to be able to communicate with both of their separate blockchains. If this cannot be achieved, the utility of the example falls apart as the smart contract cannot be executed, thus no recording of journal entries can take place. It is clear that in the future, blockchains must be able to communicate with each other if they are to reach their full potential.

Chapter 6.3: Analysis of Challenges

Looking towards the future, it is important to understand which of the challenges that have been discussed in previous sections are likely to be the strongest hindrances of the widespread use of blockchain in the accounting profession. Crucially, there needs to be a distinction made between challenges that are derived from the capabilities of the technology, and hurdles that are created by perception. This means that while technical challenges may be able to be overcome, that does not mean that sentiment around the technology will keep pace. Today, we have already begun to see this process begin as there has been a substantial growth in projects that seek to enhance the performance of all types of blockchains. It is likely that this innovation will continue in the future and overcome many of the scalability and interoperability challenges that plague many systems today, leading to the conclusion that the greatest limiting factors will be non-technical in nature.

A challenge that is often not considered regarding the potential regulatory solutions for blockchain based internal control systems, is the need for standard setters to establish internal control audit procedures that can be tested by auditors that do not have an in-depth understanding of blockchain technology. From the perspective of standard setters, not only will they have to decide what an adequate internal control within a blockchain context is, but also what a simple yet effective way to audit it is. This illustrates the core obstacle blockchain must overcome regarding regulation, as its ability to provide an automated trustworthy trail presents an opportunity for regulators to do their role more efficiently and effectively, but will force standard setters to consider difficult technical questions that have not been dealt with previously. Additionally, I believe that another major perception-based obstacle that the technology will have to overcome, is the way organizational sentiment could hamper adoption. Primarily, I believe that due to blockchain's nature as a quickly evolving and disruptive technology, there will be a knowledge lag within organizations, as it will be difficult for them to stay updated with the latest developments in the field. This will likely cause a problem for the adoption of blockchain based alternatives to existing centralized systems that require strong performance. As the technology continues to evolve, and allow private and consortium based blockchain solutions to handle more transactions efficiently, it is likely that organizations will not be able to stay current on these developments, as they represent the latest innovations in a field that is still relatively young. Moving forward, I believe that the non-technical aspects of blockchain technology will likely serve as its primary limiting factor, not the technical limitations.

Chapter 7: Conclusion

Blockchain is clearly a technology that is not only relevant to accounting innovation today, but also to the future of the profession. An exciting element of blockchain's ability to impact accountants is that it will not remove the need for accountants. Each of the topics that has been discussed in this piece cannot function without well trained accounting professionals. Whether it be accountants determining the procedures for transfer pricing, working with enhanced supply chains, or leveraging innovative audit procedures, the accountant must be at the core of an effective implementation of blockchain technology. If trained accountants are not engaged in the design of these systems, there could be wide ranging implications for our economy, as the integrity of financial information could be compromised. A common saying in software development community that I believe provides a sound analogy for the need for accountants to be essential to this evolution is "software is only as good as the people that make it." Regarding blockchain based accounting systems, this means that technical and accounting acumen must be merged to achieve the potential of blockchain. In this manner, accountants should look at emerging technologies as an opportunity to evolve their role to be one that allows them to deliver the most value for their clients.

This should not be the end point of the discussion regarding accounting and blockchain, rather this should just be another step in a field of research that is certain to evolve considerably in the future. I believe that cross-discipline collaboration will be essential to the long-term viability of this topic, as neither blockchain specialists nor accountants present the totality of knowledge that will be necessary to design blockchain based accounting systems. This demand for collaboration represents where the accounting profession is headed as a whole, with accountants focusing their time on high value add areas rather than repetitive tasks. I believe that this is a positive evolution for the profession and is an incredibly consequential area of future research that can be undertaken by accounting scholars. There are few areas that will likely impact accountants and the business world more than evolutions in accounting systems, and I hope that this piece has provided a roadmap for areas of future exploration regarding blockchain's usefulness.

Appendix

Components of a block

The block header stores information that is essential to identifying the block within its blockchain network, and can contain: (Zheng, Xie, Dai, Chen, & Wang, 2017)

- Block version: Determines how nodes validate transactions.
- Merkle Tree Root Hash: The hash value used to identify all transactions in a block.
- Timestamp: When the block was added to the blockchain.
- nBits: The maximum number of bits a block header can be.
- Nonce: An arbitrary number modified by miners in Proof of Work consensus algorithms.
- Previous block hash: The hash generated from the last block in the blockchain.

While none of these attributes refer to transactions stored within blocks directly, they are nonetheless critical in building optimized and effective blockchain networks.

The block body stores both the references to the transactions contained in the block, and a counter that keeps track of the current number of transactions in the block. The number of transactions that may be stored in a block, is not stagnant, but rather is determined by the size of the block and the size of the transactions that will be referenced within the block (Zheng, Xie, Dai, Chen, & Wang, 2017). This is why the maximum number of transactions a full block can hold will not be uniform across all blocks within a blockchain network in most cases. A simple analogy for the components of a block is a letter that will be mailed. The envelope can be thought of as the block header, it defines identifying information and the processes that should be used to mail the letter, while the contents of the envelope are similar to the block body in that it contains a dynamic number of items that holds the information desired by the party receiving the envelope and letter.

Benefits of Merkle Trees

The major benefit of Merkle trees is that they decrease the amount of data that must be maintained for verification purposes (Sharma, 2020). Merkle trees achieve this by separating the data of the transaction from proof of the transaction (Sharma, 2020). This greatly reduces the amount of computing resources required to maintain a node in a blockchain. Additionally, Merkle trees are essential to ensuring that blockchain networks are tamper proof, meaning that once data is added to them it cannot be altered. The means by which Merkle trees promote this trait is through hashing. In hashing, a unique value is generated from a specific input. In the case of blockchain, this means that as blocks of data are added, they are assigned a specific hash value. Blocks are then connected by including references to the previous block in their block header. Since hash values are unique to a specific input, if the data of a transaction is altered the hash value must change, which would break the links that connect blocks on a blockchain. Due to this fact a blockchain network that leverages Merkle trees cannot alter transactions that have already been recorded. Additionally, when retrieving data, it is far more efficient to utilize a Merkle tree structure rather than an unordered structure.

Description of Consensus Algorithms

Proof of Work

The consensus algorithm that is most commonly associated with blockchain technology, is the proof of work algorithm. The prominence of proof of work stems from it being deployed to add transactions to the Bitcoin blockchain, as well as being leveraged in many other prominent public blockchains. The reason that proof of work is incredibly popular with public blockchains, especially those in their early stages, is due to the manner in which it determines which node has the right to add a block. In order to determine which node can add the desired block, each node in the network attempts to alter the nonce contained in the block's header to match a desired hash value. Once a node alters the nonce to be equal to the desired target value, it is then broadcast to all of the other nodes in the network for them to validate the correctness of the calculated hash value (Zheng, Xie, Dai, Chen, & Wang, 2017). Other nodes in the network are motivated to participate in the validation process since it mandatory in order for them to have the opportunity to add a block in the future. After the block has been added, the node that performed the operation is given an economic reward. In summation, this process is referred to as mining and each of the nodes that attempt to gain the right to add the block are identified as miners.

One of the primary benefits of utilizing proof of work consensus is that by forcing nodes to solve a complex mathematical puzzle, the threat of malicious nodes is greatly reduced. The reason for this enhanced security is that by increasing the computing power required to gain the right to add a node, the economic incentive to power a malicious node is greatly reduced (Zheng, Xie, Dai, Chen, & Wang, 2017). This can be seen in the proliferation of Bitcoin mining operations and growth of mining pools which feature a relatively high barrier to entry. Another major benefit of proof of work consensus is that due to including a fair mechanism for selecting the node to add the block, and lack of a direct entry fee to join the network, it is well equipped to build fully decentralized applications powered by many users. While this inherent openness is a major benefit of this version of consensus, it also poses substantial performance limitations. Due to the intense mathematical computations required, proof of work consensus is incredibly resource intensive for the nodes in the network, limiting the overall performance of the network. This performance limitation is one of the primary reasons that proof of work is generally viewed as too poor performing to be suitable in business applications that demand consistent and efficient performance.

Proof of Stake

Proof of stake differs from proof of work in that it mandates that nodes in the network have a financial stake in the network succeeding. This is achieved by nodes having to first prove that they have a sufficient amount of the blockchain's currency to be deemed to have the right to add blocks to the blockchain. The fundamental thought process behind this decision, is that nodes with a financial stake in the blockchain succeeding will not have an incentive to perform maliciously within the network (Zheng, Xie, Dai, Chen, & Wang, 2017). Proof of stake differs from proof of work also in the manner that the nodes decide who will be given the right to add the node to the blockchain. Rather than relying on nodes solving a complicated mathematical problem, the nodes elect a node to have to add the block. Due to this process the nodes in a blockchain that uses proof of stake consensus are referred to as validators rather than miners. Additionally, nodes are provided opportunities to add to the blockchain proportional to their financial stake in the network. In this manner, proof of stake can be considered to favor wealthier nodes, as those with larger amounts of currency stored in the blockchain will be favored in the node selection process.

A fundamental benefit that is provided by proof of stake consensus is that it is far less resource intensive than proof of work. This is because it does not demand the computing power necessary to solve highly complex mathematical problems. For this reason, proof of stake consensus can actually be argued to improve the ability of individuals to participate in blockchain networks, as it is much easier for an average user to obtain a specific cryptocurrency as opposed to leveraging vast computing resources. This is one of the major reasons many blockchains, such as Ethereum, have moved towards a proof of stake model, as they feel that the reduced computing power demanded on individuals supports decentralization, despite proof of stake's proportional node selection. Not only does the lack of need for complex mathematical problems support decentralization by enabling a lower barrier to entry, but it also has enhanced the financial viability of blockchain technology. In reducing the computational complexity of node selection, proof of stake substantially reduces the cost of upkeep for those who choose to participate in blockchain networks. For this reason, proof of stake is often seen as an opportunity to bridge the current gap that exists between public blockchains and the business world.

Glossary

51% Attack: A security flaw in blockchains that is exposed when a single party owns most of the nodes in a network. This defeats the purpose of the blockchain as it loses decentralization.

American Institute of Certified Public Accountants: One of the largest professional accounting organizations in the United States.

Artificial Intelligence: Computers performing tasks that typically require human judgement.

Base Erosion and Anti-Avoidance Tax: A tax provision from the Tax Cuts and Jobs Act of 2017 to disincentivize large corporations from shifting profits between foreign related parties.

Bitcoin: The most widely used form of cryptocurrency, is powered by blockchain.

Block: Records the transactions that will be added to a blockchain.

Blockchain: A decentralized form of record storage that is secure, transparent and trustworthy.

Consensus Algorithm: How the nodes in a network agree on the correctness of a transaction.

Consortium Blockchain: A form of blockchain ideal for connecting multiple private companies.

Enterprise Resource Planning System: Software application used to run multiple parts of a business.

Equity Shares: Ownership of a portion of a public company.

Federal Accounting Standards Board: A standard setting group that works on GAAP.

Generally Accepted Accounting Principles: The rules for financial accounting in the United States.

Hash: An identifier that links together blocks in a blockchain.

Immaterial: An accounting term to signal that a discrepancy is too small to be relevant.

Impairment: When an asset experiences a decline in value that is deemed to be permanent.

Income Statement: Financial statement that conveys profitability of an organization.

Indefinite Life Intangible Asset: An asset that lacks physical substance and is expected to be useful forever.

Internet of Things: A way that physical objects can be connected to the internet.

Interoperability: The ability of computer systems to communicate with each other.

Journal Entry: How accounting transactions are recorded.

Liquidity: The ability of an asset to be converted into cash.

Node: Adds and verifies transactions while also maintaining a record of all transactions.

Permissioned Blockchain: A blockchain that restricts who can become a node.

Public Blockchain: A blockchain anyone can join.

S & P 500: The 500 largest stocks on the United States Stock Market.

Sarbanes-Oxley Act: Passed in 2002 to improve public trust after multiple accounting scandals. Mandates audits of internal controls and tougher penalties for managers.

Smart Contract: A technology that enables computer code to be embedded on a blockchain.

Vertical Integration: When companies own and control multiple stages of a production process.

Figures

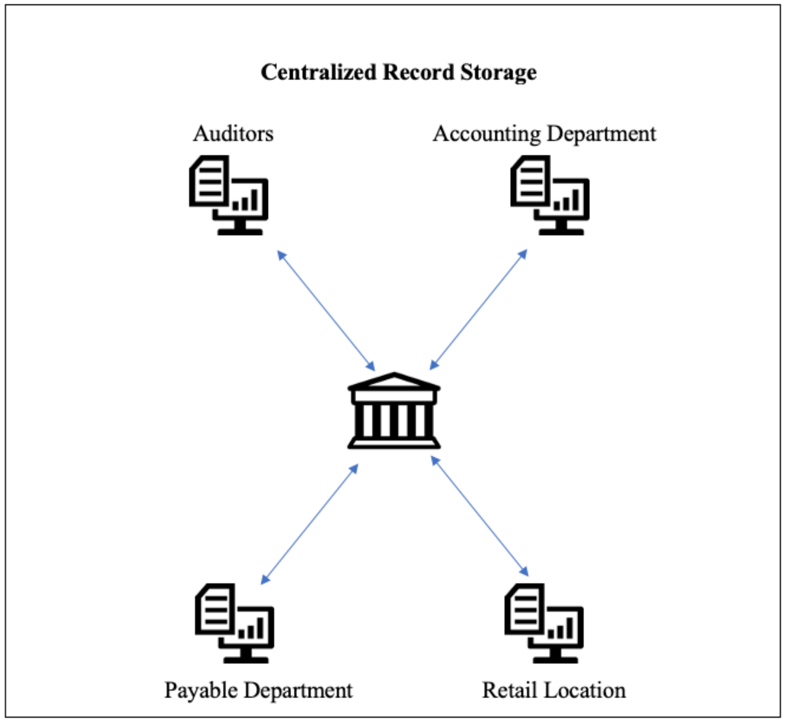


Figure 1: A centralized form of corporate record storage.

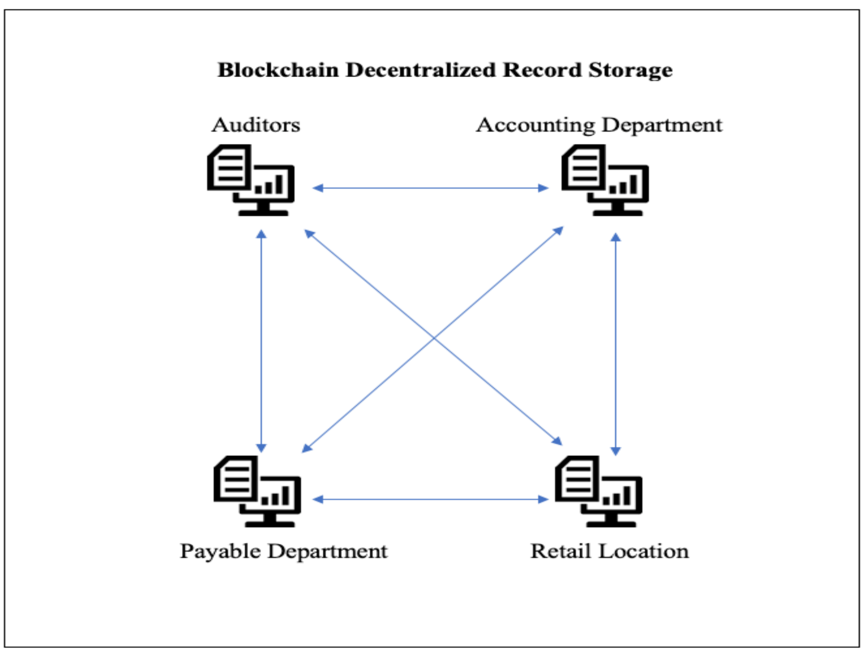


Figure 2: A decentralized (blockchain) form of corporate record storage.

Figure 3: The basic structure of a block that is stored on a blockchain.

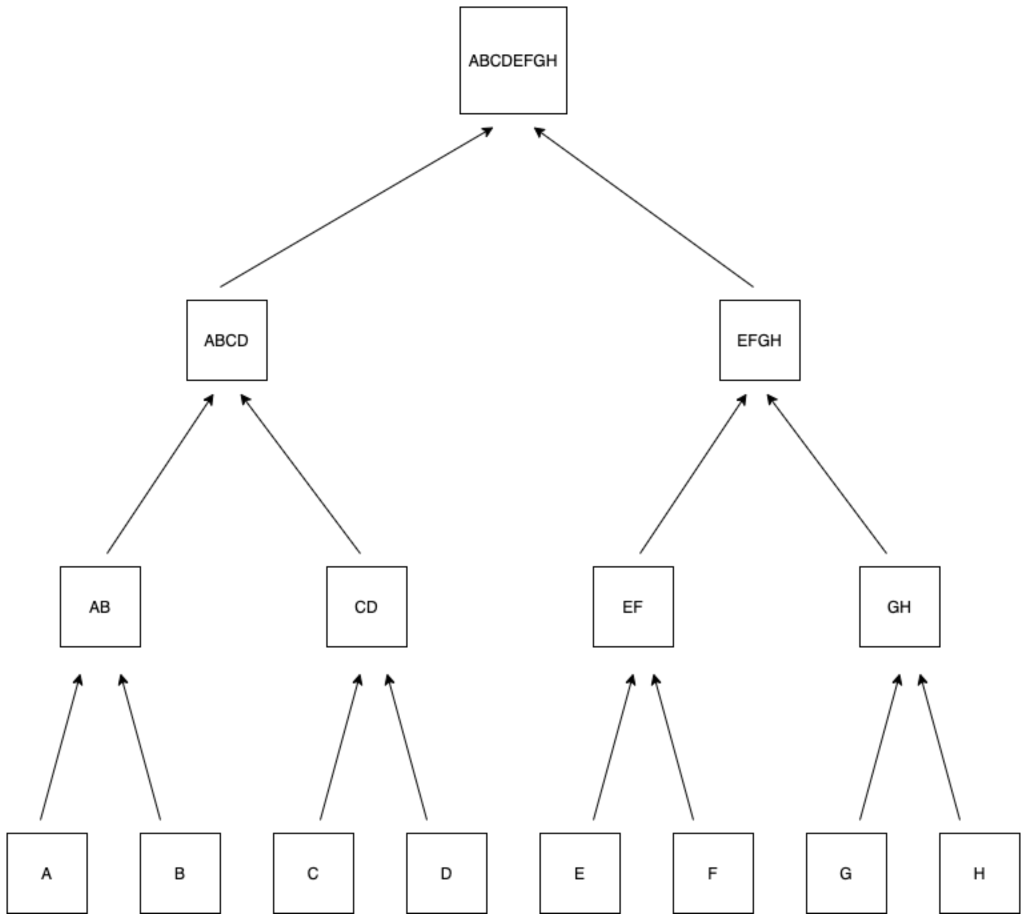


Figure 4: Basic structure of a Merkle Tree

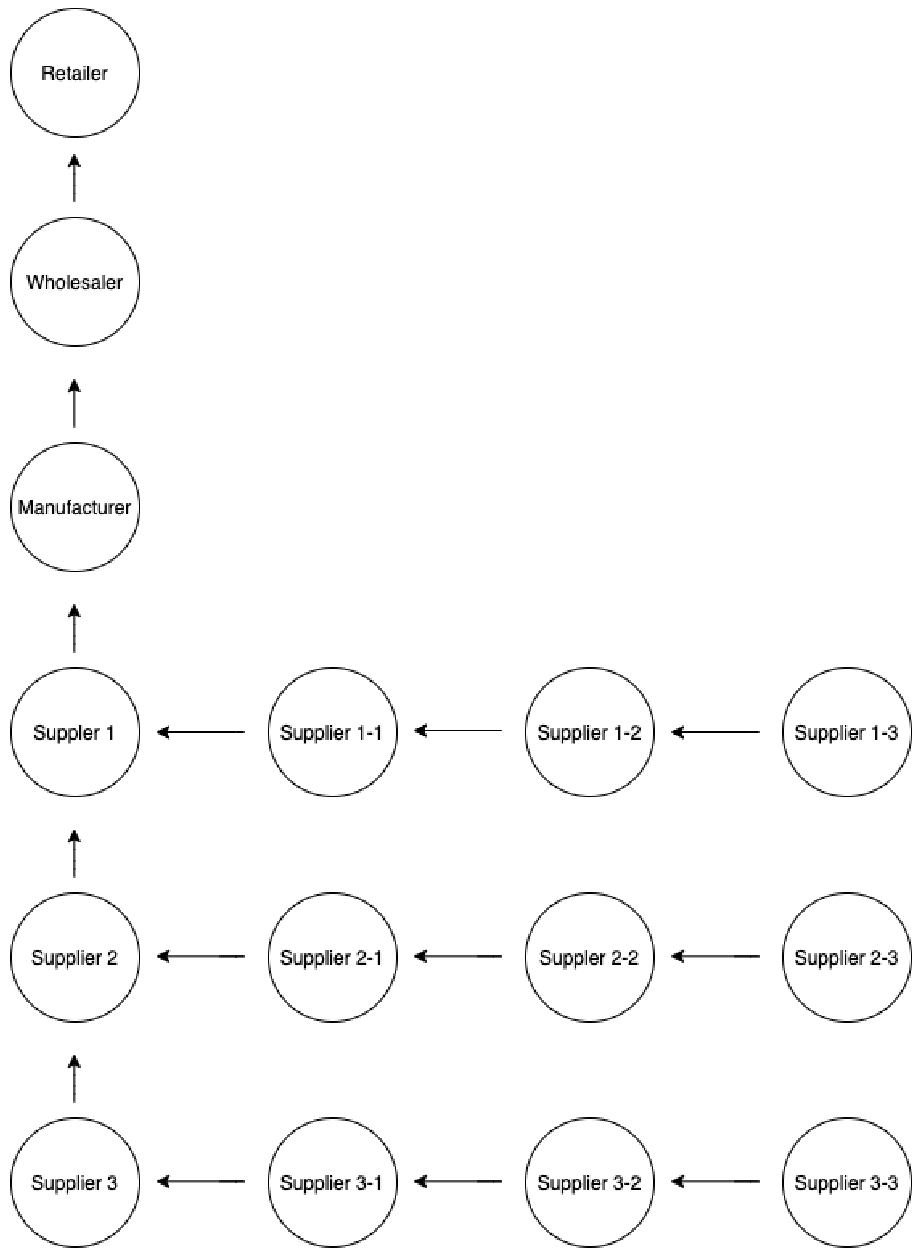
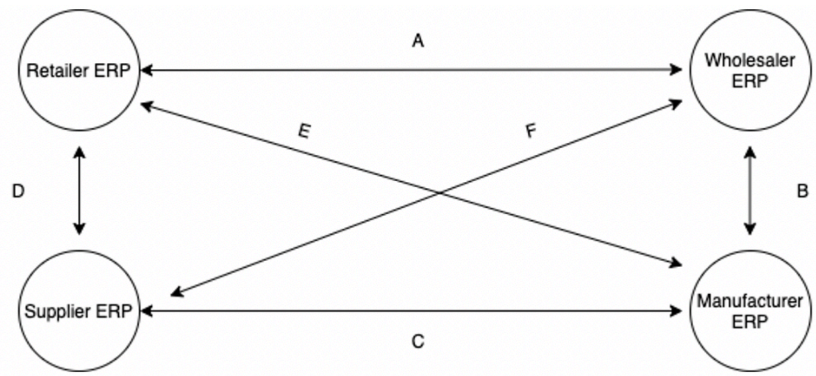


Figure 5: A depiction of the complexity of global supply chains



Member	Read Privileges by Connection	Write Privileges by Connection
Retailer	All	A, D
Wholesaler	A, B, C, D, F	A, B
Manufacturer	B, C, D, E	B, C
Supplier	C, D, F	C, D

Figure 6: A consortium blockchain model to accounting in global supply chains.

A key feature of this design is maintaining a peer-to-peer network connection of all the nodes, while restricting the read and write access of each node to only what they need. The restriction on read and write access can be achieved through multiple means, which is why it not specified, but will likely be performed by using cryptography to secure transactions. The main benefit of this is being able to maintain a single blockchain that can achieve the privacy benefits of having multiple blockchains that flow into one. The encryption from the cryptography can be thought of as placing the transaction inside of two boxes, one that clear, which is then placed inside one that is black. If a node does not have read access, they will not be able to open the black box. If the node has read access, they will be able to unlock the black box, but not able to open the clear one. In this way while they can see the transaction, they cannot alter it. When a node has write access, it will be able to open up the clear box, which is the transaction, and be able to touch it rather than just looking at it. Importantly, in this model nodes can only participate in the consensus process when they can read from the connection. This is because only firms with a stake in the transaction should participate in viewing data about the transaction. The retailer has full read ability because they must monitor the flow of goods from start to finish to have an accurate view of their inventory. This is very different than the supplier who only needs to know about its relations with the retailer and manufacturer. In general, write access is restricted to direct sequential connections, read access expands as you move through the supply chain, and no transactions should occur between nodes not placed sequentially in the supply chain. If an auditor or regulator were to be added to this network, they would be given full read access, but no write access.

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