# The Effect of Blockchain Technology on Supply Chain Sustainability Performances[1]

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**Abstract**

Improving supply chain sustainability is an essential part of achieving the UN's sustainable goals. Digitalization, such as blockchain technology, shows the potential to revolutionize supply chain management. Using distributed ledger technology, the blockchain platform provides a digital system and database to record the transactions along the supply chain. This decentralized database of transactions brings transparency, reliability, traceability, and efficiency to the supply chain management. This paper focuses on such novel blockchain-based supply chain management and its sustainability performances in the areas of environmental protection, social equity, and governance efficiency. Using a systematic literature review and a case study, we evaluate whether the three sustainability indicators can be improved along supply chains based on blockchain technology. Our study shows that blockchain technology have the potential to improve sustainability performance and we expect a continuing popularity of blockchain technology application in supply chain management.



*Keywords: Blockchain; Supply chain; Sustainability; Environmental sustainability; Social sustainability; Economic sustainability; IBM Food Trust; Wal-Mart*

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## 1. Introduction

The COVID-19 pandemic has revealed a general lack of visibility and data exchange with our global supply chains (Nguyen et al., 2020). In an attempt to build a resilient supply chain management, blockchain technology has become a prominent tool, which is a novel technology using distributed and decentralized ledger to trace real-time movement of goods and services in a supply chain, and thus bringing transparent and robust connectivity in the process. The blockchain technology has seen an extensive application among businesses such as financial services (e.g., Ripple and Libra), food and agricultural distributions (e.g., IBM Food Trust and Bumble Bee Foods), healthcare and pharmaceutical supply chains (e.g., ProCredEx and MediLedger), and many others. There is no doubt about the value of blockchain to achieve a reliable supply chain system. Among many others, one major contribution is its potential to promote sustainable development. Our project will focus on the blockchain-based supply chain and evaluates its unique contributions to the three pillars of sustainability – environmental protection, social equity, and economic development.

A central focus of the literature has been conceptualizing the impact of blockchain technology on supply chain management. Yet, less attention has been paid to its impacts on sustainable development (Saberi et al., 2019). We argue that there are two fundamental reasons why focusing on sustainability is important: First, the role of supply chains for a sustainable global economy has become increasingly prominent in recent years. About over 93 percent of the global 250 firms report on sustainability (Ene, 2019). Therefore, sustainability in the supply chain will be imperative. Second, as blockchain technology becomes more popular, it is obvious for the need to document its role in various aspects, such as promoting sustainability. Accordingly, this paper explores the role and impact of blockchain technology on sustainability performance in supply chain management. It analyzes critical sustainability measurements that can be considered to quantify corporate performance through an extensive literature review. The purpose of this project is to (i) document the association of blockchain technology and the three pillars of sustainability, including environmental sustainability (e.g., emissions), social (e.g., public perception), and

economic (e.g., inventory cost), and (ii) to provide a case study showing the contribution of blockchain technology on sustainability in the context of food supply chain.[2]

We propose a two-step framework. First, following a Systematic Literature Analysis approach (Wilding et al., 2012), we take a broad review of the previous studies regarding the association between blockchain-based supply chain and sustainable development. This method provides current studies' trend by finding the proper keywords for collecting the most relevant reviews on our topic. Our proposed analysis includes four key features: (i) blockchain technology in supply chains; (ii) blockchain-based supply chain and social sustainability; (iii) blockchain-based supply chain and economic (governance) sustainability; and (iv) blockchain-based supply chain and environmental sustainability. To explore the quantifiable indicators, we briefly introduce ESG ratings regarding sustainability performance.

Having documented these associations, in the second step, we provide a case study focusing on the collaboration of Wal-Mart and IBM Food Trust. IBM Food Trust program applies blockchain technology into food supply chains to enhance food safety and security. It aims to reduce tracking time, shorten operation process, result in reduction in truck gas consumption, and ultimately make resource planning more efficiently. Our paper aims to shed light on two issues through this case study: first, what is the overall relationship between blockchain technology on the supply chain and sustainability performance? Second, the effectiveness of blockchain technology on supply chains sustainability performance. Our study extends the literature by analyzing the effects of blockchain on the supply chain, emphasizing the sustainability concept. Our analysis provides implications for multi-stakeholders and our society in terms of sustainable development. It suggests directions for a future research agenda that will further quantify sustainability performance.

Our paper proceeds as follows. Section 2 summarizes the background of blockchain technology and the blockchain-based supply chain. In section 3, we introduce the Systematic Literature Analysis method and use it to select a list of articles for later analysis. These articles are described in several ways. Using the method in section 3, we present in section 4 the concepts of sustainability and how the blockchain-based supply chain contributes to the performance of the

[2] The three pillars of sustainability follow United Nation's Sustainable Development Goals (SDG).

three pillars, respectively. In section 5, we study a case study on Wal-Mart's collaboration with the IBM Food Trust Program. We conclude our paper with future directions in section 6.

## 2. Blockchain-based Supply Chain

Blockchain refers to a technology that stores and distributes data based on database among all users who are stakeholders participating in the network (Kamble et al., 2019; Crosby et al., 2016). All participants can access the detailed transaction information in a real-time. In the past, transaction data are stored in a centralized hub system and shared information with direct transaction participants. However, blockchain technology enables people to share all information based on decentralization, security, and smart execution. In other words, all participants can know the transaction details one after another through peer-to-peer networks (decentralization) (Wamba and Queiroz, 2020; Treiblmaier, 2018). Moreover, if transactions are performed by signatures, security is enhanced, and ultimately, transparency is secured. Therefore, if problems occur, they can be cooperatively processed promptly (Security) (Wamba and Queiroz, 2020; Treiblmaier, 2018). Besides, once a transaction recorded in the system with a validated signature given the users, it remains unchanged. This feature is called "immutability." (Kumar et al., 2020). Given all these features, this technology is currently expected to bring benefits to many industries. It greatly influences the supply chains, where information sharing is a key aspect (Song et al., 2019; Benton et al., 2018). This study explores how the blockchain technology impacts on supply chain management and understand the characteristics.

Supply chain management is a process that encompasses the entire process of transporting, storing, and delivering products from the place of production to the final consumers (Aliyu et al., 2018). In this process, the main objectives are to increase efficiency and lower costs. Blockchain technology is expected to bring various advantages to supply chains. Studying on the blockchain-based supply chains is growing (Kim and Shin, 2019). There are mainly two functions that enhance supply chains through this advanced technology; traceability, reliability, and security (Kumar et al., 2020; Song et al., 2019).

### 2.1. Traceability (or visibility)

Given the blockchain-based supply chain environment, real-time location tracking of goods becomes easy. Traceability is defined as the ability to trace all information in a real-time (Benton et al., 2018). For instance, container freight management and document process regarding

transactions can be impacted by the blockchain. Supply chains require to share all information in real-time among all players. All transaction information can be confirmed by relevant participants the movement path of cargo in real-time through blockchain technology (Pournader et al., 2020). Therefore, a blockchain-based supply chain allows for enhancing transparency (Saberi et al., 2019).

### 2.2. Reliability and Security

It is known that the blockchain system can identify not only the priority of supply but also reduce the risk of counterfeit or unlicensed products distributed in the region. This is because blockchain is a record-keeping system (Song et al., 2019; Benton et al., 2018). Many industries, such as the food industry, employ this function to their supply chains based on the blockchain technology (Rogerson and Parry, 2020; Perboli et al., 2018). Particularly, blockchain technology can manage inventory appropriately while tracking cargo and recording and managing cargo history. This makes it possible for consumers to trust the product because anyone who participates in the transaction can share and verify it. Based on these primary functions, supply chain processes and objectives are impacted positively. This study sheds light on two advantages of blockchain-based supply chains: synchronized transaction process (Banerjee, 2018) and cost efficiency (Wamba and Queiroz, 2020; Wong et al., 2020).

### 2.3. Synchronized transaction process

The contract process of supply chains is simplified on account of the blockchain technology. In the past, the contract between the seller and the buyer took a complicated procedure (Hackius and Petersen, 2017). Blockchain eliminates unnecessary and complicated documents through the smart contract. A smart contract refers to a transaction protocol supporting the automated execution and control of documents (Kumar et al., 2020). This system makes a simplified process that all relevant parties are necessary to check the agreement through digitally signed documents within the blockchain system (Pournader et al., 2020).

### 2.4. Cost efficiency

Supply chains are associated with many relevant costs, such as inventory and transportation, affecting the total cost (Ko et al., 2018). Blockchain-based supply chains allow to manage inventory efficiently and help to reduce the costs (Wamba and Queiroz, 2020; Wong et al., 2020).

Logistics covers all processes from the point of departure to the end of the destination, so unnecessary losses are profits. In particular, inventory accounts for the most significant cost, and the supplier needs to periodically forecast demand to produce and purchase inventory in a timely manner (Coyle et al., 2016). If the company has too much inventory than demand, the economic burden will increase with stock-out costs. When operations manage too little inventory, it is required to pay lost sales costs (Perboli et al., 2018). Therefore, the blockchain-based supply chain enhances cost efficiency through traceability and security functions (Benton et al., 2018).

## 3. Method

This study explores the extensive literature of the blockchain-based supply chain with the sustainability concept. We employ systematic literature analysis methods (Wilding et al., 2012) to understand current trend research objectively through the existing literature. This method reduces any bias or error issues by analyzing explanatory and objective review processes (Denyer and Tranfield, 2009). To quantify sustainability in the blockchain-based supply chain, we performed two steps: searching specific keywords and examining academics after 2017. That is because blockchain technology adopted since 2017 in supply chain management.

We first collected the most relevant prior studies by conducting keywords searching in Google Scholar database. The final list of primary keywords includes 'blockchain,' 'supply chain management,' 'Blockchain-based supply chain,' 'sustainable supply chain,' 'sustainability,' 'blockchain sustainable supply chains.' We considered peer-reviewed journal articles, academic books, and business-related news articles through Google Scholar (www.scholar.google.com) and the Web of Sciences from 2017 to 2021. As a result, we refined a total of 22 references.

Table 1 indicates a literature summary on the blockchain-based supply chain with sustainability. The most common keywords are blockchain technology and supply chain management. The most-cited two articles (number 8 and 11), share three keywords: blockchain technology, supply chain management, and sustainability. It suggests that sustainability has been a topical issue on the application of blockchain technology on supply chain management. Considering the sustainability effectiveness through blockchain technology in the supply chains is clearly increasing (see Figure 1), and we expect that this research domain will expand as many companies start adopting the blockchain technology in their supply chains (Anwar, 2020).

| Table 1: Literature Summary | | | | | |
|---|---|---|---|---|---|
| **No** | **Author** | **Year** | **Keywords** | **Journal** | **Google Scholar Citations** |
| 1 | Cartier et al. | 2018 | No Keywords | Journal of Gemmology | 15 |
| 2 | Chang | 2019 | No Keywords | Rutgers University, Doctoral dissertation | 0 |
| 3 | Cole et al. | 2019 | Blockchain Technology; Research Agenda; Operations and Supply Chain Management | Supply Chain Management: An International Journal | 52 |
| 4 | Hastig and Sodhi | 2020 | Supply Chain Traceability Systems; Blockchain; Thematic Analysis; Stakeholders; Business Requirements; Critical Success Factors | Production and Operations Management | 13 |
| 5 | Helo and Hao | 2019 | Blockchain; Distributed Ledger; Operations; Supply Chain; Logistics | Computers & Industrial Engineering | 34 |
| 6 | Hughes et al. | 2019 | Barriers; Blockchain; Information Systems; Literature Review; Opportunities; Sustainable Development Goals (UNSDGs) | International Journal of Information Management | 103 |
| 7 | Li et al. | 2020 | Production Capability Evaluation; Supply Chain Network; Blockchain; IoT; Machine Learning | International Journal of Production Research | 3 |
| 8 | Saberi et al. | 2019 | Blockchain Technology; Supply Chain Management; Sustainability; Barriers; Research Agenda | International Journal of Production Research | 304 |
| 9 | Di Vaio and Varriale | 2020 | Blockchain Technology; Operations Management; Supply Chain Management; Sustainable Performance; Airport Industry; Non-Financial Reports | International Journal of Information Management | 16 |
| 10 | Casey and Wong | 2017 | No Keywords | Harvard Business Review | 126 |
| 11 | Kshetir | 2018 | Auditability; Blockchain; IoT; Network Effects; Supply Chain; Sustainability | International Journal of Information Management | 428 |
| 12 | Kouhizadeh and Sarkis | 2018 | Blockchain; Supply Chain; Green Supply Chain; Use Cases; Applications | Sustainability | 79 |
| 13 | Nikolakis et al. | 2018 | Blockchain; Value Chain; Governance; Sustainability; Smart Contracts | Sustainability | 24 |

| | | | | | |
|---|---|---|---|---|---|
| 14 | Treiblmaier | 2019 | Blockchain; Distributed Ledger Technology; Physical Internet; Logistics; Supply Chain Management; Research Framework; Innovation; Information Technology; Triple Bottom Line; Sustainability | Logistics | 16 |
| 15 | Dayak and Dhaigude | 2019 | Supply Chain Management; Small and Medium Enterprises; Technology Adoption; Multi-Criteria Decision Making; Sustainability | Cogent Economics and Finance | 1 |
| 16 | Son-Turan | 2019 | No Keywords | Blockchain Economics and Financial Market Innovation (Book chapter) | 0 |
| 17 | Venkatesh et al. | 2020 | Blockchain; Social Sustainability; Multi-Tier Supply Chain; Supply Chain Sustainability; Traceability | Robotics and Computer Integrated Manufacturing | 19 |
| 18 | Tan et al. | 2020 | Blockchain; Green Logistics; IoT; Supply Chains | Sustainability | 2 |
| 19 | Bai and Sarkis | 2020 | Blockchain Technology; Transparency; Sustainability; Hesitant Fuzzy Set; Regret Theory | International Journal of Production Research | 17 |
| 20 | Köhler and Pizzol | 2020 | No Keywords | Journal of Cleaner Production | 1 |
| 21 | Nguyen et al. | 2020 | Blockchain; Artificial Intelligence; Security; Privacy; Machine learning; Deep learning; Coronavirus (COVID-19); SARS-CoV-2; Epidemic | TechRxiv | 6 |
| 22 | Kouhizadeh et al. | 2021 | Supply Chain Management; Sustainability; Blockchain; Barrier Analysis; DEMATEL; Technology-Organization-Environment; Framework | International Journal of Production Economics | 0 |

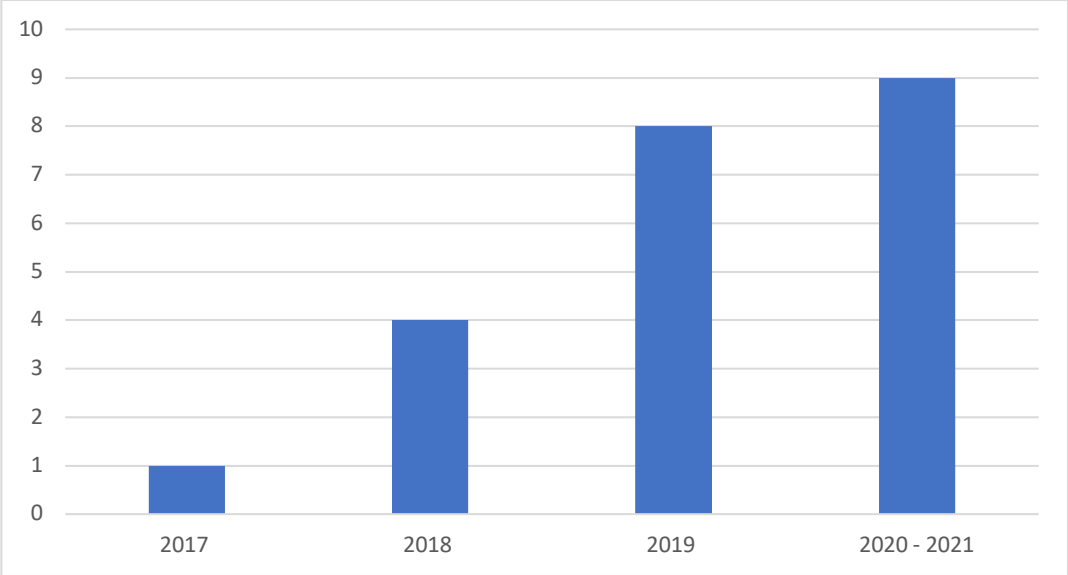


Figure 1. Distribution of published research during the years 2017-2021

## 4. Blockchain-based supply chain and its three pillars of sustainability

### 4.1. Sustainability

The concept of sustainability was first addressed by the World Commission on Environment and Development in 1987 (Brundtland Report, 1987), since then it has evolved to around 300 definitions over several decades' development (Johnston et al., 2007). From the economic point of view, sustainability means that we leave for the future generation "the capacity to be as well off as we are today," quoted from Robert Solow, the 1987 Nobel laureate in economics (Solow, 1991). Consistent with this line of thought, the most universal and widely adopted definition is provided by the United Nations (UN) in 2005, which stylizes the concept of sustainability into three core domains: environmental, social, and economic sustainability, known as the three pillars of sustainability.

The challenges of sustainable development require collective efforts from the public sector and the private sector (people and firms) of society. It becomes critical for firms to ensure the alignment of their business practices with the UN Sustainable Development Goals (SDGs). To this end, the three pillars of sustainability are reflected by firms' Environmental, Social, and Governance (ESG) engagement and performance. The environmental engagement primarily

indicates the costs that a company may have on the environment as a side effect of their business. The main criterion of environmental sustainability includes the utilization of resources, energy efficiency, the amount of waste, level of emission from business activities, and so on (Sarkis, 2002; Saberi et al., 2019). The social performance is mainly concerned with several issues such as workplace health and safety, diversity and equal opportunity, wage gender or racial gaps, and child labor, all of which are part of human rights (Venkatesh et al., 2020). The governance performance is related to the company's long-term success and profit. It also covers the company's internal affairs such as communication among stakeholders (MSCI, 2019). This ESG assessment framework has been broadly discussed and adopted by firms to indicate their sustainable engagement and performance.

Considering the three pillars of sustainability and the ESG framework, this paper is particularly concerned with the supply chains that incorporate blockchain technology and discuss how this novel technology may contribute to the ESG performance. As summarized in Saberi et al. (2019), there is increasing popularity in applying blockchain technology on supply chains. In the rest of this section, we conceptualize each indicator in the context of supply chain management and discuss how the blockchain technology's unique characteristics could improve its ESG performance through supply chains.

### 4.2. Blockchain-based supply chain and environmental sustainability

Environmental sustainability is concerned with inter-generational equity of getting benefits from the natural resources and environmental amenities, drawing significant attention and discussion from academia, industry, and government entities (Seuring and Müller, 2008; Saberi et al., 2019). In the context of supply chains, the environmental sustainability issues arise from both the early phase where raw material resources flow from the natural environment into the process of production and consumption (e.g., nature-economy interaction), and the later phase where pollution generated from economic activities flows to the natural environment (e.g., economy-nature interaction). In the early nature-economy interaction, economic activities could lead to natural resources diminishing and deterioration, and thus jeopardize future generations. In the later phase, the economy-nature interaction is often related to environmental degradation such as water scarcity, air pollution, and soil erosion, affecting humans' well-beings for generations. According to the United States Environmental Protection Agency (EPA), supply chains significantly

contribute to a company's environmental footprint, responsible for approximately 40-60% of a manufacturing company's and 80% of a non-manufacturing company's carbon footprint[3].

The environmental sustainability within supply chains requires adopting optimal management practices of natural resource and environmental protection policies. Sarkis (2002) proposes a strategic decision framework for green supply chain management, highlighting the dynamic nature of business and its relationship to the natural environment. Such a dynamic nature requires a real-time monitoring system to update information for all the participants on the supply chains synchronously. The nature of blockchain technology – traceability, reliability, synchronized transaction process, as well as cost efficiency – makes it an appropriate alternative to traditional corporate policies and practices that are often used to promote environmental sustainability (Saberi et al., 2019). In particular, the blockchain technology can enhance the following two general indicators: (i) Environmental emission abatement. The blockchain technology allows participants on the supply chain to track the location and amount of emission, especially carbon emission, wastewater, or toxic air pollutants from each step and therefore take actions to comply with environmental policies. In addition, each participant can also make sure their upstream partners not violating any environmental policy or law. Under this pressure, the supply chain as a whole will intentionally reduce their environmental emission. (ii) Resource management. The blockchain technology enables monitoring the origins of raw materials, avoiding excessive extraction and utilization of natural resources, and thus helping prevent issues such as salinization or deforestation. Yet, we do not observe any empirical study showing whether and to what extend blockchain technology could maintain a sustainable resource-use rate. (iii) Waste management. The blockchain technology allows businesses to track their waste (Kouhizadeh and Sarkis, 2018), making it possible to recycle or reuse those wastes. For example, IBM Food Trust allows food supply chain to track the amount of waste (Köhler and Pizzol, 2020), which can not only minimize cost to blockchain adopters but also protect environment. It is worth noting that energy efficiency is another area that can be benefited from blockchain technology, but that area is typically beyond supply chain management, so we leave it for future study.

[3] https://www.epa.gov/sites/production/files/2016-09/documents/improving_sustainability_in_supply_chains_091516.pdf, (Accessed on August 25, 2020).

### 4.3. Blockchain-based supply chain and social sustainability

Social sustainability is a framework of maintaining business impacts on employees, workers in an organization, customers, even local communities by supporting a healthy society (Mani et al., 2014; Hutchins and Sutherland, 2008). Despite the increased attention to social sustainability, this pillar is rarely studied in supply chain management (Seuring and Mūller, 2018; Venkatesh et al., 2020) Social sustainability within the supply chains examines social-economic conditions regarding involved stakeholders (e.g., manufacturers, suppliers, customers) involved in the supply chain such as safety, human rights by evaluating products and processes (D'Eusanio et al., 2019; Mani et al., 2016). It especially focuses on how companies develop purchasing decisions with social aspects (Mani et al., 2018). We find the examples and conceptual indirect findings of social sustainability through extensive literature review. Helo and Hao (2019) suggest an example of a socially sustainable supply chain based on a blood diamond, which indicates the exploitation of the child labor and unethical process of the diamond supply chain (Epstein and Yuthas, 2011).

The blockchain-based supply chain potentially devotes to social sustainability (Sabrie et al., 2019). Specifically, Blockchain enables supply chains to maintain stable information, and the 'immutable' feature makes all involved parties in the supply chains protecting corruption for individuals, governments, or organizations. This is because only authorized actors can change the information in the blockchain-based supply chain. Moreover, supply chains procure goods based on reliable suppliers. Blockchain keeps a transparent record of products for the whole process, promoting assurance from ethical suppliers. In the Blockchain-based supply chain context, Cartier et al. (2018) discuss the social issues in the Gem industry. This industry supply chain is growing, especially for the sourcing aspect. Before the blockchain system, the unethical sourcing processes were discussed with human rights. Still, they point out that the blockchain-based supply chain allows building a transparent procedure by verifying supplier's operations. Based on this study, we can suggest the possible quantifiable measurement can be minimum wages involving ethical sourcing (e.g., child labor, human trafficking).

Moreover, the fashion industry unethical sourcing is discussed based on a social point of view (Cole et al., 2019). There are many multi-tier suppliers in this industry, and they do not pursue social sustainability due to their costs. As a result, it leads to damage to their reputation, sales, and even stakeholder wealth (Czinkota et al., 2014). Hence, the blockchain-based supply chain enables increasing visibility by having greater transparency. Hastig and Sodhi (2020) suggest child labor,

rural poverty trap, and standard of living index can be possible measurable indexes to evaluate the blockchain-based supply chain's social sustainability. Helo and Hao (2019) introduce Walmart blockchain with the IBM food trust system to explain one of the social sustainability indicators: safety. All players in the supply chains gain data including farm origin, factory and processing data, expiration dates, and delivery details recorded in the blockchain system. Li et al. (2020) suggest evaluation criteria for social perspective based on the literature review by suggesting working efficiency, work safety, and labor health.

In summary, blockchain secures stable and immutable information, and these features help to enhance the social sustainability and other social dimensions. A transparent information system prevents corrupt all involved participants in the supply chain (e.g., forgery, nefarious participants). Moreover, traceability supports ethical sourcing by having clear information on product history. Thus, the blockchain technology protects human rights and safe and healthy business environments in supply chains (Saberi et al., 2019; Di Vaio and Varriable, 2020).

### 4.4. Blockchain-based supply chain and economic (governance) sustainability

Economic sustainability refers to a status where an economy can achieve steady growth without sacrificing social and environmental sustainability. In the context of corporate and supply chain management, the economic sustainability pillar is often referred to as *governance.* It requires the company to develop a robust management structure that ensures overall transparency, traceability, and accountability, and ultimately can strengthen relations with external stakeholders and attract potential investors (Seuring and Müller, 2008; Nayak and Dhaigude, 2019). Successful sustainable governance offers long term successes to the supply chains, because it can strengthen firms' competitiveness, realize healthy and transparent corporate management, increase profit (Tan et al., 2020), and help the other two pillars' development (Seuring and Müller, 2008). However, it faces a range of challenges in practice. First, information asymmetry among partners along the supply chains could temper the transparency management structure. This is particularly true for the global supply chains partly due to the increased outsourcing (Casey and Wong, 2017). Second, the lack of reliability is another significant concern for the supply chain governance performance, leading to error or corruption issues because of the centralized transaction system (Venkatesh et al., 2020). Last, it is often the case that the traditional supply chain management hardly achieves traceability and reliability at the least possible cost, because it requires a substantial investment and

management effort to monitor and trace the whole supply chain. Although most of the supply chains voluntarily self-regulate themselves, such as the global management system (ISO 14000), it is not a panacea for these challenges.

The factors that drive sustainable governance typically cover two themes: corporate governance and corporate behavior. According to MSCI ESG Research (2019), the former theme can be indicated by board activities; ownership; and accountability. The latter can be indicated by leadership ethics; corruption and instability; and anti-competitive practices; financial system instability; and tax transparency.[4] These indicators are consistent with Hastig and Sodhi (2020), who emphasize that capabilities, collaborations, technological readiness, supply chain practices, leadership, and governance of traceability effort could bring supply chain management success. Based on these factors, we believe that the blockchain technology could improve supply chain governance performance. We illustrate this from three aspects. First, it allows supply chain participants to instantly access accurate and reliable information, making the whole transaction process transparent and fast. Second, it provides a powerful solution to the asymmetry information issue using the smart contract, by which a transaction is made only when every participant agrees to it, bringing symmetry information among upstream and downstream partners and therefore avoid possible corruption or errors (Venkatesh et al., 2020). Last, the historical performance of a supply chain participant such as on-time deliveries or payments can be stored on blockchain, which can be further used to establish trusts and collaborations among stakeholders (Tan et al., 2020).

### 4.5. ESG ratings

Beyond the conceptual assessment of the three pillars of sustainability, ESG ratings is a widely used tool to show the sustainability performance to business leadership, investors, and stakeholders. Hence, they indicate ESG ratings in the sustainability reports such as carbon emission, percentage of the international market, etc. This study suggests measurable indicators in the context of blockchain-based supply chains; we adopt ESG ratings as indicators. There has been a number of ESG rating agencies providing the ESG ratings and scores. Each company has its own criterion and methodology to evaluate the company sustainable engagement and performance. The methodology often involves a comprehensive data collection and assessment model. The most

[4] https://www.msci.com/documents/1296102/14524248/MSCI+ESG+Ratings+Methodology+-+Exec+Summary+2019.pdf/2dfcaeee-2c70-d10b-69c8-3058b14109e3?t=1571404887226 (Accessed on August 28, 2020)

historical ESG ratings are provided by Morgan Stanley Capital International (MSCI), which reports MSCI ESG Ratings to approximately 8,500 companies worldwide by assessing 37 ESG key issues within the three pillars. Another popular ESG Rating is provided by Sustainalytics. It assesses the extent to which a company's enterprise business value is at risk due to environmental, social, and governance concerns. The rating considers an assessment of a company's exposure to industry-specific material ESG issues in addition to an assessment of how well the company is managing those risks. Yet, these ESG performance criteria are often complicated and varying by industries and social norms. Hence, those criteria are unlikely to fully represent the company sustainability assessment process (Escrig-Olmedo et al., 2019). A more detailed explanation of several other ESG ratings is discussed in Huber et al. (2017).

## 5. Case study: Wal-Mart and IBM Food Trust

### 5.1. Background

***Motivation of Wal-Mart blockchain-based supply chain***

Traditional supply chains rely on manual processes, taking a long time to discover unsafe food. Many diseases (e.g., E. coli) appear due to hazardous food for many years. Wal-Mart had massive food scandals related to milk and infant formula across China. Over 300,000 people are affected negatively (Jagati, 2019). Supply chains need to be verified by tracking the source (e.g., origin) to examine food contamination. In this process, it should be quick and accurate to identify the food sources. However, companies involve many suppliers and customers, which leads to overloading information regarding products, prices, workforces, documentation, etc. Wal-Mart found that it takes several days to find the origin of products, and this situation shows their supply chains require improving traceability. In October 2016, Wal-Mart announced a project to track the food distribution process using blockchain technology in partnership with IBM to resolve the traditional burden of processes.

***Pilot project in Wal-Mart food supply chain***

Specifically, Wal-Mart launched tracking pork products in China from origins (e.g., farms) to destinations (e.g., Wal-Mart in China) to increase food safety. Moreover, they started monitoring mangoes from Latin America to the United States, which indicates in the 2017 Wal-Mart Global Responsibility report (Kshetri, 2018). At each step-in delivering food from a supplier to a

consumer, relevant information such as the origin information of the food, batch number, factory, and processing data, and transportation details are recorded on the blockchain in real-time. As a result, Wal-Mart released a significant improvement through a blockchain-based supply chain system related to a package of sliced mangoes. They reduce the tracking time to obtain origin record in Mexico in 2.2 seconds. In the past, it took six days based on a paper record-keeping system (Kshetri, 2018).

***Impacts of blockchain-based supply chains***

After a successful pilot for two products (e.g., pork, mangoes) on food safety through blockchain-based supply chains, Wal-Mart requested all their suppliers of fresh leafy greens to use the blockchain system. Moreover, Wal-Mart expands the blockchain technology to trace the origin such as strawberries, chicken, yogurt, baby foods, etc. with Hyperledger Fabric in 2018 (Mearian, 2018). This result illustrates the blockchain-based supply chain system helps to track that makes improving trust with any involved stakeholders (e.g., suppliers, customers) by getting accurate and transparent information about their origins, processes. This technology allows supply chains to collaborate easier than before for information sharing. Suppliers need to upload data through the blockchain system (The Leadership Network, 2020). Ultimately, enhanced traceability contributes to impact the environmental, social, and governance pillars in their supply chains.

**5.2. The effects on Wal-Mart food supply chain sustainability**

Following the above discussion, our primary goal is to evaluate whether and to what extent the IBM Food Trust program, based on blockchain technology, contributes to sustainability within Wal-Mart's food supply chain. To this end, we concentrate on the 3 most important performance indicators: *food waste management*, *food safety*, and *product health & nutrition*. These three indicators are recognized as the most critical concerns of any food supply chain, as they are highly associated with environmental sustainability through managing waste, social sustainability through protecting consumer welfare, and governance sustainability through minimizing cost.

***Food waste management by blockchain***

Wal-Mart set a waste reduction goal named *Zero Waste* in 2005, aiming to reduce 25% of store waste by 2008, including all types of waste such as cardboard, plastics, metals, food waste, glass,

wood, tenant waste and residual waste.[5] Wal-Mart has been making progress in reducing waste over time, according to its annual sustainability report. However, this achievement was mainly attributed to reducing cardboard, not other types of waste, especially food waste. In 2014, Wal-Mart launched a campaign focusing on reducing food waste, but the target was not meet in 2015. This is mainly because the food waste management tracking system was insufficient to measure and manage accurately.

In response to this challenge, Wal-Mart moved to another target in 2016, *Zero Waste Future*, considering the whole food supply chain from farming to manufacturing to consumers. At the same time, this food waste tracking system has been improved by introducing the IBM Food Trust (blockchain technology) to its food supply chain. IBM Food Trust creates an intelligent system to trace waste from each stage within the food chain, allowing Wal-Mart to accurately judge the remaining shelf life and make appropriate plans to ensure the product's freshness. It enhances the efficiency and effectiveness of managing waste generated along the food chain. It also reinforces environmental sustainability by tracking and recycling the food packages, which are a major source of the waste (Kouhizadeh and Sarkis, 2018). As of the end of 2016, Wal-Mart successfully reduced food waste by 15.3% (Wal-Mart Global Responsibility Report, 2016). [6] Since then, Wal-Mart diverted more than 1.6 billion in 2018 (more than 1.4 billion in 2019) of food waste from landfill globally, receiving the highest score among supermarkets assessed nationwide by the Center for Biological Diversity's food waste study (Wal-Mart Global Responsibility Report, 2019 and 2020). In addition, all waste was reduced significantly after 2016. For example, according to Wal-Mart's annual sustainability report in 2016, Wal-Mart in the US has achieved 82% diversion of materials from landfills and diverted an average of 71% in international markets.

[5] According to Wal-Mart Sustainability Report, achieving the 5 percent goal would be the equivalent of taking 213,000 trucks off the road per year, and saving 323,800 tons of coal and 66.7 million gallons of diesel fuel from being burned.

[6] Wal-Mart measures reductions in food waste by the following: Measurement metric = total weight of non-diverted food in pounds / total weight of all food sold in pounds.

***Food safety, health, and nutrition by blockchain***

IBM Food Trust helps to secure food safety using blockchain technology. Supply chain partners and consumers can access reliable and transparent information on where the ingredients grew, and trace origins and spread if there were any cross-contamination and foodborne illness on the food chains (Köhler and Pizzol, 2020). The availability of this information improves consumer welfare and prevents additional costs for supply chain participants and society. In practice, Wal-Mart attempts to collaborate with upstream partners to ensure accountability, which relies on efficient communication among supply chain partners. In 2017, Wal-Mart collaborated with IBM and Tsinghua University to promote food safety by a blockchain-powered traceability system in China, following a similar application of blockchain technology to the leafy product Wal-Mart US in 2018. Based on the Wal-Mart Global Sustainability Report, food safety issue has been improved significantly after these two initiatives.

The blockchain technology also brings transparency and visibility to food supply chains, making life-cycle information of a product from farm to table transparent. Consumers can learn any information about the ingredients and its origins of any product in seconds, providing a great opportunity for consumers to learn health and nutrition knowledge.

**5.3. The effects on Wal-Mart overall sustainability**

We further investigate whether the IBM Food Trust program promotes Wal-Mart's overall sustainable performance. Wal-Mart has reported its approaches and assessments on environmental, social, and governance performance since 2005. The report covers a series of topics, including its ESG goals, commitments, initiatives, approaches, and progresses. Overall, the ESG performance gets improved over time, especially after 2016, when the IBM Food Trust program was first introduced to its food supply chain. To eliminate any biases, we also collected the ESG scores between 2014 and 2020 from the CSRHub Ratings (www.csrhub.com). CSRHub collects data from ESG analysis firms, NGOs, government databases, publications, and research report, which are further transformed into a 1 to 100 scale, with 100 as the best rating. The time trend of four indicators for Wal-Mart Stores, Inc. is shown in Figures 2-6. In general, it is consistent with Wal-Mart's self-evaluations reported in the annual responsibility report. The overall ESG Ratings were jumped after the second quarter of 2016, and then gradually climbing up until 2019 when there was another slight increase.

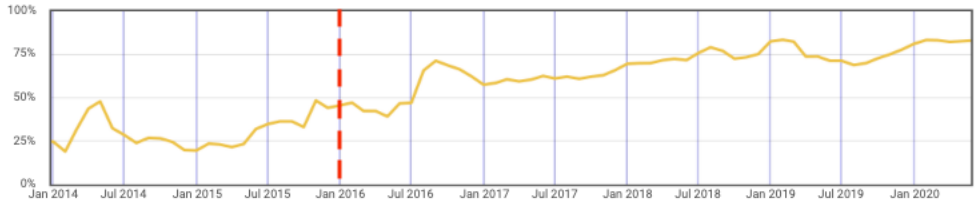


Figure 2: Wal-Mart overall ESG rating between 2014 and 2020


Figure 3: Wal-Mart environmental sustainability rating between 2014 and 2020

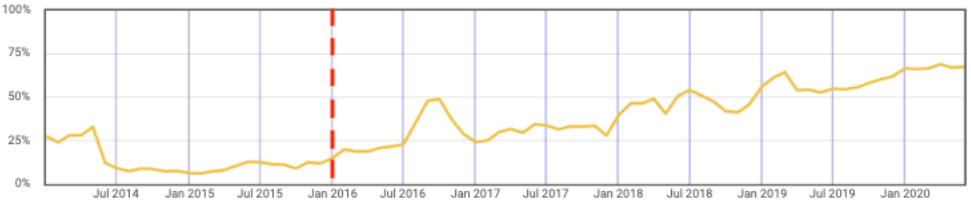


Figure 4: Wal-Mart social sustainability rating (employee) between 2014 and 2020

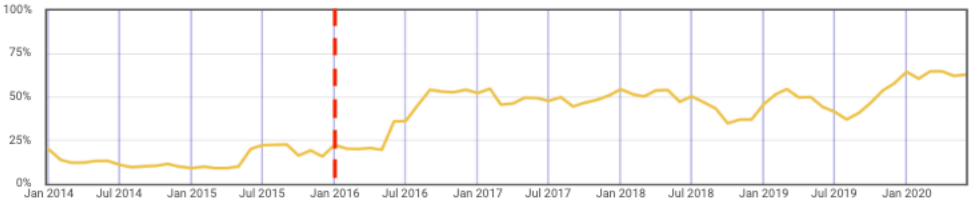


Figure 5: Wal-Mart social sustainability rating (community) between 2014 and 2020

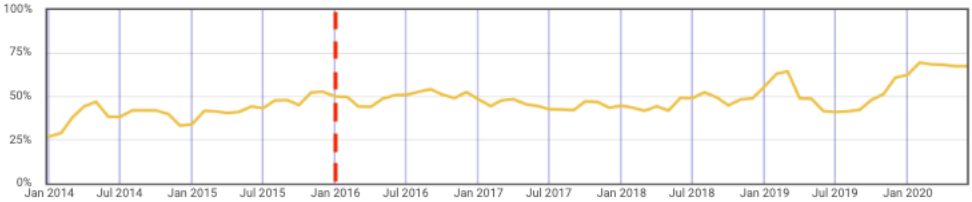


Figure 6: Wal-Mart governance sustainability rating between 2014 and 2020

## 6. Conclusions and future directions

Improving supply chain sustainability is an essential part of achieving the UN's sustainable goals. Digitalization, such as blockchain technology, shows the potential to revolutionize supply chain management. Using distributed ledger technology, the blockchain platform provides a digital system and database to record the transactions along the supply chain. All the information is agreed upon and then shared among supply chain actors. This decentralized database of transactions brings transparency, reliability, traceability, and efficiency to the supply chain management.

This paper focuses on supply chain management and its sustainability performances in the areas of environmental protection, social equity, and governance efficiency. We assess the extent to which the three sustainability indicators can be improved along supply chains based on blockchain technology. In light of three bodies of literature, i.e., sustainability, supply chain management, and blockchain-based supply chain, we assemble the studies using the systematic literature analysis. We find that studies focusing on the impact of blockchain technology on sustainability is continuously increasing in recent years, claiming a positive impact of blockchain platforms on sustainability. In addition, we provide a case study on how supply chains can take advantage of the blockchain technology by focusing on the collaboration between Wal-Mart food supply chain and IBM Food Trust. We investigate Wal-Mart's annual sustainable performance report and external ESG ratings before and after they adopt IBM Food Trust. We show that the blockchain technology improves the waste management and provides food safety, health, and nutrition along Wal-Mart food supply chain. This evidence suggests that we could use the potential quantifiable sustainability indicators (ESG ratings) for the future study.

A future study could be examined in several directions. Our collected articles are limited by collecting the most relevant research, thus containing a subjective view regarding the blockchain-based supply chain and sustainability. We can extend the more relevant research articles to reduce bias. Moreover, we collected the data of ESG ratings, primarily focused on the Wal-Mart cases. However, this case cannot be a representative case. Recently, many companies adopting blockchain technology in their supply chains (e.g., Ford, Unilever) not only in the food industry but also in many industries such as healthcare (e.g., CDC, FDA) (Anwar, 2020). Our study can be extended by performing additional case study to suggest quantifiable sustainability indexes with the context of blockchain-based supply chains. Considering other stakeholders' perspectives (e.g., suppliers, distributors, and end-customers) can be part of the future study. This

study confined only company level (e.g., Wal-Mart). However, a prospective study can suggest designing blockchain-based sustainable supply chains in more effective ways by considering other stakeholders' effectiveness (Nikolakis et al., 2018). Finally, though this study and the majority literature focus on the three pillars of sustainability separately, they are very likely to reinforce each other. Future work might consider the interacting effects of the three pillars of performances.

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**Bibliography**

**Dr. Arim Park**

Dr. Arim Park is currently an assistant professor of Marketing and Supply Chain Management at North Carolina Agricultural and Technical State University. She graduated from Rutgers University, where she earned her Ph.D. degree in Management (Supply Chain Management) in 2019. Her research interests include supply chain analytics, e-commerce, blockchain, transportation, logistics, among others. Her research has appeared in the *Journal of International Logistics and Trade*.

**Dr. Huan Li**

Dr. Huan Li is an Assistant Professor of Economics at North Carolina Agricultural and Technical State University. She received her Ph.D. in Economics from State University of New York at Binghamton in 2015. Dr. Li's research is in environmental economics, with special focuses on environmental sustainability, environmental policy effectiveness, and environmental justice. Some of her research has been published in the *Journal of Law and Economics, Journal of Regulatory Economics*, and *Ecological Economics*.

# Arim Park

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## ACADEMIC EMPLOYMENT

Assistant Professor of Marketing and Supply Chain Management, August 2019 – Present
North Carolina A&T State University, Greensboro, United States

Part-time Lecturer, Rutgers, The State University of New Jersey, Spring 2017-Fall 2018
Newark, United States

## EDUCATION

Rutgers, The State University of New Jersey, Newark, United States September 2014 – July 2019
*Ph.D. in Management (Supply Chain Management)*
*Dissertation: "Designing Electronic Marketplaces for the Freight Services"*

Inha University, Incheon, South Korea February 2013
*Master of Science in Logistics**, Summa cum laude***

Inha University, Incheon, South Korea February 2011
*Bachelor of Logistics*

## RESEARCH INTERESTS

Supply Chain Management, Transportation, Service Operation, Business Analytics, E-commerce

## PUBLICATIONS

**Park, A**., Ha, H. (2013), Comparative Analysis of Methodologies to Evaluate Air Cargo Carriers' Service Quality: Focusing on SERVQUAL and SERVPERF, *Journal of International Logistics and Trade.* Volume 11, Number 2, pp.26-46

**Park, A**., Cho, S., Kim, S., & Zhao, Y. (2019). Factors Influencing E-procurement Adoption in the Transportation Industry. In 2018 *INFORMS International Conference on Service Science* (pp. 287-293). Springer, Cham.

## SUBMITTED AND UNDER REVIEW

Song, J., **Park, A**., Zhao, Y. Hunger Chain – A competitive Supply Chain Simulation, *Decision Sciences Journal of Innovative Education.*

**Park, A**., An, H., Song, J., Chung, C., Please Do Not Disturb: The Effect of Zero-Contact Marketing on Consumers' Decision-Making Process, *Asia Pacific Journal of Marketing and Logistics.*

## WOKRING PAPERS

Chen, R., Cho, S., Park, A., and Zhao, Y. Critical Success Factors Required to Develop Digital Freight Matching in the Transportation Market, (*all authors contributed equally and are presented in alphabetical order*)

Park, A., Cho, S., Rodgers, M., and Zhao, Y. Toward Sustainable Transportation Services: Ensuring Equitable Work Distribution for Independent Truckers.

Park, A., Kim, S. The Impact of Supply Chain Justice on Truck Driver Safety

Cho, S., Li, P., Park, A., and Zhao, Y. Toward a Better Online Platform Review: Do Customer Reviews Need to be Compensated? (*all authors contributed equally and are presented in alphabetical order*)

Li, H., Park, A. The Effect of Blockchain Technology on Supply Chain Sustainability Performances, (*all authors contributed equally and are presented in alphabetical order*)

## CONFERENCE

**Do Not Disturb: The Effect of Zero-Contact Marketing on Consumers' Decision-Making Process**
- 2020 Atlantic Marketing Association (accepted, *scheduled*)

**Toward a Better Online Platform Review: Do Customer Reviews Need to be Compensated**
- 2020 DSI Annual Meeting (accepted, *scheduled*)
- 2020 INFORMS Annual Meeting (accepted, *scheduled*)
- 2019 DSI Annual Meeting (invited)
- 2019 INFORMS Annual Meeting (invited)
- 2019 Rutgers Research week

**Designing Electronic Marketplaces for Transportation Services-A Framework to Ensure Market Balance**
- 2020 Willie A. Deese College of Business and Economics
- 2019 2018 INFORMS Annual Meeting (invited)
- 2018 DSI Annual Meeting

**Critical Success Factors Required to Develop Digital Freight Matching in the Transportation Market**
- 2017 INFORMS Annual Meeting
- 2017 2018 POMS Annual Meeting
- 2018 DSI Annual Meeting

## INVITED TALKS

Inha University, Graduate School of Logistics, South Korea — December 2019

## TEACHING EXPERIENCE

**Introduction to Supply Chain Management,** Undergraduates, North Carolina A&T State University, Willie A. Deese College of Business and Economics. — Summer 2020- Present

***Online***

- Summer 2020, Instructor rating: **4.73**/5, Department Average: 4.52
  (Rating includes 10 of the 13. undergraduate students)

**International Logistics and Supply Chain Management,** Undergraduates, North Carolina A&T State University, Willie A. Deese College of Business and Economics — Fall 2019 – Present

- Spring 2020, Instructor rating: **4.29**/5, Department Average: 4.21
  (Rating includes 10 of the 13. undergraduate students)
- Fall 2019, Instructor rating: **4.43**/5, Department Average: 4.19
  (Rating includes 16 of the 19. undergraduate students)

**Materials Management,** Undergraduates, North Carolina A&T State University, Willie A. Deese College of Business and Economics — Fall 2019 – Spring 2020

- Spring 2020, Instructor rating: **4.88**/5, Department Average: 4.21
  (Rating includes 8 of the 9. undergraduate students)
- Fall 2019, Instructor rating: **4.34**/5, Department Average: 4.19
  (Rating includes 20 of the 24. undergraduate students)
  -*The Shell Oil Case Competition coordinator*

**Business Logistics and Transportation**, Undergraduates, Rutgers Business School — Spring 2017-Fall 2018

- Fall 2018, Instructor rating:**4.48**/5.0 Course rating: **4.50**/5.0
  (Rating includes 36 of the 43. undergraduate students)
- Spring 2018, Instructor rating:**4.31**/5.0 Course rating: **4.36**/5.0
  (Rating includes 36 of the 43. undergraduate students)
- Fall 2017, Instructor rating:**4.13**/5.0 Course rating: **4.22**/5.0
  (Rating includes 32 of the 36. undergraduate students)
- Spring 2017, Instructor rating:**4.42**/5.0 Course rating: **4.45**/5.0
  (Rating includes 33 of the 39. undergraduate students)

## HONORS & AWARDS

| | |
|---|---|
| Professional Development Grant, Willie A. Deese College of Business and Economics, North Carolina A&T State University | 2020 |
| Rutgers GSGA Travel Award, Rutgers University | 2019 |
| The Dean's Fund for Summer Ph.D. Research Assistants, Rutgers University | 2018 |
| Global Leader Pre-College Scholarship for Doctoral Degree, Inha University *(All expense included such as tuition, living expense)* | 2014-2017 |
| Newark Graduate Dean's Award, Rutgers University | Fall 2017 |
| The Dean's Fund for Summer Ph.D. Research Assistants, Rutgers University | 2016 |
| Honorable Mention for Paper Presentation, Ministry of Land Infrastructure and Transport, South Korea | 2013 |
| Honorable Mention for Paper Presentation, Ministry of Land Infrastructure and Transport, South Korea | 2012 |
| Global Leader Pre-College Scholarship for Undergraduate and Master, Inha University, South Korea | 2007–2013 |

## UNIVERSITY SERVICES

Faculty Advisor of Student Organization, North Carolina A&T State University — Fall 2019-Present

- Supply Chain Aggies, Department of Marketing and Supply Chain

## TECHNICAL SKILLS

STATA, SPSS, R, AMOS, CPLEX, GAMS, and Python

## PROFRESSONAL AFFILIATIONS

Institute for Operations Research and Management Sciences (INFORMS) — 2014 - Present

| | |
|---|---|
| Production and Operations Management Society (POMS) | 2014 - Present |
| Decision Sciences Institute (DSI) | 2018 - Present |

## PROFRESSONAL ACTIVITIES

| | |
|---|---|
| Designing Effective Online Course - ***Certification*** | July 2020 |
| 1ST Online Doctoral Workshop on Supply Chain Analytics | May 2020 |
| (ONLINE) Easy Video Editing | May 2020 |
| (ONLINE) Teaching Online | May 2020 |
| (ONLINE) Reduce Cheating During Online Exams | April 2020 |
| (ONLINE) Introducing Collaborate Ultra | April 2020 |
| 2020-2021 RPT, PTR Process Workshop | April 2020 |
| Endnote® Citation Management Basics | March 2020 |
| Grant Writing vs. Academic Writing | February 2020 |
| 2020 NRF Foundation Student Program Conference, Instructor for teaching | December 2020 |
| Mentoring/Coaching Workshops | November 2019 |
| Email Etiquette and Communications | November 2019 |
| Chrome River Training | September 2019 |
| CL-112 Digital Measures | October 2019 |

## REFERENCES

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## ACADEMIC APPOINTMENTS

Assistant Professor of Economics, NC A&T State University, August 2019 – present

## PREVIOUS APPOINTMENTS

Visiting Assistant Professor of Economics, Binghamton University, August 2018 – May 2019
Postdoc Fellow, Agricultural Economics Department, Purdue University, August 2015 – May 2018

## EDUCATION

Ph.D. Economics, State University of New York at Binghamton, 2015

## RESEARCH FIELDS

Primary: Environmental Economics and Justice
Secondary: Urban and Regional Economics

## PUBLICATIONS

1. Chen, D. & **Li, H.**. (2020). Money Supply and Exports: A Greater Mekong Subregion Perspective. *Journal of Academy of Business and Economics*, (Outstanding Research Paper Award, IABE-2020)
2. **Li, H.**, & Khanna, N. (2018). Does Voluntary Self-Regulation Provide Regulatory Relief? A Lesson from the Responsible Care Program in the United States. *The Journal of Law & Economics*, 61(1), 63-96.
3. **Li, H.**, Khanna, N., & Vidovic, M. (2018). The Effects of Third Party Certification on Voluntary Self-regulation of Accidents in the US Chemical Industry. *Journal of Regulatory Economics*, 53(3), 327-356.
4. **Li, H.**, & Carrion-Flores, C. E. (2017). An Analysis of the ENERGY STAR Program in Alachua County, Florida. *Ecological Economics*, 131, 98-108.

## UNDER REVIEW

1. "The Environmental Injustice of the COVID-19 Pandemic: Evidence from New York State" with N. Khanna and R. Zhang
2. "Firm Behavior Under Unanticipated Change in Regulation: Power Plant Emissions During the 2018 – 2019 Federal Government Shutdown," with N. Khanna and R. Zhang
3. "An Application of Spatially Harmonized U.S. Socioeconomic Database: A Case Study of Chicago" with I. Kumar, Y. Kim, L.Beaulieu, M. Delgado, R. Florax, T. Hertz, T. Smith, B. Waldorf, M. Wilcox, and A. Zhalnin
4. "Satellite Detection of Air Pollution: Air Quality Impacts of Shale Gas Development in Pennsylvania," with R. Zhang, N. Khanna, D. Sullivan, A. Krupnick, & E. Hill

## WORKING PAPERS

1. "The Effect of Blockchain Technology on Supply Chain Sustainability Performances," with A. Park

## GRANTS & AWARDS

1. PI, Food Deserts and Food Security among Seniors in the United States. NC A&T State University Seed Grant Award. ($5,000, 2020, current status: funded)
2. Senior Personnel (PI: Liang, C.), Building a Sustainable and Equitable Information Network to Reduce Gaps in Agricultural Systems. Sustainable Agriculture Research and Education. ($1 million, 2020, current status: LOI submitted)
3. Funded Professional Activity, Inter-university Consortium for Political & Social Research, University of Michigan. ($1,250, 2016, awarded)
4. Award for Research Excellence in Sustainable Communities Trans-disciplinary Area, Binghamton University, ($1,000, 2014, awarded)
5. Travel Award for Young Professional and Graduate Student, American Agricultural Economic Association, ($400, 2014, awarded)

## CONFERENCE

2020 Invited Panelist by NAREA–"Advice on Engaging with the COVID-19 Crisis through Our Work"

Association of Environmental and Resource Economists (AERE) Virtual ×2;

Northeastern Agricultural and Resource Economics Association (NAREA) Virtual ×2;

Western Economic Association International (WEAI)-AERE Virtual*;

American Agricultural Economic Association (AAEA) Virtual;

Southern Economic Association (SEA)

2019 AAEA, Atlanta, GA*;

NAREA, Portsmouth, NH*

2018 Invited by RUPRI–Rural Poverty Fifty Years After *The People Left Behind*, A Research Conference Looking Backward and Forward, Washington DC;

IBM Blockchain Workshop Certification, Binghamton University, NY;

Heartland Environmental and Resource Economics Workshop, UIUC, IL**

2017 AERE, Pittsburgh, PA

2016 Workshop of China Multi-generational Panel Datasets, UCLA, CA**;

NARSC Special Sessions of Poverty: People, Places, and Policy, Minneapolis, MN;

Advanced Topics in Space, Health and Population Economics Seminar, Purdue University, IN

2015 Applied Economics Regional & Urban Studies, Graduate Student Summit, UIUC, IL

Advanced Topics in Space, Health and Population Economics Seminar, Purdue University, IN

2014 SEA – AERE Session, Atlanta, GA;

AAEA, Minneapolis, MN;

Eastern Economic Association (EEA), Boston, MA

*paper presented by collaborator; **participated as an attendee

## TEACHING

- *At NC A&T State University*

  *Course #1: ECON 200 – Principles of Microeconomics:*

  Fall 2019 (4.35/5.00; 4.23/5.00); Spring 2020 (4.45/5.00; 4.43/5.00; 4.37/5.00);

  Fall 2020 (scheduled)

  *Course #2: ECON 485 – Special Topics of Economics: Environmental Economics*

  Fall 2020 (scheduled)

- *At Purdue University*

  Advanced Topics in Space, Health and Population Economics: Fall 2017, Spring 2018

- *At Binghamton University*

  Advanced Environmental Economics: Fall 2018, Spring 2019

  Principles of Microeconomics: Fall 2018, Spring 2019

  Development Economics: Fall 2014, Summer 2014

  International Economics: Fall 2013

- *Teaching Assistant at Binghamton University*

  Environmental and Natural Resource Economics: Spring 2014

  Principles of Macroeconomics: Spring 2013

  Advanced Microeconomics Theory; Game Theory – *PhD course*: Fall 2012

## SERVICE

- *To the Discipline:*

  Master's Thesis Award Committee, Northeastern Agricultural and Resource Economics Association 2020-2023

  Invited Panelist by NAREA–"Advice on Engaging with the COVID-19 Crisis through Our Work"

  Journal referee for: Journal of Regulatory Economics

  Conference referee, American Agricultural Economic Association Environmental and Natural Resources Economics Section and Econometric Section 2017, 2018

- *To the Department and University*

  Economics Curriculum and Course Revision Committee, 2019

  Co-advisor, Aggie Economic Association, 2020

## MEMBERSHIP

American Economic Association; Association of Environmental and Resource Economists; American Agricultural Economic Association; Southern Economic Association; Northeastern Agricultural and Resource Economics Association; Omicron Delta Epsilon (O$\Delta$E) Faculty Member