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Can Blockchain-Supply Chain Announcements Create Shareholder value? Evidence from an Event Study for International Initiatives

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BY ALYAA SALEH

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DR. SHERWAT ELWAN

December 28, 2021

Declaration of Authorship

I, Alyaa Saleh, declare that this thesis titled, "Can Blockchain-Supply Chain Announcements Create Shareholder value? Evidence from an Event Study for International Initiatives " and the work presented in it are my own. I confirm that:

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- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
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Abstract

This study investigates how Blockchain based Supply chain (BC-SC) announcements impact the stock market performance of the announcing firms. Using a sample of 104 news and firm announcements between 2016 and July 2021, we conduct an international event study to determine the effect of BC-SC announcements on the market performance. We find that an overall significantly positive market reaction of 1.45% to all BC-SC announcements on the announcement day. In addition, we find that the stock market reaction slightly differs when different SC challenges are targeted by the announcing firm. When blockchain is used for traceability purposes, the market response is less positive when compared to other SC challenges like resolving disputes , maintaining Cargo Integrity and Data security. We further find that firms that are part of BC industrial collaborations experience a more positive stock market response, when compared to firms using private or public BC networks. When looking into firm characteristics, we find that innovative firms experience greater positive reaction to BC-SC announcements. Interestingly, smaller firms, in terms of market capitalization, as well as early adapters of BC do not experience a strong positive market response. Leveraging the diverse industries in our sample, we investigated the market response of early & late adaptors with respect to their corresponding industry. Our findings suggest that late adaptations of BC-SC in the manufacturing industry only, are received with a significant positive response on the market.

Contents

List of Figures

Chapter 1

Introduction

Blockchain is usually associated with financial decentralization conversation, which includes electronic currencies like Bitcoin, Ethereum etc. However, the general concept of having a shared, open and distributed ledger that can help store/record data and transactions backed by a cryptographic value across a peer-to-peer network, introduces endless applications in various fields to that conversation. Applications include but are not limited to, designing smart contracts to track frauds in finance or securely share medical records between healthcare professionals. One of the blockchain applications that have been extensively researched since early 2017 is using blockchain technology to enhance supply chains. The key useful features that make Blockchain of an edge for supply chains include, the fact it's a digital shared ledger which is distributed over the network. Once the records are added they unalterable (unless the consent of all/majority of involved parties is provided), commencing extensive data security to business operations. Also, Blockchain brings end to end traceability of the supply chain to the next level. In a supply chain, blockchain can be used to track who is doing what as well as the timing and place of the activities. So, when the Blockchain ledger is updated by all entities in the supply chain, with info like: GPS location, bar code, radio-frequency identification (RFID) Tag, shipping containers...etc, an enriched real-time tracking system will be accessible to all entities to track goods at every step. Such system enables efficiency and cost reductions by eliminating intermediaries like auditors. For instance, suppliers can perform their own checks and balances on a real time basis without an auditor in the process. (Gurtu and Johny, 2019)

The effect of adapting blockchain technology in supply chains have been analysed mostly using qualitative approaches. In a systematic literature review paper, (Chang and Chen, 2020) concluded that the research methodologies used when addressing the use of blockchain for supply chains, are mainly qualitative or explanatory (e.g. case studies, proof of concept (POC), theory building, and literature reviews, etc) and instead few quantitative studies are allocated in the sample as blockchain is considered an emerging information technology. In another literature review paper, (Nabipour and Ülkü, 2021) concluded that "there are substantial shortcomings in both the empirical and quantitative methods". This conclusion was reached by systematically analyzing 72 journal papers covering the adaption of blockchain for supply chain purposes particularly during COVID-19 pandemic. Although, this thesis is not covering pandemic period in particular, the conclusion of the study is important to the scope of our research and the selected methodology accordingly. In (Nabipour and Ülkü, 2021) study only 6 out of 72 papers were analyzing the impact of adapting blockchain technology using quantitative approaches.The majority of the literature was focusing on explaining potential benefits and challenges of the technology relative to a certain industry or region. Thus, the identified gap is: there are no general studies conducted so far addressing blockchain financial effectiveness upon supply chains adapting it. To address this gap, test and validation to the following research questions will be conducted:

- Do announcements of Blockchain based Supply Chain (BC-SC) initiatives lead to a significantly positive increase in stock prices of firms taking the initiatives?
- Which firms benefit considerably from the announcements related to Blockchain Supply Chains?

1.1 Organization of the thesis

This thesis presents some quantitative work and contributions in the area of Blockchain based Supply Chain (BC-SC) and how initiatives associated with it impacts listed firms. The thesis is organized as follows:

- Chapter (2) presents a literature review of Blockchain (BC) Technology and Supply Chains (SC) key challenges.
- Chapter (3) discusses the research methodology followed to filter and collect sample. As well as, the details of the event study approach.
- In Chapter (4), the empirical analysis and results of the event study as well as the conducted Cross-sectional regression are discussed in this chapter
- Chapter (5) we provide the conclusions of this thesis ,propose some managerial implications and directions for future research.

1.2 List of contributions of this thesis

- We introduce an empirical event study to evaluate the impact of Blockchain based Supply chain (BC-SC) announcements on the announcing firms' stock prices.
- We provide empirical evidence that among the SC challenges, there are different market reactions when BC usage is announced as a novel solution to over come these challenges.

- We compare the market reaction with respect to the type of BC solution used for Supply chain Management (SCM).
- To study the impact of firm characteristics on the BC-SC market reaction, we exploit how firm size, innovation intensity and early adaptation of BC technology could affect the overall performance of the firm from a shareholder's wealth point of view.

Chapter 2

Literature Review

2.1 Overview on Blockchain Technology

2.1.1 Origin and History of Blockchain

This section provides general information about blockchain technology and its associated features, as well as the relation between the characteristics of this technology and cryptocurrencies particularly the well-known bitcoin.

In 2008, a person known by pseudonym "Satoshi Nakamoto" introduced two ideas that have had extensive influence and provided an enormous opportunity for additional innovation. The first idea was the notion of blockchain (Nakamoto, 2008), which is defined as a public ledger that uses a peer-to-peer approach to capture a database of transactions with an 'append' only approach that enhances data security among the distributed databases. In other words, an entity can only add new data in the form of additional blocks, which will then be chained together with previous blocks of data. The second idea was 'Bitcoin', a peer-to-peer and decentralized currency that does not have any government or other central backing. From 2008 onward, bitcoin usage has been widely growing. The market cap of bitcoin now reached $1 trillion dollars (Statista, 2021), and is used by millions of people for payments, including a large and growing remittances market. Also, the realization that the underlying technology behind bitcoin could be separated from the currency, especially after the bitcoin hype,and that it can be used for inter-organizational purposes has introduced blockchain technology to multiple industries like pharmaceuticals, food and auto - manufacturing industries. (Vinod Kumar, Sriman Narayana Iyengar, and Goar, 2021a)

Multiple commentators perceive smart contracts as the 2.0 version of the blockchain. The concept was introduced by Vitalik Buterin in 2014 in his white paper (Buterin, 2014). It is similar to that of Bitcoin Blockchain, in the sense that it is decentralized. However, the added feature is the ability to develop decentralized applications (DAPPS) and more importantly write smart contracts (Christidis and Devetsikiotis, 2016). Smart contract is a form of digital agreement through an autonomous code which executes when the specified conditions are met. These smart contracts are powered by EVM (Ethereum Virtual Machine) and written in a programming language known as "Solidity"(Christidis and Devetsikiotis, 2016).

Figure 2.1 shows an overall timeline of the history of blockchain,revealing how multiple applications rise after the origination of both cryptocurrencies like Bitcoin and Ether as well the origination of smart contracts.

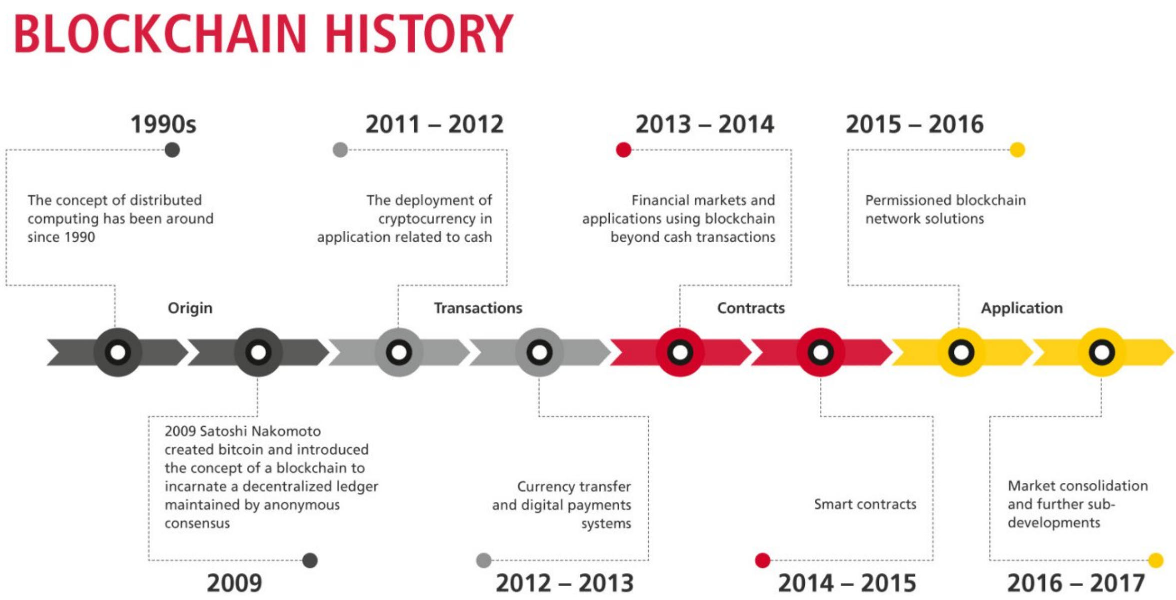

FIGURE 2.1: History of Blockchain (Vinod Kumar, Sriman Narayana Iyengar, and Goar, 2021b)

2.1.2 Blockchain Workflow

The mechanism of data flow is one of the main edges of blockchain as it is the factor that ensures transparency and security of data entries. The typical blockchain system is outlined in Figure 2.2. The flow begins when ***two parties enter into contract*** usually via smart contract arrangement. Eventually, this ***transaction is represented as a block***. Each block in the blockchain has a hash number (256 bit), which is created with consent by a scientific algorithm(Nakamoto, n.d.).The block includes the movement of an asset that can be tangible (a product) or intangible (intellectual data). This provides means of securely recording the needed information like for example: who, what, when, where, how much and even the condition — such as the temperature of a food shipment. The ***block is then broadcasted to the network***, forming a chain of data as the asset changes location or ownership entity providing details about: the exact time and sequence of transactions. Thus, each block is connected to the ones before and the ones after it preventing any block from being altered or a block being inserted between two existing blocks. Validating the blocks before broadcasting them on the network is the key of the workflow, this validation relies on the fact that all the transactions (blocks) are linked together in an irreversible chain. Thus, each added block strengthens the verification of the previous ones and hence the entire blockchain. This removes the chances of having a malicious actor tamper with the ledger of transactions, creating the "immutability" factor of blockchain solutions. From supply chain management prospective, multiple details can be added securely during a certain transaction (in other words, in a single ***block)***. Figure 2.2 shows an example of the kind of data that could be stored on a block in simple supplier-buyer transaction. Information like certification of Origin, batch number and production data can be added by the supplier and automatically verified against agreed specs and conditions on the smart contract. Similarly, triggers for other transactions will take place once key milestones are achieved, for instance: goods being issued (creates a shipment order), or once pickup is confirmed (a sensor is triggered or a proof delivery (invoice) is issued). This takes place automatically without the use of any paperwork or intermediary entities. In addition, smart contracts can trigger automatic payments, if cryptocurrencies are part of the business model.

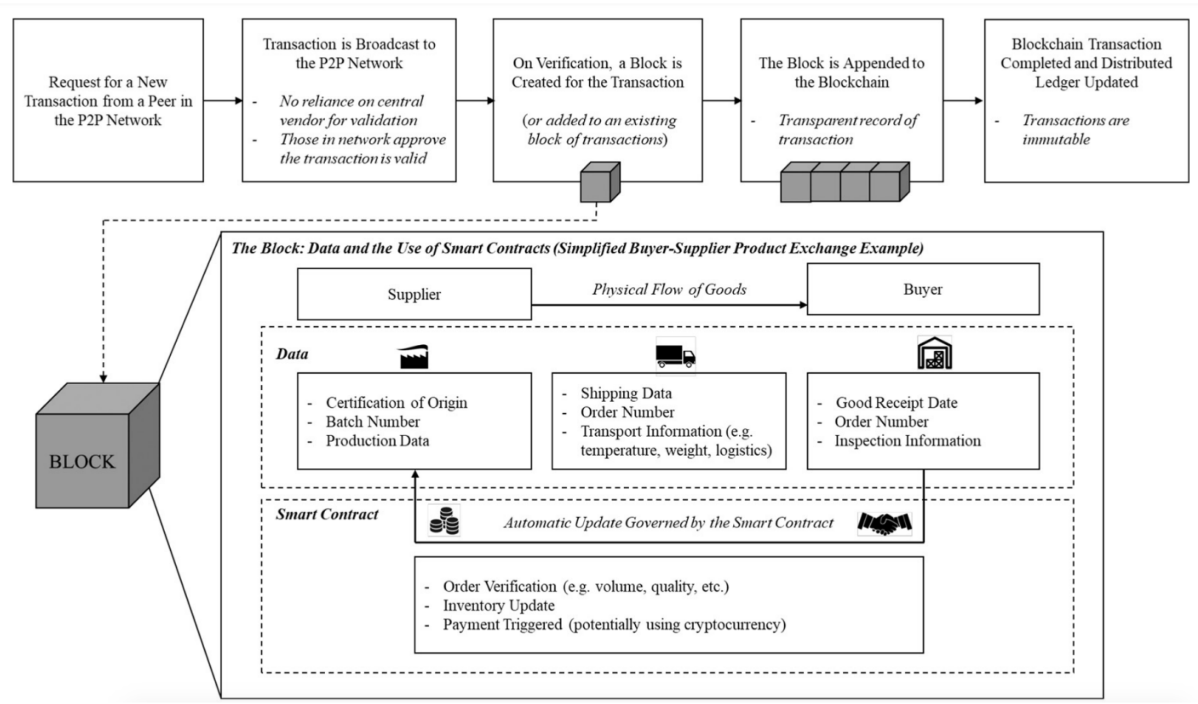

FIGURE 2.2: Overview of Blockchain Workflow (Cole, Stevenson, and Aitken, 2019)

2.1.3 Types of Blockchain

Some key definitions have to be introduced to understand how blockchain technology is used and developed over time. There a lot of definitions that come with blockchain technicality but some of the main differentials are the two concepts of “Public vs Private” and “Centralized vs De-centralized” blockchains (O’Leary, 2017). The first concept of “Public vs Private” blockchain is defined by who is authorized to use the network, run protocols and maintain the shared ledger/blockchain. A public blockchain is based on the high visibility of the transactions among all participants and likewise participants have the ability to perform needed transactions through the public blockchain(Jayachandran, 2017). The second definition of “Centralized and De-Centralized” blockchains is usually associated with the Bitcoin way of moderation. Bitcoin is the first de-centralized cryptocurrency, where each participant or owner of the Bitcoin has the same ‘permission’ as to what can be accessed and viewed. On the other hand, a centralized blockchain has an authority to regulate such ‘permissions’. This is usually adapted on corporate level. Typically, private blockchains are centralized and public ones are de-centralized(O’Leary, 2017).

Figure 2.3 shows the types of Blockchain(BC), in the context of permission vs permissionless. Public or open blockchain allows anyone to interact with another transacting party. The identity between the two parties is anonymous (i.e., the transacting parties do not know each other prior to the transaction; (Morkunas, Paschen, and Boon, 2019)). The cons of using a public blockchain includes that it provides little to no privacy for transactions, meaning that all transactions are visible to all participants. Also, public blockchain requires a huge amount of computational power to maintain a distributed ledger on a wide scale (Jayachandran, 2017). The computational power comes from the fact that to get consensus in a public blockchain, each node must solve a cryptoraphic problem, this process is referred to as "Blockchain Mining". Along the famous Bitcoin, Public blockchain examples also include: Litecoin (a cryptocurrency designed to be faster than Bitcoin), and Ethereum, that is used for smart contracts, initiating the concept of a contract that is based on a self-executing code that automatically implements the terms of an agreement between parties.

The permissioned Blockchain include private or closed blockchain, which allow only permitted individuals or groups to access the BC ledger and enter and view data. The second variant of the private blockchain is the federated or *consortium model*, in which the blockchain operates under the supervision of a certain group. This type of blockchain is a private network, in which shared records of transactions are accessible only by those who are pre-validated. In contrast to a public blockchain, private blockchain offers more privacy, which is crucial for sensitive data (e.g., the exchange of medical or financial data). Private BCs are easier to expand, and lead to cutting costs as they feature high transparency and trust among stakeholders (Coburn, 2018), however, multiple blockchain developer web communities still do not consider private blockchains to be blockchains, multiple arguments have been ongoing in both web communities and conferences (Kessels, 2018). Examples of closed blockchains include Linux-based Hyperledger, which supports the widest collaborative of blockchains and tools in banking, finance, Internet of Things, supply chain, manufacturing, and technology. In addition to, R3, a distributed ledger technology that leads a consortium of more than 200 firms and develops applications for finance and commerce on its blockchain platform (Vaughn, 2015).

Despite the differences described, open and closed blockchains share some common features:

•Both are decentralized networks, such that participants can maintain a duplicate of a shared ledger that is digitally signed to document transactions; •In both networks, the replicas are in sync through a protocol referred to as consensus(Coburn, 2018)

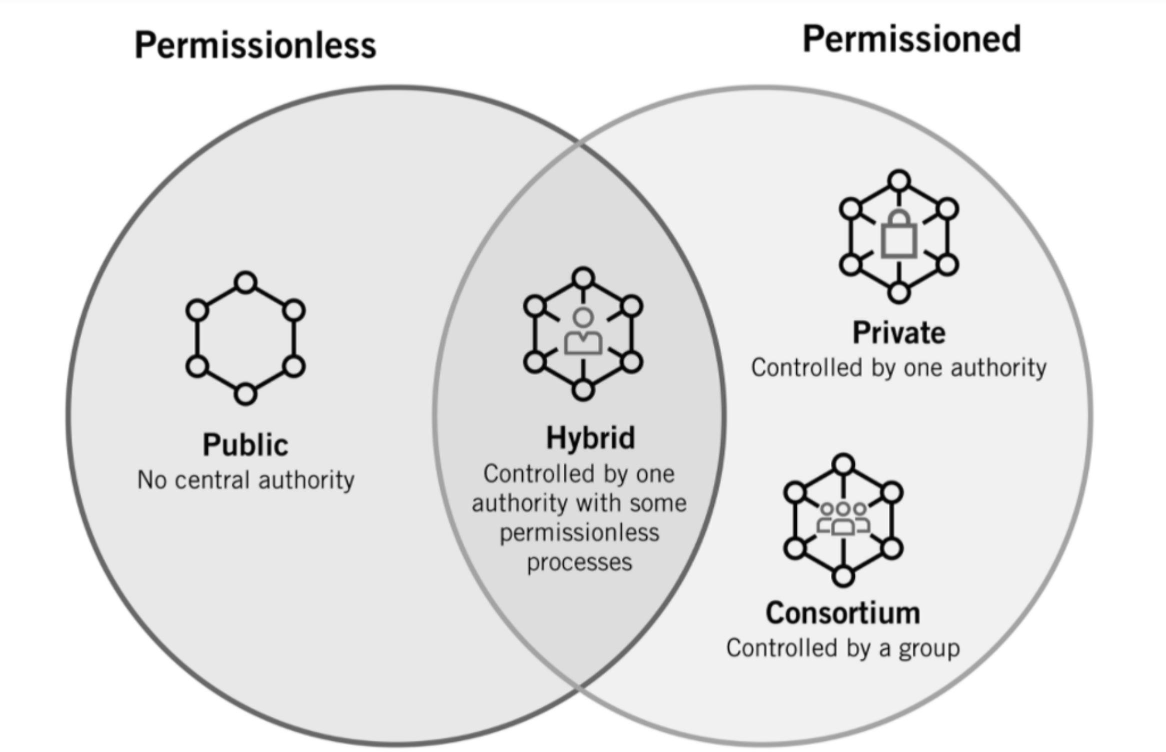

FIGURE 2.3: Types of Blockchain (Wang and Wegrzyn, 2021)

2.2 Supply Chain Challenges

Supply chain management is a complex segment of businesses involving information & capital flow, logistics and business flow creating a product lifecycle, with suppliers, manufacturers, retailers and end users as the key stakeholders (Mou, Wong, and McAleer, 2018). The complexity of supply chains is highly visualized when disruptions occur, this is when both upstream and downstream enterprises are intensely impacted. Figure 2.4, shows that the number of supply chain disruptions from 2019 to the 1st half 2021 is rising. In the first half of 2021 alone, 5,425 supply chain disruptions worldwide were reported. North America was the region with the highest share of disruptive events. To quantify the cost of these disruptions, a 2021 survey conducted by Statista & Resilinc showed that supply chain disruptions cost organizations around the world, an average of 184 million U.S. dollars per year. Figure 2.5, show a regional distribution of supply chain disruptions' costs. Again, the United States is ranked the region with highest financial burden, where the estimated average annual cost of supply chain disruption amounted to 228 million U.S. dollars (as per 900 survey respondents').

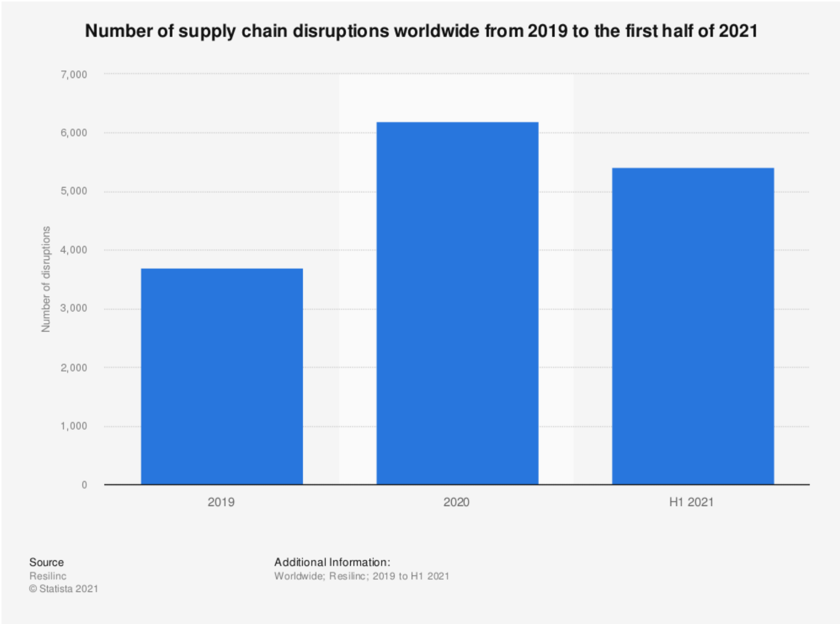

FIGURE 2.4: Number of worldwide SC Disruptions

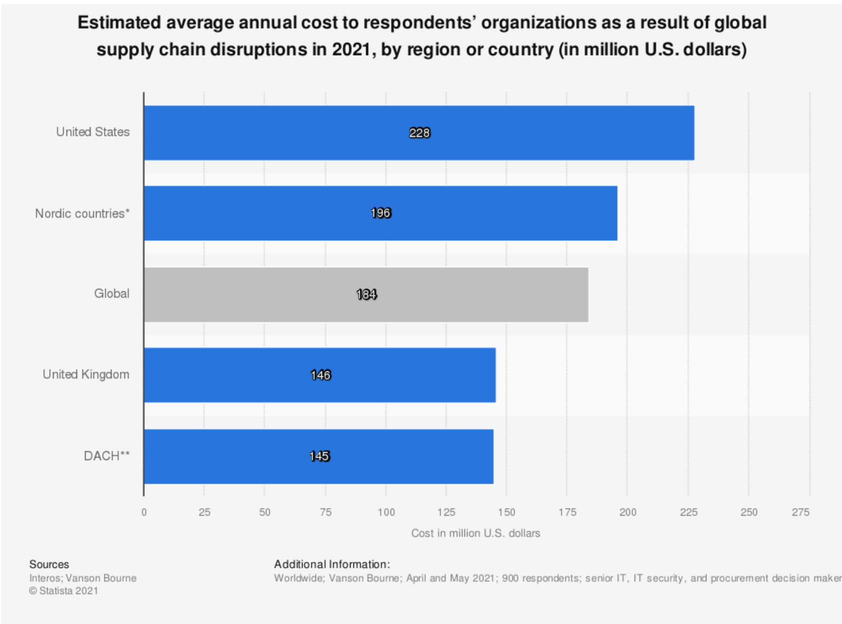

FIGURE 2.5: Estimated Average annual costs due to SC Disruptions in 2021

There are several common problems with supply chains across various industries, that occasionally escalate causing disruptions. First, the data flow with the supply chain is usually inaccessible by external stakeholders and remains privileged within an enterprise (Jiang and Ke, 2019). Upstream and downstream enterprises misevaluate the supply - demand information due to lack of complete visibility over the supply chain, causing a bullwhip effect (Jeong and Hong, 2019). Second, the lack of visibility on the data flow leads to reducing the trust between all the chain parties and accordingly, obstructs the real information exchange process(Jia et al., 2020).Third, product visibility, usually referred to in the literature as traceability of the product, is getting more difficult as the supply chains become convoluted product tracking is difficult. The core difficulty is allocating the origin of the problem when counterfeit or inferior products are delivered to the market (Zhang and Guin, 2020).

With the rise of recent sustainability frameworks like Industry 4.0 (I4.0) and Circular economy (CE), supply chain challenges became more evident to firms' decision makers(Carter and Rogers, 2008). Also, additional challenges raised to attention to achieve such frameworks for supply chains, to achieve the goal of Sustainable Supply Chains (SSC)(Beske and Seuring, 2014; Khalid et al., 2015).

Industry 4.0 (I4.0), the German project that aims to integrate manufacturing with IT particularly using aspects like inter-connectivity, automation, machine learning, and real-time data(Kamble, Gunasekaran, and Gawankar, 2018), includes sustainability as a primary driver(Beier et al., 2017). Sustainable Supply chains within I4.0 framework is an end- to end process, from raw materials to end of life of the product. This framework is changing the structure of supply chains and modifying the roles of all stakeholders (suppliers, manufacturers, and the consumers) in the chain, creating a hybrid long term solution that enhances the economy, the society, and the environment uniformly. Information technology (IT) solutions like machine learning, IoT and blockchain (Fernández-Caramés et al., 2019; Kamble, Gunasekaran, and Gawankar, 2018; Ramirez-Peña et al., 2020) are the key mechanism that allows active data sharing among value chains. Thus, sustainability is fueled by verified data flow of information about operational flow, supplied components and production of machines and factories allowing high level monitoring that leads to sustainable decision-making process. Industry 4.0 aims to replace the traditional approach of having supplied materials "manufactured, utilized and then disposed" with a novel circular approach that aids organizations, particularly, supply chains economically, socially and environmentally(Geissdoerfer et al., 2017). Circular Economy (CE) mainly underlines the adoption of 6 R's (recycle, reuse, reduce, refuse, rethink and repair) among the organizations (Merli, Preziosi, and Acampora, 2018), which according to (Ghisellini, Cialani, and Ulgiati, 2016) when used directly correlates to organization's sustainability. The "Recycle" term signifies the consideration of product wastes and recycle the material for use in new production cycle. “Reuse” refers to considering an already existing product that is categorized as waste and use its material or parts for another purpose, without processing it. “Reduce” entitles minimizing in quantity, the material and/or the energy utilized during the production life cycle. “Refuse” refers to dismissal of any production component in case it is not environmentally or socially sustainable. “Rethink” is the process to assess the current design process and allocate ways for optimization. “Repair” entails finding an immediate approach to fix any interruption that can occur within the entire process flow (Yadav et al., 2020).

To re-evaluate Supply Chain challenges, contemplating Sustainability frameworks, (Bressanelli, Perona, and Saccani, 2019)analyzed academic papers, particularly with the rise of sustainability concepts such Circular Economy, aiming to emphasize on some of the key challenges and how they could be addressed by systematically. The review paper results included systematic allocation of 24 challenges in supply chains, clustered into seven categories: Economic and financial viability, Market and competition, Product characteristics, Standards and regulation, Supply chain management, Technology, and Users’ behavior. The Supply chain management category included key challenges such as: Return flows uncertainty: Reverse logistic is a vital topic for most organizations due to the growing environmental concern, government regulation, economic value, and sustainable competitiveness. It is defined as the set of activities needed to re-claim a used product from a customer and either dispose of it or salvage it (Govindan and Popiuc, 2014; Kocabasoglu, Prahinski, and Klassen, 2007). However, Uncertainty is one of the crucial considerations in the reverse supply chain to be considered (Paduloh et al., 2020). (Bressanelli, Perona, and Saccani, 2019) addressed the returns flow uncertainty in terms of products quantity, time and location of return confirming that the low collection rate of products from customers to be reused or correctly disposed limits the sustainability frameworks as a whole and supply chains in specific.

2.3 Blockchain and Supply chain (BC-SC)

(Ghadimi, Wang, and Lim, 2019) highlighted in their study that the literature strongly demands for innovative solution measures such that the organizations can easily adoption SSCM according to changing industry environment. Hence, it becomes essential to note that the solution measures required to overcome the SSCM adoption challenges must include the essence of present industry environment that includes industry 4.0 as well as circular economy (Gopal and Thakkar, 2016). Blockchain addresses many of supply chain challenges, such as lack of transparency due to unreliable or unavailable data, high proportion of manual (paper) work, lack of interoperability, and limited information on the product’s life cycle or transport history. A well-known example is the blockchain based Supply chain for beef production illustrated in figure 2.6. This model makes the impact of blockchain apparent. In response to customers’ increasing mandate for local and organic products with clear origin, for instance, through an app, retailers could provide selected product-related data. Also, with a QR-code scan via a smartphone, customers could check every step the beef has taken through the supply chain, and accordingly match that journey against customer expectations. All details like the historical and real-time data of the product, related to the origin (such as feed or breeding), timelines (such as aging duration, time in transport, best before date), location (of the plantation and of the beef throughout the supply chain) or advanced information (such as recipes and wine suggestions) is continuously available from the blockchain database in a single, reliable version(Fu and Zhu, 2019).

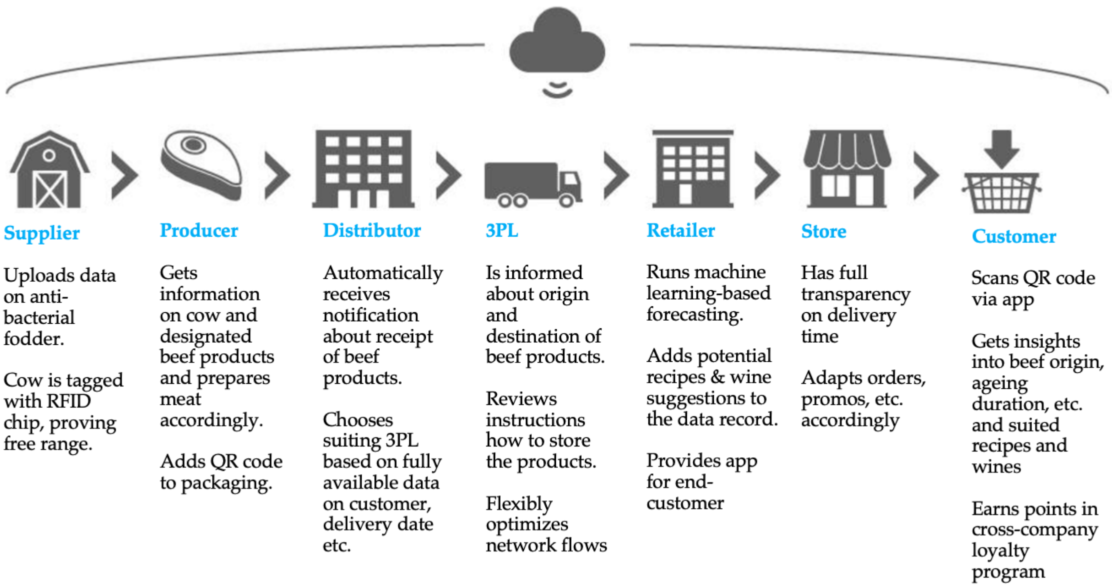

FIGURE 2.6: End-To-End Blockchain-Enabled Supply Chain Example for Beef Production(Fu and Zhu, 2019)

2.3.1 Blockchain benefits for Supply Chains

In response to the challenges introduced by supply chains, blockchain is introduced to oppose the impact of those challenges. Benefits of blockchains in this scope include: data management, improving transparency, improving response time, smart contract management and operational efficiency. Multiple papers addressed these benefits from different aspects. (Chang, Chen, and Lu, 2019; Saberi et al., 2019; Wang, Han, and Beynon-Davies, 2019). (Kshetri, 2018) looked at how Blockchain can impact major supply chain management goals including cost, quality, speed, reliability, risk mitigation, sustainability, and flexibility. (Ivanov, Dolgui, and Sokolov, 2019) see BC as an improved tracking and tracing technology that may improve supply chain visibility and efficiency through record-keeping. In India and the United States, (Queiroz, Telles, and Bonilla, 2019) looked at individual Blockchain adoption. The findings revealed that the adoption of Blockchain by logistics and supply chain management experts is still in its infancy. (Kamble, Gunasekaran, and Arha, 2019) created a model based on the integration of three adoption theories: the technology acceptance model (TAM), the technology readiness index (TRI), and the theory of planned behaviour to better understand user views of Blockchain adoption in the supply chain (TPB). The findings revealed that insecurity and discomfort have a little impact on perceived ease of use and utility. The behavioural intention is influenced by perceived usefulness, attitude, and perceived behavioural control. The influence of subjective norm on behavioural intention is modest. (Treiblmaier, 2019) demonstrated how the consequences of Blockchain on SCM may be explored from several viewpoints using a framework based on four well-known economic theories: principal agent theory (PAT), transaction cost analysis (TCA), resource-based view (RBV), and network theory (NT). (Wang, Han, and Beynon-Davies, 2019) utilised sensemaking theory to investigate how Blockchain technology may change supply networks. In times of greater risk and uncertainty, (Min, 2019) explored how to use Blockchain technology to improve supply chain resilience.(Montecchi, Plangger, and Etter, 2019) created a provenance knowledge architecture and shown how it may be used to improve guarantees and minimise perceived risks through the use of blockchain. The authors also included a tutorial on how to use Blockchain to build provenance knowledge, as well as a friendly reminder about the significance of showing Blockchain's value to consumers. (Cole, Stevenson, and Aitken, 2019) believes that Blockchain can help improve product safety and security, improve quality management, reduce illegal counterfeiting, improve sustainable supply chain management, advance inventory management and replenishment, reduce the need for intermediaries, influence new product design and development, and lower supply chain transaction costs.

According to certain research, Blockchain is a catalyst for long-term supply chain management. Inter-organizational, intra-organizational, technical, and external impediments to Blockchain technology adoption were identified by (Saberi et al., 2019). The authors also noted the relative value of Blockchain technology in supply chain sustainability. The primary focus of (Kouhizadeh and Sarkis, 2018) was on identifying potential uses across the spectrum of green supply chain management functions and activities, particularly on environmental sustainability in the supply chain, and they provided an overview of Blockchain technology's potential in the sustainable supply chain context.

The preceding studies mostly focus on a broad overview of the impact of Blockchain on supply chains. There are also several in-depth investigations on the use of Blockchain in the supply chain. For instance, (Perboli, Musso, and Rosano, 2018) developed a framework for designing Blockchain technology use cases that aren't linked to financing. Similarly,(Toyoda et al., 2017) presented a product ownership management system for post-supply chain anti-counterfeiting. (Tseng et al., 2018) used the Gcoin Blockchain to investigate pharmaceuticals supply chain governance. The Gcoin Blockchain's double-spending prevention technique was used to solve the counterfeit-drug problem in that study. (Choi et al., 2019) explored how Blockchain technology might be used to make mean-variance risk analysis for global supply chain operations easier to execute. (Figorilli et al., 2018) pioneered the application of Blockchain technology for electronic wood tracking from the standing tree to the end user. (Mao et al., 2018) developed a Blockchain-based credit rating system to improve the efficacy of food supply chain monitoring and management. (Venkatesh et al., 2020) established a system architecture that blends Blockchain, IoT, and big data analytics to assist sellers in efficiently and effectively monitoring their supply chain social sustainability. (Wang, Han, and Beynon-Davies, 2019) developed a Blockchain-based information management system for a precast supply chain in order to handle information sharing, real-time scheduling control, and information traceability. (Sund et al., 2020) investigated the viability of using Blockchain at IKEA, a prominent multinational retailer. To cope with the highlighted events that are crucial in the supply chain process, the authors designed a prototype based on Quorum. (Liu et al., 2020) presented an industrial Blockchain-based PLM architecture to make data interchange and service sharing easier across the supply chain during the product lifecycle.

2.3.2 BC-SC Pilots

In order to validate the mentioned benefits and provide imperial evidence, blockchain pilots have been analyzed through multiple research publications. Overall, the four main industries that had a great deal of blockchain based pilots for supply chains since early 2016 were food &agriculture, pharmaceuticals, transportation, manufacturing and maritime. For instance, T-Mining, a start-up in Antwerp has developed a blockchain solution for the port's container release operations. All obligatory and vital data for releasing a container are gathered in a database and the information is restricted to only transaction stakeholders. The blockchain solution adds value by ensuring that: (i) the rights can be transferred between stakeholders and (ii) the sender no longer has the authority to change the transaction. Thus, no unauthorized party can claim ownership of the containers at the terminal, because all transactions are securely and permanently stored in the blockchain. Traditionally the operations involved a large number of intermediaries; the developed solution has securely digitized the operation process without any middlemen. Another example is the joint collaboration between Maersk and IBM to develop a trading platform called 'TradeLens' for the maritime shipping industry. The platform authorizes multiple trading participates and partners to share information securely and to collaborate by establishing a single shared view of a transaction without compromising confidentiality. Basically, multiple parties can interact with each other by accessing real-time shipping data and documents. Similarly, in the food industry, the leading French based retailer Carrefour launched a blockchain-based food traceability system. The system captures all the relevant information about the supply chain participants and their associated activities. Accordingly, the customers can trace their supplies just by scanning a QR code(Sunny, Undralla, and Madhusudanan Pillai, 2020).

In the area of luxury supply chains, there has been an inclination to introduce blockchain based solution especially for tractability. For instance, Tracr, Provenance Proof and TrustChain are the names of some of the important initiatives in that domain. They serve their customers by satisfying their demand for revealing the source information of the jewelry items (Cartier, Ali, and Krzemnicki, 2018). Overall, the reasons for adapting blockchain are associated with the quality of the supply chains' operations, whether it is in the form of tractability enhancement or strengthening the trust among stakeholders via a secured network. To summarize some of the pilot projects and their achieved goals, (Chang, Iakovou, and Shi, 2020) has consolidated figure 2.7, representing the targeted benefits on Supply Chain Management (SCM) and global trade.

	Domain	Traceability	Dispute Resolution	Cargo Integrity & Data Security	Digitalization	Compliance	Trust & Stakeholder Management
Port of Antwerp & T-Mining	Port	X		X	X		X
Maersk & IBM's "TradeLens"	Container Shipping	X	X	X	X		X
Accenture, APL, Kuehne + Nagel, and AB InBev	Freight and Logistics	X		X	X	X	
BiTA	Transportation and Logistics					X	
UPS	Logistics	X	X		X	X	X
Walmart & IBM	Food	X			X	X	X
Carrefour	Food	X			X	X	X
Medi Ledger	Pharmaceuticals	X			X	X	X
SAP "Advance Track and Trace"	Pharmaceuticals	X				X	X
Foxconn	Electronics Manufacturer				X	X	X
MOBI	Mobility	X				X	X

FIGURE 2.7: Pilot Examples against benefits (Chang, Iakovou, and Shi, 2020)

1. Traceability

   Traceability has become one of key requirement for supply chains. With novel complexities such as the cross border trade and multi operational systems that facilitate data exchange, the need for clear transfer of goods in many supply chain industries including the agri-food sector (Costa et al., 2013), pharmaceutical and medical products (Rotunno et al., 2014), and luxury goods (Bandelj, Wherry, and Zelizer, 2017) has become mandatory.

   When effective traceability is achieved, multiple supply chains gaps are addressed. For example, the overall observability of supply chain procedures (Ringsberg, 2014), which offers information about the products raw materials' origin, legitimacy, chain of custody, as well as integrity of market offerings(Marucheck et al., 2011). As a result, due to their crucial role in establishing provenance, effective and efficient traceability capabilities are key operational vehicles of supply chain transparency(Sodhi and Tang, 2019). Also, investments in the traceability aspects are usually triggered by the need to meet legal and compliance requirements. For example, the traceability of food items is originally of interest to address the food safety regulations (Dai, Tseng, and Zipkin, 2015; Dai et al., 2017), to improve inventory management (Alfaro and Rábade, 2009) or to improve vertical coordination, in supply chains that aren't completely intertwined (Stranieri, Orsi, and Banterle, 2017). Besides, many firms are leveraging the added informational value of having an enhanced supply chain that features traceability. Information like shelf-life prediction (Wang and Li, 2012), sales forecasting (Wang et al., 2010), product provenance certifications (Aiello, Enea, and Muriana, 2015; Brofman Epelbaum and Garcia Martinez, 2014),and product recalls (Dai, Tseng, and Zipkin, 2015) become available to the firms with high accuracy when effective traceability is applied. The same concept applies for luxury and high value goods, such goods rely on paper certificates and receipts that can be lost or altered. Thus, any lack of transparency in the supply chain can block the verification and the validity of the real value of the product. Besides compliance, cost reduction comes as one of the reasons to deploy effective traceability in supply chains. The costs that come with handling intermediaries and third part entities increases as the SC widens. In addition, the strategic and reputational issues that arise from lack of transparency eventually lead to additional costs on the firms. For example, the salmonella outbreak linked to Maradol-brand papayas in the United States, which has affected hundreds of people, has tarnished a brand and its supply chain. The reason was mainly the contaminated papayas, yet the fact that not all shipments were traced, prolonged the impact of safety concerns. Another example is Chipotle Mexican Grill outlets outbreak in 2015, that led to the illness of dozens of customers. The outbreak led to major losses for the firm, as its stock price fell by up to 42%. Lack of traceability across Chipotle supply chains , especially in real time was the main obstacle for the outbreak (Saberi et al., 2019).

2. Dispute Resolution
The wide-scaled supply chains contain multiple entities that interact with one another. So in case one of the stakeholders fails to deliver products on time or fail to fulfill the agreed upon requirements (e.g: the origin of the raw materials does not meet the criteria or the products have been compromised on the route),a conflict occurs between the two or more parties, this is usually referred to as a *"Dispute"*. When this occurs, SC stakeholders have to identify the origin of the dispute in a timely manner, and this is handled via fines or compensations (Azure, 2018). For instance, Walmart has begun, as of April 2018, fining its suppliers who fail to deliver a minimum of 85% of their shipments on time (with respect to the contractual agreement between them). This step was taken with the aim to push for full deliveries on timely manner from all stakeholders(McKevitt, 2018).

Despite the compensation and fines approach, still SC disputes are considered a complicated SC pain area. As it costs the stakeholders both time and high expenses. The stakeholders involved in the dispute, have to track back the facts that led to the conflict (Coates and Rathke, 2015). Furthermore, the cross-boarder trade disputes, sometimes involve legal court involvement. However, the parties involved become reluctant to enter the other's court to resolve or settle the conflict, due to reasons like being unfamiliar with local laws. These scenarios complicates dispute resolutions furthermore (Okazaki, 2018).

In face of these difficulties, blockchain capabilities can introduce some fixes. BC relies on recording transactions in the form of a unchangeable "block", thus the records including the information like: transaction owner (the responsible person/entity for the conducted transaction), the time stamp at which the transaction took place, acknowledgment of legalities and signatures confirming safety requirements have been met, all on real-time basis, can present a solution to some problems and accordingly reduce the likelihood of dispute occurrence. In addition, if a dispute occurs, the secure records, will provide visibility on the steps giving more insights when tracking back the events.

A BC-specific feature that is usually highlighted with Dispute Resolution discussions is *Smart Contracts*. A smart contract is a code recording predefined rules between entities using the same distributed ledger. In some cases, smart contracts can trigger an action (usually a payments for compensations or fines) if pr-set compliance terms are violated. The general idea of a smart contract is that it helps the pre-defined stakeholders on the network to interact amongst each other and within the system. It creates a data sharing network between supply chain participants leading to continuous process improvement. For example, regulators and and standards organisations can digitally verify stakeholders' profiles and products' requirements. The visibility is easily accomplished as both stakeholders' profiles and the products have their e-profile on the distributed ledger. Accordingly information like description, certifications, locations and time stamps of critical actions are all displayed(Laurence, 2019; Feng Tian, 2017).

3. Digitalization
Paperwork is the keyword when SC digitalization is discussed. Some of the key industries like maritime shipping industry, handles around 90% of global trade (United Nations Conference on Trade and Development, 2017) is still relying on manual systems. Multiple containers transfers across the world's ports are documented by tons of paperwork (Digital, 2018). The problem with paperwork documentations is that it introduces high costs under administration expenses. In addition, it introduces issues like data duplication, redundancies, lack of transparency , inconsistency , etc (Economist, 2018a). For example, Mearsk, one of the largest shipping companies in the world, found that a single shipment from Mombasa to Europe required 200 communications among 30 entities. Besides, paperwork can lead to delays at ports because the paperwork is simply not in sync with real-time product flow (Allison, 2016), and at the same time a report published by IBM in 2017, confirms that processing trade documents can cost fifth the cost allocated to shifting goods (Newsroom, 2017a).

On the other hand, BC is vastly growing as key component for SC digitalization along with Artificial Intelligence (AI) and Internet of Things (IoT)(Gartner, 2018; Economist, 2018b). The solutions BC-SC collaboration offers solutions to bring sown some of the paper work barriers discussed. For instance, replacing lengthy paper trails with automated data that keeps procedure in a tamper-evident digital format, which will accordingly save transaction time and administrative expenses and speed up freight movement (Thurner, 2018). In addition, using Smart contracts can speed up transaction processes, by increasing the direct interaction between stakeholders and automating the payments and documenting the transfer of ownership as the product moves along the SC(Economist, 2018b). SCs that include multiple intermediaries/third party entities, such as insurance firms or regulators, will benefit the most from introducing BC for digitalization purposes. Similarly, SMEs (Small and Medium Enterprises) can benefit from BC by allocating safer sources of financing without any intermediaries (Kuznetsov, 2018; Clarke, 2018; Silitschanu, 2019).

4. Cargo integrity and Data security
The relationship between a buyer and a seller in international trade is moderated by several sensitive documentations. To protect both sides, documents like bill of exchange, bill of lading, letter of credit, certificate of origin of goods and inspection certificate are exchanged (Board of Governors of the Federal Reserve System et al., 2021; Ganne, 2018). However, these documents are sometimes sufficiently duplicated by fraudsters who create fake cargo documents to take control of the shipment deliveries. An estimated \$30 to \$50 billion worth of cargo are stolen worldwide. In 2020, around \$25 million worth of cargo were stolen in thefts in the U.S only and, only \$6.7 million U.S dollars worth was recovered (Ashe, 2017). Of the U.S theft figure, \$3.92 million worth of consumable goods and \$3.6 million of medical equipment were stolen, of which 2.66 million U.S. dollars worth were recovered(Statista, 2020).

   Similarly, with global trade the risk of cyber-attacks increases, especially that now most of the trading activities rely on IT systems and electronic platforms. According to a report published by IBM and Ponemon Institute in 2021, the average cost of a data breach in the healthcare sector amounted to \$9.23 million. The global average cost of a data breach in the measured period was \$4.24 million. Data breaches in the public sector ranked last, costing an average of 1.93 million U.S. dollars during the measured period. A famous example, demonstrating the cost of the cyber-attacks is the Belgian port of Antwerp case in 2013. Crime syndicates were said to have employed long-term cyber-attacks for drug trafficking, with the intrusions staying unnoticed for more than two years. The traffickers were able to get remote access to the terminal systems and subsequently release containers to their own drivers as a result of the breach. Access to port systems was exploited to remove data and generate a large number of 'ghost containers.' (Maritime, 2013).

Again, BC technology can address these challenges by establishing a robust relationship between digital and physical transportation of goods. The physical transportation of goods in a secure way is achieved by BC tracking and monitoring cargo along the entire SC. This includes: (1) Providing a unique identifier for each stakeholder on the SC, which ensures that products will be delivered to its true recipients, (2) Because of the block encryption and the way blockchain operates, hackers and criminal gangs will have a harder time disrupting the system, (3) the unique profile of each member of the BC network can enhance the fast digital transfer of ownership among stakeholders in a secure and swift manner (Laurence, 2019).

5. Compliance
With the rise of sustainability concepts that are widely introduced with Industry 4.0 and circular economy, as highlighted in section 2.2, compliance with global standards has become mandatory. The compliance standards in the global market and environment, include a vast number of requirements that need to be monitored and adhered to, including safety and integrity of products, technical regulations, social and environmental responsibilities of suppliers, and ethical sourcing, etc. (Deloitte, 2021). These standards are enrolled under the umbrella of ESG (Environmental, Social and Governance) goals and thus any failure to apply those standards, lead to regulatory scrutiny and negative impacts to the firms' reputation. For example, every year, 200 million tonnes of food degrade before reaching the market owing to a lack of cold transport equipment(Microsoft, 2018). Also, customers were duped into buying expired chicken by altering with food safety documents by the UK's leading supermarket chicken supplier(Goodley, 2017). On a social aspect, firms are moving forward with ethical sourcing which include checking the basics of the social and environmental legislation in the countries of production for each prospective suppliers. The reason lies in NGO reports in the past few years that highlighted the serious human rights violations associated with some activities like for instance cobalt mining (Somo, 2016). As a result, businesses are now actively looking for ways to achieve "responsible" cobalt imports. Usually the two main questions when SC compliance is addressed are: (i) How all the stakeholders can consolidate information about their compliance requirements? and (ii) How do they communicate with one another throughout the SC to validate effective execution of these compliance requirements?

Blockchain technology has the ability to address the two questions. The first is answered via the use of "real-time visibility" feature. BC allows all stakeholders to view all transactions on real-time basis, which forces firms to abide by the compliance requirements. At the same time, the data is securely stored on the distributed ledger for regulatory and compliance entities to verify as needed (Azure, 2018). The second is addressed via the use of smart contracts. Smart contracts can prevent degradation in products' quality by for instance sending real-time warnings if the temperature in a certain container does not meed the specs on the contract. The readings are captured by the means of IoT sensor inside the containers.The immutable blockchain structure has been used by multiple entities including: the British Standards Institution, the United Kingdom's national standards body,who have been collaborating via BC network to achieve compliance on several regulations (Suberg, 2019).

6. Trust and stakeholder management
   Trust among SC stakeholders has been a challenge with the expanded cross-boarder trading. The lack of trust arise from the presence of multiple intermediaries between the key SC stakeholders (such as: legal and financial institutions). Intermediaries don't only add to the firm expenses, but they also are the usual cause of unnecessary and increased variability (Global, 2021).

   Blockchain creates a platform where parties may trust one another and conduct transactions without the use of middlemen. The nature of BC technology itself is the origin for creating a trust bond between stakeholders. The technology relies on the consensus mechanism such that all members must agree on the accuracy of the ledger. Thus, all transactions and product specs can be verified and audited on real-time basis (Upham, 2020; Klaudia, 2020). Furthermore, accurate achieves can be available to all stakeholders, reflecting information like: the timestamp of the transaction. The transactional data stored on the chain cannot be edited (Development Asia 2018). This can assist regulators and governmental agencies in identifying the provenance of products in order to better handle the challenge of asymmetric trust in cross-border commerce (Capell, 2018).

Figure 2.8 represents a summary of the key blockchain capabilities and the corresponding SC pain points discussed. The supply chain pain points originate from four key flows: (1) Product Flow, (2) Process Flow, (3)Information/Data Flow and (4) Cash flow. (Chang, Chen, and Lu, 2019; Saberi et al., 2019; Wang, Han, and Beynon-Davies, 2019).

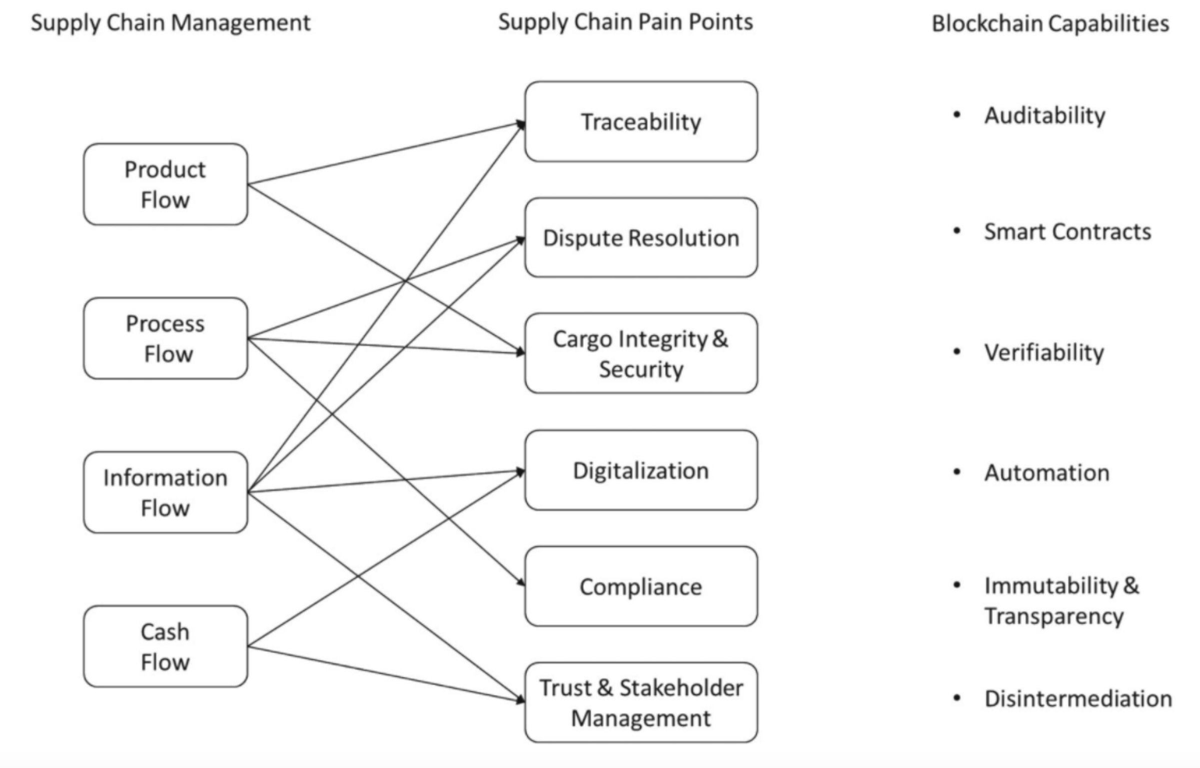

FIGURE 2.8: SC management pain areas with their corresponding BC features as benefits (Chang, Chen, and Lu, 2019)

2.3.3 Collaborations for Innovation purposes

Internationalism has introduced the opportunity of partnership for innovation purposes. This opportunity has facilitated the exchange of knowledge between firms across the globe, with the aim to enhance performance and reduce costs, while keeping the risks that arise from knowledge exchange activities at a minimum (Hagedoorn, 1993; Giacosa, Ferraris, and Monge, 2017). It was proposed and validated by (Narula, 2004) that large companies are partnering with SMEs to benefit from their flexibility and innovation capabilities. In exchange, SMEs benefit from the large firms RD scale and capabilities. The partnerships for innovation are common among various industries. (Prain et al., 2020) introduced how partnerships in agriculture sector can create a system approach to innovation that can better handle the complexity of scaling processes and provide frameworks that integrate innovation and scaling processes together. In the Biotech sector, (Lee and Vavitsas, 2021) discussed how Private-Public Partnerships (PPPs), that are common in biomedical and pharmaceutical research, can serve business and societal goals via innovation partnerships and interactions. The study concluded that the PPPs have the potential to build considerable bio engineering skills and to transform scientific knowledge into practical applications. Similarly, in the energy sector, Private-Public Partnerships (PPPs) were addressed by (Shahbaz et al., 2020) to show the vital role technological innovations plays in carbon emissions function for China. The author concludes that PPPs for technological innovations have negative effect on carbon emissions. Thus, both research and practice confirm that global competition and technological progress have prompted corporations to seek out external knowledge partners in order to build various types of inter-organizational alliances (Lefebvre, De Steur, and Gellynck, 2015; Ferraris, Santoro, and Bresciani, 2017).

In addition, (Han et al., 2012) conducted an event study to examine "How does the market evaluate a firm's strategic decision to participate in OIAs. OIAs most famous example is the alliance between Google, T-Mobile, Samsung and Qualcomm, in 2007, to launch the Open Handset Alliance, Android. The alliance aimed to create an innovative infrastructure where software applications are available for the mobile technology. The results of the study showed that when an allying firm's participation in an OIA is made public, significant positive abnormal returns are observed.

Chapter 3

Hypotheses Development

The highlighted pilots in the previous section, include both major listed corporations as well as startups. Since 2016, a considerable number of startups emerged to provide blockchain as a service for enhancing the operations of supply chains. Their customers vary in industry and scale. However, still tech giants like IBM and Microsoft, SAP, ORCALE and Huawei dominate the market share in providing BC as a solution for SC. To quantitatively analyze the impact of BC-SC, only listed customers will be considered in the scope of this study. This is due to the data availability for listed firms such as firm characteristics (like market capitalization, expenses...) and firms' daily performance represented by its stock price. However, all solution providers (both listed and non-listed) will be considered if their solution is used by a listed firm. The scope of this study focuses on the impact of BC-SC when used by listed firms not when provided by them.

3.1 Market Reaction to firms adapting Blockchain Supply chain (BC-SC) initiatives

When looking into the developed research, few financial analysis studies for the blockchain adaptions with Supply chains is available in the literature (Klöckner, Schmidt, and Wagner, 2021). However, multiple research papers have been exploring the financial effects of adopting blockchain technology on the corporate returns and how are these announcements related to bitcoin price. Those blockchain adaptations are general and cover multiple areas with no focus on supply chain as intended for this study. For example, (Cahill et al., 2020) conducted an event analysis using news headlines, to investigate the market reaction to a company's intention to adopt blockchain technology and provide systematic analysis of the market reaction, and the association it has with bitcoin returns. The results were: there is an average abnormal return of 5.3% on the announcement day, with smaller companies experiencing greater abnormal returns compared to larger companies. The abnormal returns observed on announcement days increase during the period 2016 to 2017, followed by a sharp decline at the beginning of

2018. Those findings show a link between cumulative abnormal returns and bitcoin performance. This observation may be explained as the markets perceive blockchain as something resembling bitcoin, at least during the sample period. Another important conclusion was the observed increase in the number of company announcements during the period when the bitcoin price was rising, which suggests companies may announce their involvement for rent-seeking purposes, rather than value creation. Yet this was a bit contradicted when this trend did not persist as companies continued to show interest in 2018 when the price of bitcoin was falling, highlighting the apparent benefits of blockchain, particularly in the finance industry(Yermack, 2017). The event analysis approach is usually used when a new initiative, approach or technology is introduced to the market and researchers want to evaluate its financial worth and shareholders' interest. The same approach has been used in multiple research papers particularly to evaluate new supply chain strategies such as green Supply Chain (SC). For instance,(Bose and Pal, 2012), have analyzed the impact of green supply chain announcements on their stock prices and which firms benefit considerably from these announcements. The data used for this analysis relied on news announcements and an event analysis was conducted to test and validate the raised hypotheses. Since most of the literature indicates that blockchain financial implications are usually positive, it becomes intriguing to know if this effect will remain positive when focusing on SCM only. Accordingly, the below hypothesis will be tested and validated.

*H1: The **announcements** of Blockchain supply chain **(BC-SC)** initiatives lead to a significantly **positive** increase in **stock prices** of firms taking the initiatives.*

3.2 Key SC Objectives for using BC technology

According to multiple survey papers in the literature, there are several SC areas where BC technology can step in and cause drastic improvements. As highlighted in Section 2.3.2 the commonly repeated areas/pain points are: (1)Traceability, (2) Dispute Resolution, (3) Digitalization, (4) Cargo Integrity & Security, (5) Compliance and (6) Trust Stakeholder Management. (Wang, Han, and Beynon-Davies, 2019; Saberi et al., 2019; Montecchi, Plangger, and West, 2021; Chang, Iakovou, and Shi, 2020; Surjandy et al., 2019). Although there are different SC pain areas that BC implementation can address, each pain area when targeted as a firm objective may have major impact on society and the firm. We argue that the shareholder value effect of traceability as an objectives is higher than others. The reasoning is as follows. First, in the literature, multiple papers have addressed traceability as the primary goal for adapting BC-SC applications (Chang, Iakovou, and Shi, 2020; Montecchi, Plangger, and West, 2021; Kshetri, 2018; Sodhi and Tang, 2019; Pun, Swaminathan, and Hou, 2021). Some of the examples include BC-SC traceability for food, drugs, automotive raw materials and luxury goods. In practice, Walmart has established the "from farm to fork" project in collaboration with IBM. The project aims to trace the SC flow from raw materials at the suppliers end to the end customer, ensuring that standards and contractual guidelines are applied throughout. Second, some studies in the literature addressed the link between traceability using BC-SC and cost savings, for instance, (Pun, Swaminathan, and Hou, 2021) compared BC-SC to other approaches when it comes to selling products in the presence of counterfeit products in the market. The results showed that using BC was more beneficial than other approaches like: differential pricing. Similarly, (Chod et al., 2020) found that inventory signaling costs can be reduced by the use of BC. Thus, investors might positively link the cost reduction benefits that come with traceability as an objective for adapting BC-SC, thus we hypothesize:

*H2: Compared to other **SC objectives**, firms targeting **Traceability** will show **stronger positive** impact in their **stock prices** when they make blockchain related announcements.*

3.3 Impact of Industrial BC-SC Consortium announcements on Market Reaction

Like many of the highlighted innovation alliances/partnerships highlighted in section 2.3.3, Blockchain initiatives are commonly introduced as inter-organizational collaborations or as commonly labeled in practice, *consortia* (Babich and Hilary, 2020). The more interesting feature is that BC is evolving on an industry-level creating what is known as Industrial BC Consortium. The consortia are features in industries like finance, supply chain, manufacturing, healthcare, energy, and smart city (Li et al., 2021). However, what we are interested in the scope of this study are Industrial BC Consortia for SC purposes only. For instance, (Eluubek kyzy et al., 2021) confirmed that the experimental results and analysis show effectiveness and accuracy of the use of BC Consortium in the agriculture sector. The trading side of the agricultural SC is usually complex, involving multiple entities. The integration between the different stages and entities, lead to higher profitability for the producers ,in the study's case, the farmers. From Energy industry point of view, (Bischi et al., 2021) proposed a BC model for distributing trading of electricity across the grids. In practice, multiple industrial consortia were launched since 2016. Among the famous consortia is IBM Food Trust consortium. The project involves more than 10 major food manufactures like Nestlé, Unilever and Tyson Foods, that use BC in their SCs to achieve transparent and secure interaction among stakeholders. When the project first launched it was declared that BC-SC can reduce the cost of returning products by 80% (Li et al., 2021). Thus we expect that Industrial BC Consortia will perform better, specifically when compared to public and private BC networks, for five reasons.

First, an industrial consortium, includes diverse organizations from the same industry, this includes suppliers, competitors, standards regulators, research and academic institutions, all of which are focusing on achieving specific standardization's and customer requirements. The high visibility and interaction the BC consortium creates, will allow all the partners to leverage resources for sustainable operation, innovation and knowledge exchange (Ravichandran and Giura, 2019). The diversity among partners comes in size as well. For example, one consortium like IBM Food Trust can include a wide range of partners, from small, medium and large enterprises. In addition to the fact that the ecosystem is bringing together some of the key stakeholders in the food industry like food manufactures, logistics, agribusinesses and restaurants(IBM, 2015).

Second, Industrial consortia is usually perceived as a model where business value is added to all involved participants. In case of SCM, business values of interest that Industrial consortium can introduce includes: fast time-to-value for partners, regardless of the company's size. A clear example for this is smart contracts, the smart contract is automatically executed after most of the partners reaching a consensus on the event. At the same moment, all of the nodes will be updated. The result of the contract execution will then be recorded on the distributed ledger (Li et al., 2021).

Third, the exchange of information among partners is key for operational efficiency (Chen and Deng, 2015; Ebrahim-Khanjari, Hopp, and Iravani, 2012). Industrial consortia establish an ecosystem where there is balance between data exchange and data security. For example, many consortia focus on uploading, ownership and sharing of data policies, where data owners has the to decide who sees their data via consensus mechanisms. This balance is the customization BC consortium provides and equivalently private and public BC networks lack.

Fourth, as mentioned in section 2.1.3, private BC networks have their limitations. There are even some debates that this type should not be considered BC, because they are controlled by a single authority. This structure resembles the old "closed innovation" model in some aspects (Han et al., 2012). Traditionally, firms oversaw all of the procedures involved in the innovation life cycle internally ("Open Innovation" 2004). A corporation that invests in internal R&D, for example, seeks to identify scientific breakthroughs that can eventually be sold as new goods and services. Increased sales and earnings from invention are often spent to strengthen the company's innovation capacity, resulting in more discoveries. During this process, the corporation often seeks legal protection for its intellectual property and know-how. Similarly, private BC networks that are controlled by one firm, are using BC technology to benefit internally from BC security and transparency features, rather than expanding their collaborations externally like the case with BC consortium. Thus, it seems reasonable that Industrial BC consortia would be more attractive to investors compared to Private BC networks.

Fifth, the other extreme side on the scale of data privacy are Public BC networks. Such networks are permissionless, where there are no central authorities controlling the network, resembling the original concept of Bitcoin. The problem of the public networks lies in the little to no privacy for transactions, meaning that all transactions are visible to all participants. Also, public blockchain requires a huge amount of computational power to maintain a distributed ledger on a wide scale (Jayachandran, 2017). Thus, it seems reasonable to argue that investors would be interested in BC-SC consortium adaptations compared to public ones.

Industrial BC consortia don't come without disadvantages. (Pun, Swaminathan, and Hou, 2021) confirms that multiple firms could be concerned with exchanging data on BC Consortium, due to privacy policies intolerance. Also, the different interests between the competitors of the same consortium could create additional costs (Vakili and Kaplan, 2021). Thus, investors might perceive those risks and limit their valuation of BC-SC consortia initiatives. Overall, we argue that the potentials and benefits of BC-SC Industrial consortia will outweigh its risk, leading to a stronger positive impact on stock prices adapting them. Thus, we hypothesize:

H3: Firms that are part of ***Industrial BC-SC Consortia*** *will show* ***stronger positive*** *impact in their* ***stock prices*** *when they make blockchain related announcements compared to firms adapting Public or Private BC-SC networks.*

3.4 Deeper look into the Firms Characteristics

- *Effect of Firm Size*

According to (Fama and French, 1995), the size of an organisation can affect its operating performance. The impact of an organization's size on its performance has been extensively researched in the strategic management literature. In addition, multiple empirical research papers focused on diverse issues and their impact on firm value/performance considering firm size as one of the key important factors. Some of these adaptations included: ERP implementations (Hayes, Hunton, and Reck, 2001), IT investment(Im, Dow, and Grover, 2001), supply chain glitches(Hendricks and Singhal, 2005), outsourcing (Hayes, Hunton, and Reck, 2000) and product introduction delays(Hendricks and Singhal, 2008). The size of the firm play a role in adoption of BC-SC practices. An earlier paper by (Cahill et al., 2020) investigated the impact of the size of the firms when investigating the market reaction to general blockchain related announcements (not specific to BC-SC like this study). By categorizing, the announcements into large and small firms using market capitalization as a reference, it was found that an average abnormal return on the announcement day for smaller companies is greater compared to larger companies. Thus, it is logical to check if firm size has any impact in our analysis, which is considered similar to (Cahill et al., 2020) in its interest in the market reaction of BC technology but with a special focus on Supply chain management only. Now, the question is will the market react similarly to small firm announcing its plans for getting involved in BC-SC initiatives. Another key factor to evaluate the impact of firm size is the **"Capital valuation theory"**. According to the Capital Valuation theory, smaller businesses' announcements of additional capital expenditures elicit higher market reactions than larger firms' disclosures (Atiase, 1985). Similarly, (Im, Dow, and Grover, 2001) provides empirical evidence of large returns for smaller enterprises in the context of IT investment. Hence, we hypothesize:

*H4: **Smaller firms** making Blockchain announcements for SCs will show more **positive** impact on **stock prices** than larger firms.*

- *Impact of research and development (R&D) Intensity*

The existing literature suggests that well-orchestrated R&D activities are important to implementation of successful innovation practices. (Savrul and Incekara, 2015) confirms that the rapid increase in the investment in Information Technology (IT) and communication areas and the impact of such investments on shareholders wealth, is one of the widely researched area, showing that the role of technology enhancements on the economy. Thus, companies from diverse sectors have been innovative to maintain their forefront in the global competitive environment. Also, (Helpman, 1998), shows that previously, due to problems in measuring innovation contribution to economic growth, it was not included in economic growth related studies, however current studies of economic growth put technology and innovation in the center. Accordingly, multiple indicators were introduced to quantify the gap between the complex technological solutions and economic value added to the firms adapting them. Among these variable, R&D intensity is one of the most prominent (Yiu et al., 2020; Chan, Lakonishok, and Sougiannis, 2001). Thus, firms with a high R&D intensity are thought to have superior competence, execution, and experience in creative R&D projects, and hence are more likely to innovate effectively. In multiple studies on firm performance, R&D intensity has been used as the innovation variable. For instance, (Danak and Rajpurohit, 2017) evaluated the impact of R&D expenditure (that reduces current profit, but has a potential for enhancing future profit) on shareholder value creation in the pharmaceutical industry. The results indicate that companies having higher R&D intensity command higher valuations in terms of Market Value to Book Value ratio. Similarly, in a developing market environment, (Zhang et al., 2007) investigated the contingent link between R&D intensity and performance of international joint ventures (IJVs). The result indicated that, IJVs with an export market emphasis and where multinational businesses (MNCs) possess a majority stake, R&D intensity is positively connected to performance. From Circular Supply Chain (CSC) prospective,(Chen et al., 2021), explores the link between R&D intensity and supply chain management for high-tech manufacturing enterprises in China to learn more about how to boost CSC adoption in emerging nations. From panel data of 310 Chinese listed companies from 2006 to 2019, it was concluded that R&D intensity positively affects firms' CSC adoption. From Blockchain perspective, (Sun, Fan, and Hong, 2018), presented some challenges of using blockchain widely in different domains and from the perspective of technology, lack of R&D investment was among the mentioned challenges. The author stated that "behind the rapid development of the blockchain industry, there is a hidden reality of insufficient investment in the R&D of the underlying blockchain technology". Among the recommendations was increasing R&D investment in architecture, verification mechanisms, consensus algorithms,(cross-chain) communication protocols, and hardware to achieve the needed objectives such as: performance and security. Thus, we expect that the stock market reacts more positively to the BC-SC announcements made by firms that address this challenge, which formalizes H5 as:

*H5: Firms with **high R&D intensity** will show **stronger positive** impact in their **stock prices** when they make BC-SC related announcements compared to firms with low R&D intensity.*

- *Effect of early adoption of BC-SC initiatives*

Early adaptation of innovation has been addressed in multiple IT and Supply chain initiatives. According to diffusion of Innovation theory, individuals in a social system do not all accept innovations at the same time. Instead, they tend to adopt in a chronological order, and may be divided into adopter types based on how long it takes them to implement a new concept. Practically speaking, knowing which group the adaptors fall into is extremely beneficial for a change agent, as most change agents' short-term purpose is to assist the acceptance of an invention. Therefore, we see in the literature some studies addressing SC initiatives (Green SC and ERP adaptations) using the diffusion of innovation theory. For example, (Zhu, Sarkis, and Lai, 2008) argued that early adaptors of Green SC initiatives have an advantage over the late adaptors as they are aware of the benefits and the economic gains that can be achieved from the initiative first hand. Arguably, (Westphal, Gulati, and Shortell, 1997) confirmed that late adaptors are likely to benefit and learn from the mistakes of the early adaptors and also work with a standardization that was not found in the early stages. The same arguments were raised for IT initiatives that serve SC sector. In general, time delays have negative impacts on business. (Forrester, 2012) studied the impacts of decision-making delays in a business system that included a factory, a warehouse, and various retailers, and developed a model to demonstrate the negative implications of such delays on an organization's performance. Also, there are other studies that show that late joiners to initiatives tend to have higher costs on the long run (Review, 2014), less market share (Robinson and Fornell, 1985; Urban et al., 1986) and more importantly negative impact on the stock prices (Hendricks and Singhal, 1997). Reflecting this on BC-SC initiatives, to the best of our knowledge no studies tackled the early adaptors edge so far. Thus, we argue that following the same theoretical approach of previous initiatives, early BC-SC adaptors will demonstrate more positive performance than late ones. Hence we hypothesize:

H6: Firms that are ***early adopters*** *of BC-SC initiatives will show more* ***positive*** *impact in* ***stock prices*** *than firms that are late adopters.*

Chapter 4

Research Methodology

This chapter is divided into four sections. In the first section, we discuss the systematic approach used to construct the sample. Then, the second section presents the construction of sub samples to address each of the developed hypotheses respectively. The Third Section is a summary of the main sample characteristics and the last section covers the event study methodology and the design flow used to measure the impact of BC-SC announcements on the stock returns and their corresponding statistical significance.

4.1 Sample Construction

First, our sample of BC-SC events is collected from Nexis Uni (formerly Lexis Nexis) database using “Blockchain” and “Supply chain” as the two main search keywords, resulting in a total of 1,890 news headline and their associated dates. We follow a systematic approach illustrated in figure 4.1 to achieve a sample that reasonably represents the market interest in blockchain technology particularly for supply chains from the original 1,890.

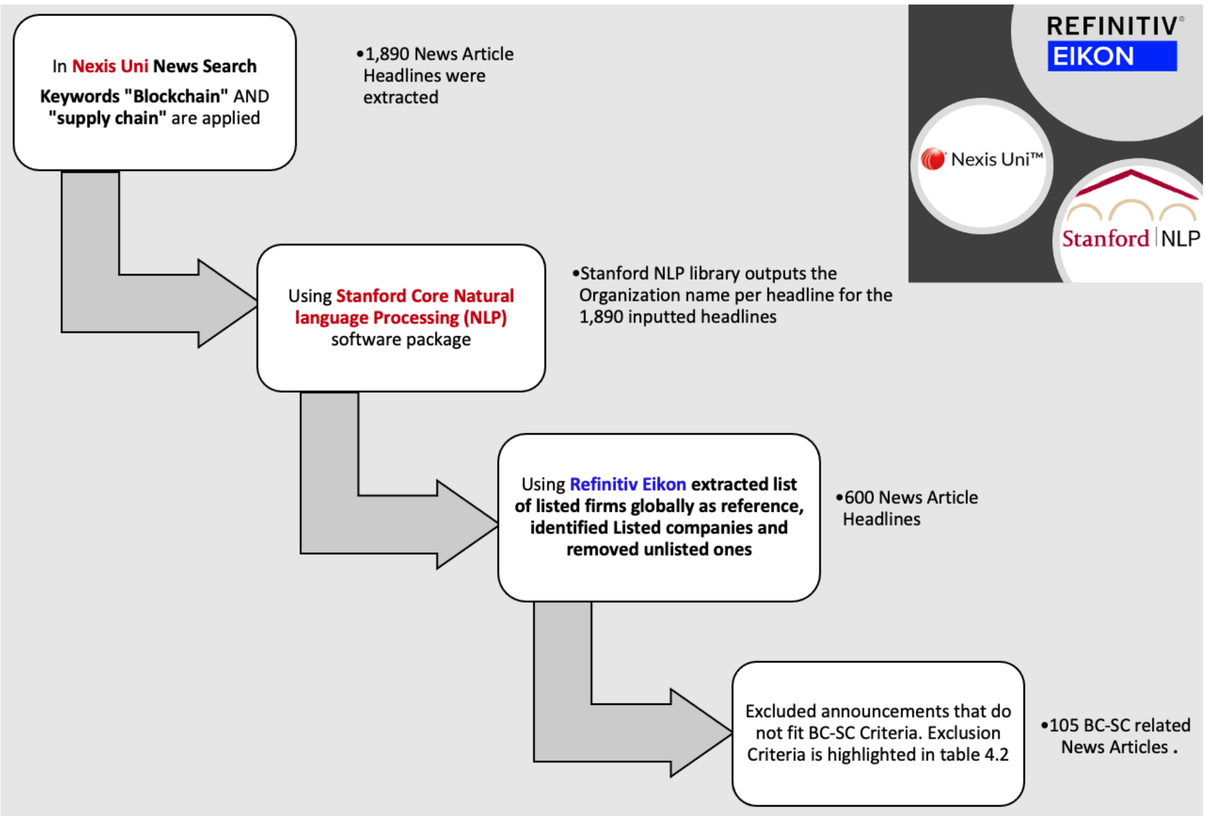

FIGURE 4.1: Data Filtration and Methodology Flow

Second, using Stanford Core Natural Language Processing (NLP) software packages, particularly Named Entity Recognition (NER) package, the firm names in the news headlines are captured. Stanford CoreNLP is a set of natural language analysis tools that can take raw English language text input and return the base forms of words, their parts of speech, whether they are names of companies, people, or other entities, mark up the structure of sentences in terms of phrases and word dependencies, and show which noun phrases refer to the same entities. How does it work? The centerpiece of CoreNLP is the pipeline. Pipelines take in raw text (in our case: news headlines,) run a series of NLP annotators on the text and produce a final set of annotations. Multiple packages are embedded with the software that enable tagging/labelling the components of a sentence, which has multiple uses like machine translation, sentiment analysis and identifying named entities among other numerous applications. For the scope of this study, a systematic approach is needed to identify all organization/firm names per each headline. "Named Entity Recognition" – NER package with Stanford NLP package comes a fitting solution for this goal. To illustrate on the look and feel of CoreNLP output (particularly NER package). Figure 4.2 shows an example of the output using a headline in the sample and how it is segmentated and labelled with annotators. The key feature in the output is the ability to label the firm name in the headline as "Organization", this was conducted on all 1,890 headlines, resulting in a new list in the data set that includes all organization names in each headline.

Third, the firm names extracted from the CoreNLP – NER package are used to further filter the data, by comparing the CoreNLP firms' list against a list of listed companies globally extracted using Refinitiv Eikon Datastream. Only headlines which have at least one listed company are kept and the remaining with unlisted companies' in the headline are removed. This step reduces the number of headlines in the data set to 600 headlines.

FIGURE 4.2: Stanford CoreNLP annotation Example

Fourth, the list of keywords in Table 4.1 is then applied to obtain BC-SC announcements only and exclude any irrelevant or confounding announcements. The following types of announcements are excluded:

1. **Announcements in which firm names (allocated using NER- Stanford NLP) are unlisted**. To quantitatively analyze the impact of BC-SC, only listed firms that use blockchain for enhancing their supply chains will be considered in the scope of this study. This is due to the data availability for listed firms such as firm characteristics (like market capitalization, expenses...) as well as firms' daily performance represented by its stock price. Thus, using a Refinitiv Eikon extracted list of listed firms globally as reference, a cross check is conducted on the extracted NLP firm names. By comparing the two firm lists, 600 firm names per headline (obtained via Stanford NLP) are labelled as listed.

2. **Announcements in which firm names are allocated by NER - Stanford NLP and the firm names are for Blockchain Vendors only.** For example, "Blockchain in Supply Chain Market to Witness Huge Growth by 2026: Key Players: Microsoft, IBM, Oracle". NER – Stanford NLP captures "Microsoft, IBM, Oracle" as the firm names in the headline. Since they are BC Vendors and not adaptors(users), this announcement will be excluded and so on. The list of BC vendors (solution providers) is selected based on published market surveys and BC-SC literature. For instance,(Chang, Iakovou, and Shi, 2020)mentioned IBM, SAP and Oracle as blockchain solution providers for multiple supply chain initiatives in numerous industries like Transportation, Pharmaceutical and Food Supply chains. In addition, research market reports like "Statista" and "Research and Market" published that the growing Blockchain market particularly for supply chains are dominated by the vendor profiles in table4.1 - Panel A.

3. **Announcements in which multiple firm names are allocated by NER – Stanford NLP, however, none of the firms adapting BC solution are listed**. Only solution provider firms are listed. For example, "PIL, PSA and IBM to develop blockchain technology in supply chain business", where BC Adaptors: PSA (PSA International) and PIL (Pacific International Lines) are

Panel A

Major vendors in Global Blockchain as a Service Market	**Country**
IBM	US
Microsoft	US
SAP	Germany
AWS	US
Huawei	China
R3	US
HPE	US
Accenture	Dublin
Wipro	India
Infosys	India
Bitfury	Netherlands
Factom	US
LeewayHertz	US
Altoros	US
VeChain	China
Salesforce	US
OpenXcell	US
Oodles Technologies	India
Blocko	South Korea

Panel B

Keywords	
Patent	Award
Conference	Dividend
Enumeration	Appoints
Board	Acquisition

TABLE 4.1: Keywords used as Exclusion Criteria

not listed companies, while BC Vendor (IBM) is listed. To capture this type of announcements, vendor providers names in Table 4.1 - Panel A will be used as reference.

4. **Announcements that include the firm applying for a patent after a BC collaboration**. The main aim from these announcements is subsidies, which will have a positive effect on firms. An example is "General Electric Applies for Patent on Blockchain Enabled Collaborative Transaction Information Processing for a Supply Chain". "Patent" is used as the main keyword to categorize this type of announcements.

5. **Announcements that are marketing related such as awards, conferences and how BC impacts ESG initiatives**, which have little relevance to the business operations of the firm. For instance, "United States: IBM's Global Supply Chain Transformation Wins 2019 NextGen Supply Chain Leadership Award for Blockchain and IoT"

6. **Confounding announcements for the same firm within a period of three trading days**, ranging from the previous trading day before the event day to the next trading day after the event day. This category of announcements includes dividends or acquisitions or enumeration announcements. Table 4.1 - Panel B, summarizes the keywords used for the last three exclusion criteria.

7. **Announcements that are follow-up reports to previous BC-SC announcement**. If a BC-SC event appears in more than one announcement, then we retain the announcement with the earliest publication date.

Table 4.2 shows the exclusion criteria and its equivalent removed number of announcements. Excluding confounding announcements is one of the event study requirements discussed in details in Section 3.3. The market reaction of the firm can be confounded by multiple events. The event study requirements help reduce the possibility of conflicting events driving the stock market reaction and exclude events that are outside the scope of this study. Our final sample consists of 104 announcements. This gives us one announcement per firm in our sample, which covers a period from September 2016 to August 2021.

Announcement Type	Number
Announcements matching Keywords: "Blockchain" and "Supply chain"	1,890
Announcements related to private firms	1,290
Announcements related to BC Vendors only	361
Announcements related to marketing (e.g. Awards, conferences, patents,...)	46
Announcements confounded by other news	18
Announcements that are follow-up reports to previous BC-SC announcement	71
Number of announcements selected for analysis	**104**

TABLE 4.2: Exclusion Criteria

4.2 Sample Characteristics

Table 4.3 provides the descriptive statistics of the BC-SC announcements samples. The number of announcements by year is shown in Panel A. The peak number of BC-SC announcements occurred in 2019 and represent 37% of the sample set. The majority of 2019 announcements were for US listed companies, like for example Pfizer, McKesson, AmerisourceBergen joining MediLedger pharma contracting blockchain group, and Starbucks teaming up with Microsoft to track its coffee beans. The rest of the sample years observe smaller numbers of BC-SC events, with a slightly increasing trend over time. It is worth mentioning that starting November 2019 until May 2020, no announcements were captured on our sample set, this could be due to COVID-19 outbreak at the time. However, the number of announcements start to increase from July 2020 and continue to rise until the first half of 2021. In addition, a single announcement was captured that covers the use of BC-SC solution to foster near real-time tracking of vaccine administration during the pandemic. The announcement was published by IBM and Moderna in March 2021 stating that "Moderna and IBM Plan to Collaborate on COVID-19 Vaccine Supply Chain and Distribution Data Sharing". Since this is the only announcement involving COVID-19 captured in our dataset and it is still speculative news, i.e., no actual collaboration occurred until this study was completed. Thus, the impact of COVID-19 is not part of the scope of this study. Panel B shows the sample distribution across 21 industries. More than half of the sample (60%) belongs to Transportation Equipment (15%), Chemicals and Allied Products (13%), Metal Mining(11%), Food and Kindred Products(11%) and Oil and Gas Extraction(10%). The top two industries entail the automotive manufacturing industry and the pharmaceutical industry respectively. Thus, BC-SC initiatives are most prevalent in those two areas, followed by the Metal Mining and Oil Gas industries. Panel C presents the sample distribution by region, half of the announcements in the sample were made by companies in the NAM region, where approximately 46% of the announcements are made by US firms. Although, China come after US representing 10% of the observations, still EEMEA (32%) as a region endorsed more BC-SC initiatives than APAC(18%).

TABLE 4.3: Descriptive statistics of the BC-SC announcements

Panel A: Sample Distribution Over Time							
Year	2016	2017	2018	2019	2020	H1 - 2021	Total
Number of Observations	1	6	15	38	23	21	104
Percentage (%)	1%	6%	14%	37%	22%	20%	100%

Panel B: Sample Distribution Across Industries			
Industry Distribution	2 Digit SIC	Number of Observations	Percentage (%)
Transportation Equipment	37	16	15%
Chemicals and Allied Products	28	14	13%
Metal Mining	10	11	11%
Food and Kindred Products	20	11	11%
Oil and Gas Extraction	13	10	10%
Industrial and Commercial Machinery and Computer Equipment	35	10	10%
Transportation Services	47	7	7%
General Merchandise Stores	53	3	3%
Wholesale Trade	51	3	3%
Business Services	73	3	3%
Miscellaneous Retail	59	3	3%
Health Services	80	2	2%
Depository Institutions	60	2	2%
Fabricated Metal Products, except Machinery and Transportation Equipment	34	2	2%
Electronic and other Electrical Equipment and Components, except Computer Equipment	36	1	1%
Railroad Transportation	40	1	1%
Real Estate	65	1	1%
Bituminous Coal and Lignite Mining	12	1	1%
Eating and Drinking Places	58	1	1%
Paper and Allied Products	26	1	1%
Motor Freight Transportation and Warehousing	42	1	1%
	Total	104	100%

Panel C: Sample Distribution by Region

Region	Number of Observations	Percentage (%)
APAC	**19**	**18**%
India	1	1%
Taiwan	1	1%
South Korea	1	1%
Japan	6	6%
China	11	11%
EMEA	**33**	**32**%
Austria	1	1%
Finland	1	1%
Russia	1	1%
United Arab Emirates	1	1%
Denmark	1	1%
Italy	1	1%
Netherlands	1	1%
Belgium	2	2%
Sweden	2	2%
United Kingdom	3	3%
Switzerland	5	5%
France	6	6%
Germany	7	7%
NAM	**52**	**50**%
Canada	4	4%
United States	48	46%
Grand Total	104	100%

4.3 Event Study: Estimating Abnormal Returns and Test Statistics

We use an event study approach to assess the market reaction of BC-SC announcements. Particularly, we compute a measure of abnormal return, which is an estimate of the percentage change in stock prices associated with a BC-SC event. This approach is widely used in the field of accounting and finance (Henderson, 1990)and is appropriate for the scope of this study because it allows investors to estimate the instantaneous impact of the action taken by the firms (Borah and Tellis, 2014; Fama et al., 1969; Hiau Abdullah, Abdul Rashid, and Ibrahim, 2020; Klassen and McLaughlin, 1996). The other alternative would be to wait and check the impact based on accounting measures, such as ROI or profitability, that are not immediately available, they are rather published on low frequency (annually or quarterly), which makes it difficult to capture the value-added from the event only, because these metrics provide insights about the overall performance of the firm. In addition, "event study has become a classic because it works". It can be used under less than perfect conditions and still produce reliable results (McWILLIAMS and Siegel, 1997; Henderson, 1990).Thus, the event study method has been selected for this research. The event study design follows a certain convention (McWILLIAMS and Siegel, 1997; Sorescu, Warren, and Ertekin, 2017). It starts with ***determining the event window*** for a BC-SC announcement; where the day of the announcement is denoted as Day 0, the next trading day as day 1 and the previous trading day as day -1. The event date (the day of the announcement) in our case is the earliest date when a firm announces adapting BC for supply chain purposes. Since most of the data includes international firms, we account for differences in time zone, exchange close times, weekends, and public holidays. If an announcement occurs after the market closure or on a non-trading day, the next available trading day is considered the announcement day (Day 0). Also, to account for news leakage, a time window that includes at least one day prior to the event, to account for the possibility that some information was leaked to the market about the upcoming event. Event windows typically range in their length between 1 and 11 days and centre symmetrically around the event day (Holler, 2014). According to a literature survey paper by (Oler, Harrison, and Allen, 2007), the most common choice of event window length is 5 days, representing 76.3% of the reviewed studies. Thus, our model will have an event window of 5 days (2 days prior to the BC-SC announcement, 2 days post the BC-SC announcement and the announcement day). Figure 4.3 shows the event windows used in the scope of this study adapted from (Benninga, 2008).The estimation window usually varies between 30 to 750 days (Holler, 2014). Also, studies investigating the sensitivity of results (e.g., the predicted return on the event date) suggest that results are not sensitive to varying estimation window lengths as long as the window lengths exceed 100 days (Armitage, 1995; Park, 2004). Thus, an estimation window of 109 days is used in our case, leaving 9 days between the estimation and event windows to avoid any confounding events' impact.

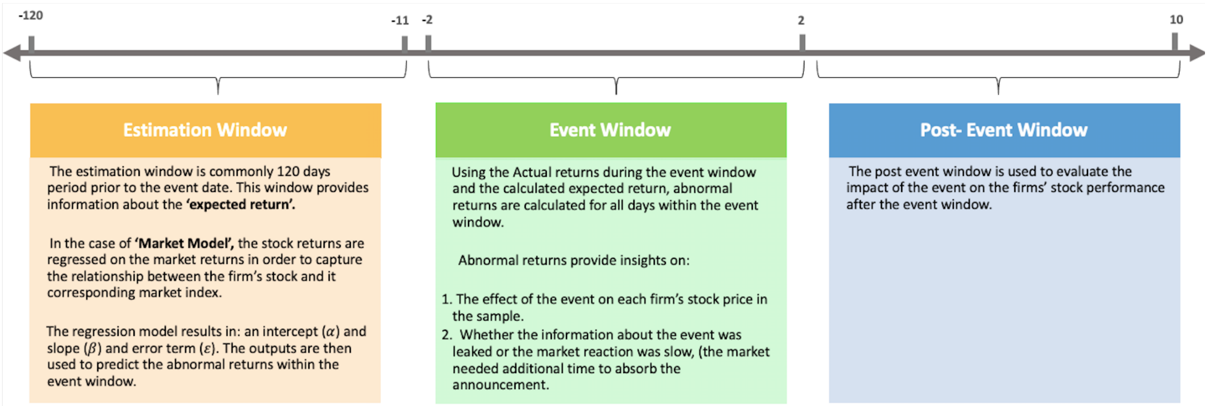

FIGURE 4.3: Event Windows Used

The second step of the event study design is ***Data Source Selection***. This step involves identifying the correct data source that provides optimum coverage and at the same time the correct event date (i.e., the first date when the event became public). Early event studies usually focused on announcements published by major publications such as the Wall Street Journal (e.g.(Chaney, Devinney, and Winer, 1991)). More recently, researchers are inclined to use news Databases like Factiva and Nexis Uni (previously known as: Lexis-Nexis). The databases include a broad selection of news wires such as: The Guardian, Financial Times, Telegraph, the New York Times, which upturns the number of captured announcements. Multiple event studies have relied on one of the mentioned databases for example (Borah and Tellis, 2014; Homburg, Vollmayr, and Hahn, 2021; Sood, James, and Tellis, 2009; Urbschat and Watzka, 2020). Thus, to collect BC-SC announcements, Nexis Uni was used as the primary source for data collection. Nexis Uni captured multiple companies' press releases, BC-SC announcements from newspaper articles like Financial times, Telegraph, New York Times, Reuters and others. The third step of the event study design is ***overcoming confounding effects due to overlapping events.*** One of the main concerns in event studies is handling scenarios where one entity makes multiple announcements in proximity (Sorescu, Warren, and Ertekin, 2017). For example, a firm may announce the introduction of a new product a day after they have announced their dividends increase. If the measurement window for the abnormal returns includes the dividends increase announcement, the change in stock's price will be reflecting the effect of the two announcements. This is referred to as the "confounding effect" and it is usually encountered and eliminated from event studies. Thus, to capture the impact of BC-SC announcements only, confounding, and duplicated announcements were removed. Table 5 highlights the systematic approach followed to eliminate confounding, duplicate and irrelevant announcements.

The fourth step in the event study design is the ***Selection of an appropriate asset pricing model.*** This step includes selection of the metric to evaluate the investors' reaction to the event of interest. The metric is based on abnormal stock return, which is calculated as:

$$AR_{it} = R_{it} - E(R_{it}) \quad (4.1)$$

R_{it} is the actual rate of return of the stock of firm i at period $(t-1, t)$ and $E(R_{it})$ is the expected rate of return of the stock of firm i at period $(t-1, t)$. Thus, the abnormal return represents the difference between the actual and expected returns over a certain period. Abnormal returns are measured using daily stock data obtained from Refinitiv Eikon (formerly Thomson Reuters Eikon), depending on the measurement horizon selected for the focal event where:

$$R_{i,t} = ln(P_{i,t}/P_{i,t-1}) \quad (4.2)$$

The expected returns are calculated using various models and this where a selection must be made. Models like market model, market adjusted model, Capital Asset Pricing Model (CAPM) and Fama- French model have been adapted in multiple event studies.

Market model has been selected as the appropriate model for this study based on two reasons:

1. The performance of Asset pricing models (referring to Market, market adjusted, CAPM and Fama-French) is similar over short-term windows. (Brown and Warner, 1985), being an original reference for short term event studies (those conducted using daily stock data) concluded that: (1) "the performance of these models is very similar over short-term windows. The expected returns over a one-day period are close to zero, while the returns associated with events of interest are often higher than 1% in magnitude. Thus, if the stock is expected to return 10% per year, its daily expected return is 10/250 = 0.04%. When subtracting a small number from 1% it does not matter if that number is 0.05% or 0.03%. This issue, however, becomes critical over the long-term horizon.". This conclusion was also verified in the scope of this study, by conducting the event study using the 4 models, results of this comparison are highlighted in figure 4.4. Although general comparisons between the models, usually refer to multi factor models (e.g. Fama French 3 Factor Model) as better approaches because they take into consideration additional factors (such as: size, value and market risk factors), this happens to be true but not for short term event studies, as all models are still similar on short-term windows. (2) (Brown and Warner, 1985)confirmed that the Fama French Factor Models, are designed to compute abnormal returns for long -term event studies using monthly data and examine the abnormal returns of portfolio of stocks tracked over long-term periods (in the case of Fama and French, for 342 months).

2. Most studies used the 'market model', since abnormal return biases tend to be small, most researchers interested in the economic impact of a certain event, rather than methodological approaches, still use the 'market model'. A literature survey paper focusing on the models used for event studies (Holler, 2014) found that in its sample of 400 reviewed event studies, 79.1%

of the studies used the 'market model', 13.3% the 'market adjusted return model', 3.3% the 'constant mean return model', 3.6% 'multi-factor models', and only 0.7% the CAPM model.Thus, market-model was selected for the scope of this study.

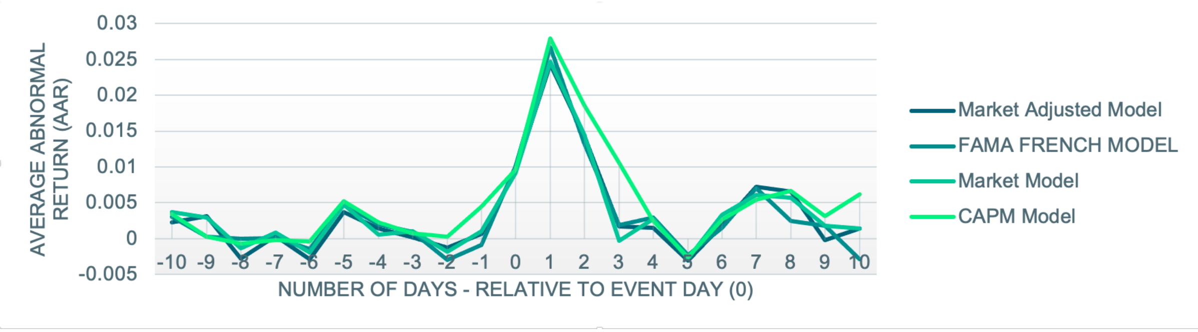

FIGURE 4.4: Asset Pricing Models Compared

After calculating the natural logarithm of returns in equation 4.2, we use the market model to estimate abnormal returns as follows:

$$AR_{i,t} = R_{i,t} - \alpha_i - \beta_i \left(R_{m,t} \right) \tag{4.3}$$

Where, on a day t, $AR_{i,t}$ is the abnormal return and $R_{i,t}$ is the actual return for stock i, and $R_{m,t}$ is the SP500 index for US listed companies, and other country specific indexes for firms listed in other countries (e.g. DAX Performance index for Germany, SSE Composite Index for China and so on). $alpha_i$ is the y-intercept, $beta_i$ is the slope that measures the sensitivity of $R_{m,t}$. $beta_i$ is estimated using returns from the pre-event window [-210,-30], that is also referred to as the estimation window. Studies investigating the sensitivity of results (e.g., the predicted return on the event date) suggest that results are not sensitive to varying estimation window lengths as long as the window lengths exceed 100 days (Armitage, 1995; Park, 2004). Thus, this model requires that each company to have at least 100 days of trading history prior to making the announcement, which has been verified on the 104 data points. Accordingly, we calculate the abnormal return (AR_0) as the return for company i on the event day and the cumulative abnormal return (CAR) for the pre-event window [-10,-2], event window [-2,2] and the post event window [2,10]. For each firm stock i , CAR is calculate for an event interval [T1,T2] and calculated using Eq.

$$CAR_{i;T1,T2} = \sum_{t=T1}^{T2} AR_{i,t} \tag{4.4}$$

The abnormal and cumulative returns averaged over all firms (N) are given by:

$$\overline{AR_t} = \frac{\sum_{i=1}^{N} CAR_{i;T_1,T_2}}{N} \tag{4.5}$$

$$\overline{CAR_{T_1,T_2}} = \frac{\sum_{i=1}^{N} CAR_{i;T_1,T_2}}{N} \tag{4.6}$$

The fifth step in the event study design, is to calculate corresponding test statistics to determine the significance for each event window. To test whether the abnormal returns and cumulative abnormal returns are significantly different from zero, we use parametric t-statistics to determine the statistical significance of the mean abnormal returns and non-parametric test like the Generalized Sign Z statistic to determine whether the percentage of positive abnormal returns is significantly greater than 50%. The t-statistic is computed as:

$$t_{CAR_{T_1,T_2}} = \frac{\overline{CAR_{T_1,T_2}}}{\frac{1}{\sqrt{N}}\sigma\ \left(\overline{CAR_{T_1,T_2}}\right)} \tag{4.7}$$

Where:

$$\sigma\ \left(\overline{CAR_{T_1,T_2}}\right) = \left(\frac{\sum_{i=1}^{N}\left(CAR_{i;T_1,\ T_2} - \overline{CAR_{T_1,T_2}}\right)^2}{N-1}\right)^{1/2} \tag{4.8}$$

4.4 Determination of sub-samples

In order to determine the sub-samples, we characterized the firms in the data sample according to a number of factors based on hypotheses H2-H6.

4.4.1 BC-SC Objectives Categorization

For H2, by reading the articles, we grouped all the sample by assigning it to one or more **SC objective** for adapting BC for SC purposes. Based on the articles content, we found that the objectives for adapting the BC solutions matched multiple ones that were allocated in the literature. The objectives (in the announcements) fitted 6 main objectives that were repeated as the main benefits for BC-SC in multiple literature survey papers (Chang, Iakovou, and Shi, 2020; Wang, Han, and Beynon-Davies, 2019). The common 6 objectives are (1) Traceability, (2) Dispute Resolution, (3) Cargo Integrity Data Security, (4) Digitalization, (5) Compliance and (6) Trust Stakeholder Management. Another important observation, is that most of our data set announcements fits multiple objectives in the same article. For example, on January 16^{th}, 2019, Forbes published an article with the title "Ford Motor Company Launches Blockchain Pilot On IBM Platform To Ensure Ethical Sourcing Of Cobalt", by reading the article, both **traceability** and **compliance** are mentioned as targets for using BC technology. In this example, Ford uses blockchain technology to trace and validate ethically sourced minerals to comply with industry standards. Thus, for that particular example we categorize the announcement by setting entries under traceability and compliance to "1" and the remaining 4 objectives to "0" and so on for the entire 104 announcements in our sample.

Four examples with their categorizations are provided below:

Example 1: *"Carrefour, a European leader in food traceability through the gradual application of blockchain technology to its Carrefour Quality Line products, has joined other participants involved in building the IBM Food Trust platform. The objective of the collaboration between Carrefour and IBM Food Trust is to implement a global food traceability standard across all of the links in the chain– from producers through to sales channels."*
This first example of BC-SC Objective is classified as **Traceability** objective due to aim of creating clear links from producers to suppliers, and also is considered a **Compliance** Objective as it aims to meet global food traceability standard. Another objective that is mentioned in the article is Trust Stakeholder Management, as the company joined forces with IBM and joined IBM Food Trust, to help *"ensure that the information that reaches stakeholders like consumers is reliable, and transparent"*. Thus, **Trust Stakeholder Management** is classified as the third objective for this announcement.

Example 2: Pharmaceutical industry is one of the leading industry in the BC-SC initiatives, multiple projects launched early on compared to other industries. This example covers one of those projects, the Mediledger BC Consortium. The consortium includes increasing number of pharmaceutical companies. This article in the sample was announcing Pfizer, McKesson and AmerisourceBergen joining Mediledger in 2019, along with Group Purchasing Organization (GPO) Premier which represents more than 4,000 hospitals. Other companies are involved but chose not to be part of this announcement(Ledger, 2019). There are multiple challenges in the pharmaceutical industry that Mediledger is trying to over come, first, resolving contractual dispute between the 3 key entities in the industry: pharmaceutical companies, Wholesalers and GPOs. *"That involves the pharma company charging one price to the wholesaler, but the wholesaler needing to sell to the GPO at a special low price agreed between the GPO and pharma company. As a result, the wholesaler has to know the discounted GPO price and also recoup the discount from the pharma company as a charge back."*. Another challenge addressed by Mediledger is the Cargo Integrity Data Security. The project aims to secure and monitor all the data related to the drugs and pharmaceutical products in recording on real-time basis the back and forth data between all entities in the supply chain by using BC. This was explained in the announcement by stating : *"In addition to the GPO discount prices, the wholesalers need to know which hospitals are currently members of the GPO and whether it is currently eligible for discounts. And the prices and hospitals are continually changing causing issues with synchronizing data and providing ample scope for error. Blockchain is being used to keep track of the latest changes and provides a real-time capability as opposed to batched data"*. Therefore, this announcement was classified as **Dispute Resolution** and **Cargo Integrity Data Security**.

Example 3: *"The world's fifth and sixth largest container shippers, Hapag-Lloyd and Singapore-based Ocean Network Express (ONE) have now integrated with the TradeLens blockchain, the container shipping industry network. It's been almost two years since the two carriers first announced plans to participate in the network, a joint initiative from IBM and Maersk. TradeLens aims to digitize shipping data, automate processes and enable participants to share data in a permissioned manner using enterprise blockchain"*.
This BC-SC announcement is classified as **Digitalization** as one of the primary objectives of the Tradelens BC Consortiums (that Hapad-LIoyd is now a member) is the digitalization of shipping data and accordingly automating the process. Example of steps toward digitalization are: (1) bringing all stakeholders in the supply chain to a digital ecosystem where both internal stakeholders (part of the same contract and members of the Tradelens consortium) and external stakeholders (customers) have access to transparent and secure data of shipping milestones and trade documents. Also, the announcement mentions a second objective, which is establishing **Trust** among **Stakeholders**, not only for the customers but also the importing regulators who are facing the asymmetric trust problem as it is getting harder for them to verify the origin of issuers of certificates of cross-border trade, however by the use of BC in the shipping industry, where the consensus is achieved only when all participants agree to the same version of the ledger, all the needed information can be verified and audited in real time with little cost.

The most common SC objective in our sample is **Compliance**, with 81 out of 104 BC-SC announcements, equivalent to 77.14% of the announcements. The second SC Objective is **Traceability**, with 76 out of 104 announcements, equivalent to 72.38%. **Dispute Resolution** and **Cargo Integrity Data Security** are the least targeted SC objective in our sample, with 11 and 13 occurrences at 10.48% and 12.38% respectively. Digitalization (39.05%) and TrustStakeholder Management (38.10%) have roughly similar proportions.

Another important observation in this sub-sample, is that most of the announcements targets more than one SC objective (around 85% of the sample) . In other words, the companies adapting BC-SCs are using the new technology for multiple purposes in a way that overcomes critical challenges simultaneously. Fig 4.5 shows the distribution of objectives per announcement, the most common number of objectives per announcement is 2, with 34 out of 104, equivalent to 36% of the announcements. The second dominating count per announcement is 3, with 28 out 104 announcements, equivalent to 27%. The least occurring count is 5 objectives per announcement, with only 5% of the total sample.

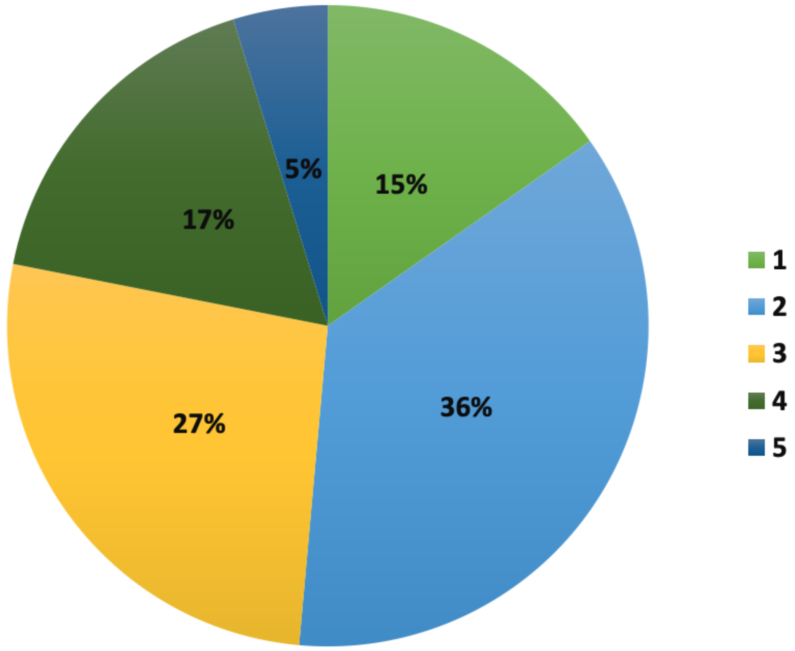

FIGURE 4.5: Number of objectives per announcement

4.4.2 Industrial BC Consortium Categorization

Similar to the approach followed in the previous section, for H2, the sub-sample for H3 was determined by reading the 104 articles. Based on the articles content, we answered the question "Is the company/companies mentioned in the announcement part of a BC Consortium (collaboration)?" and accordingly, assigned a "Yes or No" label to the announcement as well as the name of the announced collaboration. As highlighted in section 2.1.3, there are different types of BC that can be deployed to fit the business need. So, to answer the "Yes/No" question, first we differentiate BC types by grouping the BC-SC announcements in our sample into Public, Hybrid, Private and Consortium. This way, only announcements about companies that are part of a consortium were given a label "Yes" and the remaining blockchain types were labelled as "No". The following example announcements show how this categorization was achieved for each BC type.

Example 1: *"Coke One North America Services (CONA), owned by the major Coca Cola bottling companies, is to try out the Baseline Protocol, a* ***public Ethereum blockchain technology*** *targeted at enterprise use cases. Blockchain startups Unibright and Provide jointly announced the project, which was confirmed on LinkedIn by CONA's Director of Innovation"*

The first example of BC-SC announcement is classified as **Public** BC technology deployment, due to the use of public Ethereum platform. A public blockchain network is a blockchain network where members can join whenever they want. Basically, there are no restrictions to participate. More so, the visibility on the ledger and the ability to take part in the consensus process is open for all members. However in that particular example, the use of the baseline protocol allow certain application features on top of the public Ethereum platform. For example, *"The Baseline Protocol enables the internal systems of two or more companies to be synchronized without storing confidential data on the public blockchain. Hence, if a supplier has insufficient stock, instead of the buyer being surprised at the delivery of a different quantity, when a supplier makes an alteration, the change is represented on the blockchain."*

Example 2: *" Japan's NEC Corporation announced a collaboration with Cisco Systems to use blockchain for confirming the authenticity of network equipment used for security areas and industrial infrastructure. In the first phase of the initiative, NEC and Cisco will use their proprietary technologies to verify the authenticity of equipment, and then hash the data on a blockchain. Cisco's 'Trustworthy' technology uses device-specific IDs, digital signatures, and other technical elements to verify authenticity. Meanwhile, 'Tamper Detection' technology from NEC uses embedded software to monitor for any changes made to the devices.*
This second BC-SC announcement example is classified as **private**. In this case, there is a one to one collaboration between NEC and Cisco, aiming to verify the authenticity of Cisco's equipment. The key part of the article that confirms that this privately handled solution is "*Although NEC is a Premier member of Hyperledger, it has its own blockchain solution*", indicating that the private network is operating under NEC and Cisco's supervision in which transactions are accessible by those two entities only.

Example 3: *"Committed to supporting human rights and environmental protection while helping infuse more transparency into global mineral supply chains, Ford Motor Company, Huayou Cobalt, IBM, LG Chem and RSBN Global announced plans to use blockchain technology to trace and validate ethically sourced minerals.* This third example is focusing on the third type of BC types, **BC consortium**. An example is a BC Consortium built on the IBM Blockchain Platform , with the name RSBN (Responsible Sourcing Blockchain Network). The platform is designed to be adopted across automotive industry to allow interested entities of all sizes and roles in the supply chain easy and secure traceability of the product and its manufacturing materials. Accordingly, the consortium has members like: the original equipment manufacturers (OEMs) across the automotive, electronics industries and their supply chain partners such as mining companies and battery manufacturers. The aim for this industry wide network is to trace and validate minerals across the entire supply chain.

Reflecting this on our sample, we found there are 3 types of BC deployments in our data set. Thus, we group all the sample BC-SC announcements into three categories, Private, Public, and Consortium (Hybrid BC is also a considered type of BC deployment, however, none of the 104 announcements mentioned the hybrid type). Figure 4.6 shows the number of announcements representing the BC type distribution among the companies adapting BC-SC. The most common BC type used for SC purposes in our sample is BC Consortium with 78 out of 104 BC-SC announcements, equivalent to 75% of the announcements. This observation comes in sync with multiple sources in the literature that highlighted the benefits of private BCs, especially Consortiums compared to the public BC solutions. These benefits included: security privacy of sensitive data, easier to expand and lead to reducing costs as they feature key SC objectives tackled in H2 such as: traceability and Trust among stakeholders(Coburn, 2018).

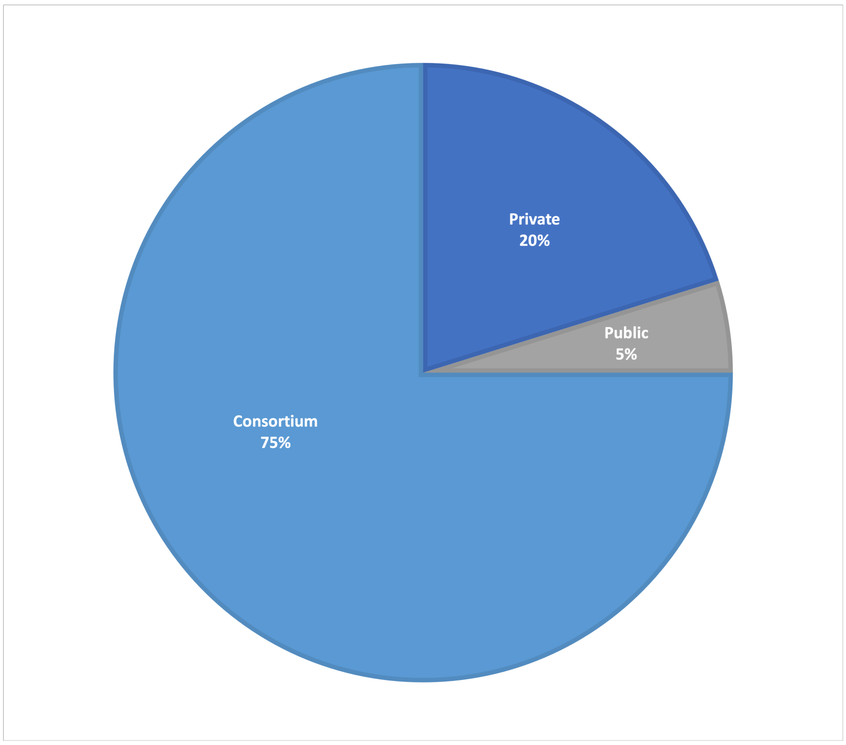

FIGURE 4.6: Types of BC Solutions in the Sample

Figure 4.7 shows a summary of listed companies that are mentioned in the announcements grouped by their BC Consortium and its corresponding high-level industry. H3 Sub-sample covers six industries: (1) Automotive, (2) Transportation & Logistics, (3) Tech. & Electronics, (4)Pharmaceuticals & Healthcare, (5) Energy and (6) Food & Agribusiness.

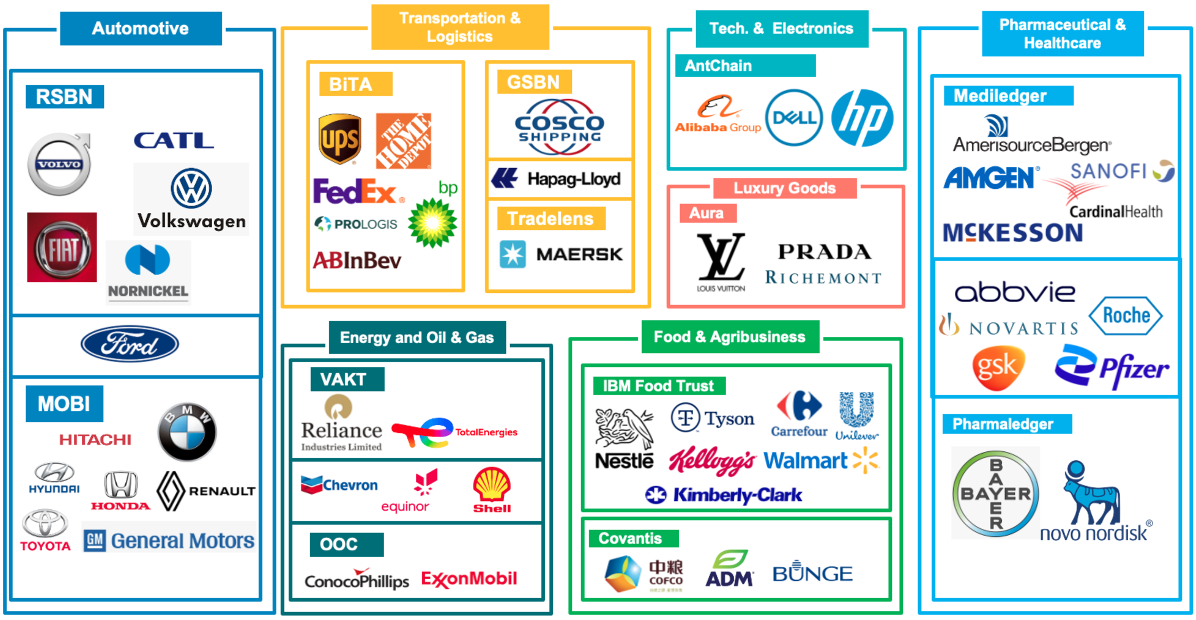

FIGURE 4.7: Companies in the sample categorized by Industrial BC Consortia

There are multiple interesting observations in these industrial collaborations. First, each consortium includes companies that are fierce competitors in the market and the industry. For example, under the Food agribusiness industry, we see that two of the famous competitors in this industry, Unilever and Nestle, are members of IBM Food Trust Consortium. Second, a single consortium has members from different parts of the supply chain, in other words both the upstream and downstream. For instance, the RSBN (Responsible Sourcing Blockchain Network) includes raw material provider Nornickel, that supplies large productions of Nickel, platinum and copper to automotive (among others) manufacturers. Also, CATL (Contemporary Amperex Technology Co. Limited) is a RSBN members as it secures significant and long-term battery supplies with major auto Original Equipment Manufacturers (OEMs) outside of China. From a downstream side, multiple OEMs are members as well such as Volvo, Volkswagen, Ford and Fiat. These observations come in coherence with Deloitte's 2018 Global Blockchain Survey, where 29% of businesses representatives answered the question "which of the following best describes your organization's position on participating in a Blockchain Consortium with competitors?" stating that they've already joined a blockchain consortium, while 45% confirmed they are likely to join one within the next year and 13% said they're interested in starting a private consortium(Deloitte, 2018).

So **what's the motivation for these competing businesses to work together?** To better understand the benefits of working together and improvements blockchain technology introduces, the consortia in our sample are analyzed case by case.

(1) Responsible Sourcing Blockchain Network (RSBN)

RSBN is an automotive BC consortium built on IBM platform, that aims to introduce key SC sustainability factors economically and socially. Cobalt (essential raw material for lithium-ion batteries) as well as other minerals (like lithium, nickel, copper) are key industrial components that pose responsible sourcing risks, and carry a high cost in human suffering. More than 60%of the world's cobalt supply comes from the Democratic Republic of Congo (DRC), where children and adults labor under harsh and dangerous conditions to extract ore by hand. Multiple manufacturing companies want to keep such circumstances out of their supply chains and at the same time have full visibility on their raw material sources, in that case from "cobalt to battery". This is where BC comes in, by creating an immutable audit trail that documents proof of ethical production of a raw material and its maintenance at every step from mine to manufacturer. More importantly, without relying on any third-party audits to establish compliance, instead miners, smelters, distributors and manufacturers are all directly connected via a distributed ledger. The ledger tracks production from mine to battery to end product, capturing information regarding responsible sourcing at each step of the supply chain. As a result, downstream companies would have access to verified proof that they support and contribute to responsible sourcing practices, which can then share with auditors, corporate governance bodies and consumers(Dickinson, 2020).

(2) Mobility Open Blockchain Initiative (MOBI)
The Mobility Open Blockchain Initiative is an international, multi-stakeholder initiative that aims to utilize blockchain-based standards to achieve a connected mobility ecosystem(MOBI, 2021). Mobility ecosystem is a system that comprises various forms of transportation and their users, as well as how they interact, and accordingly introduces the concept of Mobility as a Service (MaaS), where a large segment of the automotive industry is collaborating together to unlock potentials for mobility payments networks, including: Vehicle to Vehicle (V2V) transactions, electric vehicle to grid integration, usage-based services, fleet operations, carbon footprint management, congestion pricing and more (MOBI, 2019). Thus, multiple stakeholders across the mobility value chain are involved, including original equipment manufacturers, mobility service providers, technology companies, and governmental and non-governmental entities.Some of these stakeholders are captured by our sample, such as: Hitachi, BMW, Hyundai, Honda, Renault, Toyota and General Motors.

(3) BiTA
Transportation is a key in supply chain management, thus Blockchain in Transport Alliance Consortium (BiTA) was founded in 2017 to promote the use of blockchain technology in the supply chain. BiTA serves as a community where members collaborate to create greater efficiencies, trust and transparency. It is a member-driven BC Consortium; members are primarily from

the freight, transportation, logistics and affiliated industries. Alliance members share a common mission of driving the adoption of emerging technology forward and this is accomplished by developing industry standards; educating members on blockchain applications/solutions; and encouraging the use and adoption of new solutions. The core uses include visibility on shipping vehicles performance history, truck maintenance, quality assurance, dynamic optimisation, capacity monitoring, fraud detection, payment and pricing and theft prevention (Forbes, 2018). Thousands of companies have applied for membership, some of these members in the sample are: UPS, Fedex, and The Home Depot.

(4) Global Shipping Business Network (GSBN)
The second consortium in our sample within the transportation logistics industry is GSBN. It was built in partnership with multiple BC solution providers such as Oracle, Microsoft and Alibaba Cloud. It was founded by multiple shipping container lines and major ports. The ones captured by our sample were COSCO (the largest liner carrier in China) and Hapag-Lloyd (The fourth largest container shipping company world wide according to Alphaliner as of 01 May 2021). The main aim of the collaboration is to create a BC Network that achieves digitalization and security of the data and cargo. For instance, since the platform was first launched in Hong Kong and one of the key partners is COSCO, this raised the China question, in other words, "How Western clients worry about putting competitor sensitive data on a Hong-Kong based platform where high profile members include Chinese state-owned enterprises". The secure BC data exchange process comes as answer to this question, the dara encryption that comes a default feature when using BC will allow each member to share encrypted data with the network, which will usually be deployed within the company's own data center.

(5) VAKT
VAKT is a consortium that includes leading energy companies as well as financial institutions like banks. It aims to transform the global commodities trading industry. Traditionally, the post-trade transactions involve, the two or more trading entities checking paperwork and modifying records on separate manual systems, which is prone to error and time consumption(Vakt, n.d.). Now, VAKT is introducing the new concept of shared platform that secures transaction privacy; by featuring the ability to control access and distribution of transactions and its related data on a "need to know" basis amongst participants. Also, models of authorisation with appropriate roles and permissions are implemented to ensure platform security for all partners.(ThroughWorks, 2019). Some of the VAKT members like Total Energies and Reliance Industries limited in our sample, focus on digitization of cargo post-trade processes for a safer, faster and cheaper logistical operation, which are key in commodities' supply chain management (Reuters, 2019).

(6) OOC

The Offshore Operators Committee (OOC) Oil Gas Blockchain Consortium was founded to develop Oil Gas industry using blockchain learning's. The key purpose is to transform the way the companies in the industry interact with one another and accordingly establish industry standards, frameworks and capabilities utilizing emerging blockchain technology. The consortium was established under the not-for-profit organization Offshore Operators Committee and offers membership-based participation. So far, OOC Oil Gas Blockchain Consortium includes 10 oil and gas members , Chevron, ConocoPhillips, Equinor, ExxonMobil, Hess, Marathon, Noble Energy, Pioneer Natural Resources, Repsol and Shell (Wire, 2020). Figure 4.7 shows the ones that were captures in our sample under OOC. The members aim to solve common pain points like lack of transparency across the SC, securing payments to vendors, low efficiency that lead to increased costs.

Some of the key achievements of the initiative to overcome SC pain points included (Wire, 2020):

- Process workflow was reduced from 90-120 days to 1-7 days instead, using digitalization, in other words, no manual intervention was needed.
- 85% of all volume measurements were automatically validated against data from multiple entities, introducing the potential of 100% auto validation with some future enhancements.
- When measurements' validation was met successfully, automatic triggering of related invoice transactions was executed, which extensively reduces financial risk by giving assurance that payments are in sync with field activity.

(7) AntChain

Antchain, the blockchain technology unit of Ant Group, one of China's and the world's largest tech companies, was launched in July 2020. The same group runs Alipay, the largest digital payment system in China, that is subsidiary of Alibaba Group. The aim behind the BC unit is to improve openness and trust in industries with a large number of players facing inefficient procedures, such as supply chains . One of AntChain's blockchain solutions will be adapted by Tech. giants like Dell, HP and Lenovo (Insights, 2020a). The tech. companies need the BC consortium to help with leasing contracts particularly with SMEs. The digitalization of the contract and the payment process has been widely utilized on AntChain especially in China, but the what's unique about the collaboration with Dell, HP and Lenovo is that it's considered the first collaboration for AntChain outside China(Ong, 2021).

(8) Aura

Targeting luxury brands and niche products' authenticity, Aura BC consortium was founded by

Prada, LVMH Moët Hennessy Louis Vuitton and Cartier. Communicating authenticity, responsible sourcing and sustainability are challenges for the luxury goods industry, that Aura BC Consortium overcomes in a secure digital format. For instance, consumers can easily trace a product's life cycle, from the design phase through manufacturing and distribution, via trusted data throughout. Also, from a customer prospective, proving authenticity ownership of goods can be drastically enhanced by having product history information on a distributed ledger. As for the brand itself, it can benefit via different aspects like: (1) Ensuring that products are manufactured and controlled according to the standards set by the consortium partners, (2) establishing consumers' trust by making use of the "no intermediaries" feature that BC technology introduces, in other words no need for auditing or legal or financial entities instead secure ledger and smart contract will be in place.(3) Most important benefit for luxury good is protecting the industry against counterfeiting and controlling secondhand markets(AURA, 2021).

(9) IBM Food Trust

IBM Food Trust is one of the early consortia in the Food Agribusiness industry. It was launched in August 2017 and it is composed of growers, processors, wholesalers, distributors, manufacturers and retailers as members. The aim of the collaboration is to enhance visibility and accountability across the food supply chain. Built on IBM Blockchain, this network connects participants through a permissioned, immutable and shared record of food provenance, transaction data, processing details and more (IBM, 2017). Some of IBM Food Trust members were captured in our sample such as Nestle, Tyson Foods, Carrefour, Uniliver, Walmart, Kellogg's and Kimberly-Clark. The main aim of this initiative is to set new standards for the industry, that's why all competing companies are working together; in order to verify aspects like "Was this batch of grain shipped through a warehouse with shoddy safety practices?" or "Has this grower been inspected recently?". Certifications and related documents available on the ledger establish that a facility is properly inspected, that livestock have been treated according to law, that a supplier is legally able to do business, and that a farm is certified as conforming to industry standards. As the consortium expands, greater insight and transparency is provided to the members. For instance, IBM Food Trust network has stored data for 1M items in about 50 food categories, including Nestle canned pumpkin and Tyson chicken thighs (Nash, 2018b).

(10) Covantis

Another important initiative in the Food Agribusiness is Covantis, a blockchain Consortium jointly developed by Archer Daniels Midland Co., Cargill, Inc., Bunge, Ltd., and COFCO International, Ltd. The initiative members' aim to enhance the trading process particularly in the grain and oil seed sector (COFCO, 2018) by replacing legacy post-trade processes with a blockchain- and Artificial Intelligence (AI)-based ones. An example showing the market relevance of Covantis, was covered by (Lakkakula et al., 2020), where the benefits of using BC key features like Smart contracts on an international trade on the soybean market, included Transparency, traceability, and efficiency as the three important aspects of the agricultural supply chain, especially that the supply chain is a network that includes a buyer/importer, seller, local bank, advising bank, shipping agency, federal grain-inspection service, and customs. Also, the quantitative results were supporting the use of BC in that particular sector, for instance; the savings include 2.3 cents per bushel of soybeans and a 41% reduction in the total time. Thus, the author concluded that "*These results are significant for agribusinesses and other agricultural stakeholders who are evaluating the benefit of adopting blockchain technology in international commodity trading*."

(11) Medildger

The MediLedger Project was established in 2017, it is an industry consortium with members adapting BC platforms from different providers like Chronicled, IBM Blockchain, FarmaTrust, OriginTrail, Provenance and VeChain. The aim of the project is to : (i) bring pharmaceutical stakeholders such as :manufacturers, wholesale distributors and GPOs (Group Purchasing Organizations)together to adapt and standardize the use of blockchain technology for tracking and tracing prescription medicines; and (ii) collaborate to prevent counterfeit medicines from entering the pharmaceutical SCs, and at the same time (iii) ensure compliance with DSCSA in the U.S (Clauson et al., 2018) along with GS1 standards (that aim to improve the efficiency, safety and visibility of supply chains across physical and digital channels in a wide variety of sectors(GS1, 2021)). Also, a key cost-reduction opportunity that Mediledger introduces to the pharmaceutical industry is the verification of drugs that a retailer or hospital returned to the company. Using, the old systems it is difficult to verify the history of the returned drugs, however using the secured, immutable distributed ledger, the company can review all the historical details and accordingly returns can be resold if their history proves that they still meet standards(Nash, 2018a). One of the members that want to streamline this opportunity and is captured by our sample is Amerisource. The company's CIO mentioned that *"We're making sure of the provenance of the product, guaranteeing it hasn't been tampered with all the way through the chain to the patient and Blockchain is such a natural fit for that kind of capability."*

(12) Pharmaledger

Like Mediledger, Pharmaledger is an industry BC Consortium, It was established in January 2020. Multiple pharmaceutical companies are part of the two initiatives, however, Pharmaledger is an EU project that focuses on regional issues and compliance with EU standards, with the aim to scale beyond Europe in the future(Morris, 2020), Mediledger however is focused on US standards, particularly Drug Supply Chain Security Act -DSCSA (Drug Evaluation and Research, 2013) that aims to *"enhance FDA's ability to help protect consumers from exposure to drugs*

that may be counterfeit, stolen, contaminated, or otherwise harmful". Aside from the specific standards and the different jurisdictions, both Consotia share the same aims to increase visibility on pharmaceutical supply chains and protect patients from counterfeit or stolen drugs, while reducing costs and complying with local standards.
Thus, by working at the consortia level, these members share costs, create unified industry standards and expedite innovation by leveraging scale. On another note, the BC Consortium subsample shows an adequate number of companies from each consortium and from different industries to avoid bias during the analysis.

4.4.3 BC-SC announcements Categorization by Firm Characteristics

Firm Size

Following (Cahill et al., 2020) approach, the BC-SC announcements sample was categorized into quartiles based on the firms' market Capitalization. Table 4.4 shows the descriptive statistics of each category, where Category 1 firms represent the largest firm size quartile and Category 4 represents the smallest quartile. Daily share prices, market-index data, and firm size measured by market capitalisation are all sourced from Refinitiv (formerly Thomson Reuters) Datastream.

TABLE 4.4: Firm Size Categorization by Market Capitalization

	Market Capitalization Range (Billion USD)	# of Observations	Mean	Std. Dev
Category 1	2358 - 182.20	26	458.38	514.02
Category 2	174.3 - 71.73	26	113.67	25.33
Category 3	71.305 - 28.57	27	46.93	11.46
Category 4	27.76 - 1.46	25	13.59	7.27

Research & Development (R&D) Intensity

Research & Development (R&D) Intensity being the representative of firm's innovation was calculated as the R&D expenditure of the firm divided by the sales. Similar to the firm size categorization, both R&D expenses and Sales data were obtained from Refinitiv Data stream and are captured at the fiscal year end prior to the BC-SC announcement. Table 4.5 represents the descriptive statistics of the two variables used to compute the R&D Intensity. The minimum of R&D Expenditure is zero, reflecting that some firms in the sample don't allocate resources for R&D (innovation), while others invest in that scope with an average of $71.90M and maximum value of $3.09B.

TABLE 4.5: Descriptive Statistics of R&D Intensity

	RD Expenses (M $)	Sales (B $)	RD Intensity
Mean	71.90	675.22	1.06E-04
Standard Error	34.13	284.83	1.20E-04
Median	0.65	70.00	9.23E-06
Mode	-	127.57	0
Standard Deviation	349.68	2,918.64	1.20E-04
Kurtosis	55.84	41.59	1.34E-03
Skewness	6.99	6.33	1.11E-03
Range	3,097.06	21,663.81	1.43E-04
Minimum	-	0.19	0
Maximum	3,097.06	21,664.00	1.43E-04
Count	104	104	104

Early Adaption of BC-SC Initiatives

Although some references still consider BC-SC announcements up to date as early announcements,(Dede, Köseoğlu, and Yercan, 2021; Fernando, Rozuar, and Mergeresa, 2021; Guo et al., 2021), there is still room for comparison in the sample. As shown in table 4.3 - Panel A, the sample covers BC-SC announcements form 2016 to the first half of 2021. To determine the cut off date for the time period of adaptation, a cut-off date of August 9, 2018 is used. This is date that marks the beginning of TradeLens project that was founded by Maersk and IBM in the transportation section, particularly for shipping purposes. The selection of this date is based on multiple reasons. First, from 2016 to 2018, most of the major BC-SC initiatives were founded. For instance:

- Walmart and IBM collaboration was founded beginning of 2017, for food traceability purposes.(Newsroom, 2017b)
- Blockchain in Transport Alliance Consortium (BiTA) was founded in August 2017 (BiTA, 2017)
- The MediLedger Project was established in 2017 (Mattke et al., 2019)
- Mobility Open Blockchain Initiative (MOBI) was launched in the middle of 2018 (MOBI, 2020)

Then, 2018 ended with Tradelens project as a collaboration between IBM and Maersk. Thus, to evaluate the impact of early adaptors, we look into the founding firms of the projects from 2016

TABLE 4.6: Descriptive statistics of early/late adaptors

Year	Early Adaptors (2016 - 2018)	Late Adaptors (2019 - H1:2021)	Total
Number of Observations	22	82	104
Percentage (%)	21%	79%	100%

to 2018. Second, the count of firms adapting BC-SC over the years, spikes in 2019 as shown in table 4.3 - Panel A, reaching maximum of 37%, which reflects that increasing number of firms joining the founded initiatives in the previous years. For example, Tradelens was founded in August 2018, but over the years, the platform has grown to include over 100 different companies (Tradelens, 2021), including airlines, ports, terminal operators, 3PLs, freight forwarders, and shippers. Participants collaborate to publish and subscribe to data using a digital permissioning scheme established by the shipper. Table 4.6 represents the descriptive statistics of the two categories used to compute the early adapters. Approximately 21% of the sample of BC-SC are early adaptors, representing 22 firms out of 104. The majority of the sample is late adaptors, in other words, the 79% of the firms adapted BC technology after 2018.

Chapter 5

Empirical Analysis and Results

This chapter is divided into two sections. In the first section, we discuss the market reaction to all BC-SC announcements based on the event study approach discussed in the previous section to verify H1. Then, in the second section, cross-sectional regression analysis is used to test how the market reactions are influenced by firms' characteristics and objectives for using BC, also referenced as H2, which include multiple subquestions.

5.1 Market Reaction to all BC-SC announcements

Table 5.1 shows the mean and the median of the abnormal returns and cumulative abnormal returns associated with BC-SC announcements. To test whether the abnormal returns and cumulative abnormal returns are significantly different from zero, we use parametric t-statistics to determine the statistical significance of the mean abnormal returns and the Patell Z-statistic to determine the statistical significance of the median abnormal returns. Generalized Sign Z statistic test is used to determine whether the percentage of positive abnormal returns is significantly greater than 50%. Columns 2–6 of Table 8 summarize the abnormal returns associated with all 105 BC-SC announcements on each day from day 2 to day 2. The mean of the abnormal returns for day 0 is 1.45% which is significantly different from zero at the 1% level. The percentage of positive abnormal returns is 70.47%, on the event day which is significantly greater than 50% at the 1% significance level. Similarly, the mean of abnormal returns for day 1 or day 2 are 2.17% and 2.11% respectively at 1% significance level. The only exception is the abnormal returns for day 1, which is 0.0018.

Columns 7–9 of Table 3 present the results of the cumulative abnormal returns associated with all 105 BC-SC announcements on three- and five-day periods. The mean of abnormal returns from day 2 to day 0 and the one from day 0 to day 2 are 1.34% and 4.98% respectively, and both are significantly positive at the 1% level. The percentage of positive abnormal returns is 86.67% which is significantly greater than 50% at the 1% level. For the overall 5-day event window, represented from day -2 to day 2, the cumulative abnormal return is 4.85% and the percentage of positive abnormal returns is 80% both statistically significant at 1% level. Thus, the percentage of positive five-day abnormal returns exhibit similar patterns as the three-day

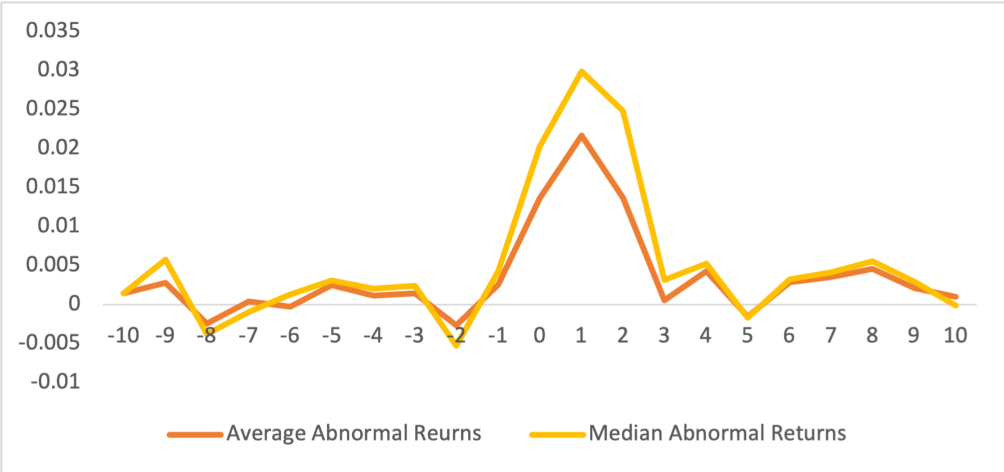

FIGURE 5.1: Abnormal Normal Returns of the Market Model from Day -10 to Day 10

	Day -2	Day -1	Day 0	Day 1	Day 2	Day -2 to 0	Day 0 to 2	Day -2 to 2
Number of Observations	105	105	105	105	105	105	105	105
Mean abnormal returns	-0.0023	0.0018	0.0145***	0.0217***	0.0211***	0.0134*	0.0498***	0.0485***
t-statistic	-1.0675	0.9349	2.6563	3.9849	5.031	1.9663	7.0404	5.8585
% Of positive	43.8%	54.29%**	70.47%***	67.61%***	72.38%***	60.95%***	86.67%***	80%***
Generalized Sign Z statistic	-1.1943	0.952	4.2709	4.1528	5.0242	2.3191	8.133	6.5409

Two-tailed test: ***, **, and * indicate significance at 1%, 5%, and 10%, respectively.

TABLE 5.1: Abnormal and Cumulative Abnormal Returns of the Market Model for all BC-SC announcements

returns. The overall results reveal that the stock market in the areas covered by this selected sample, highlighted in Table (6 - Panel C) reacts positively to BC-SC announcements on the short term. Hence, we can conclude that H1 is partially supported. As the hypothesis is not fully supported, we proceed to investigate if BC-SC initiative announcements have greater impact in specific situations as stipulated in hypotheses H2 through H6. For the sub-sampling analysis, the CAR during the event window [-2,2] is chosen as it showed partial significance for H1. We also estimate the abnormal returns from day 10 to day 10 for all BC-SC announcements using the market model. Figure 5.1 shows the results. The mean and median of the abnormal returns show that the stock market reacts positively to BC-SC announcements particularly from day 1 to day 1, and this positive influence lasts for approximately 3 days.

5.2 Market Reaction to BC-SC announcements targeting specific SC Challenges

As mentioned in Section 3.2, the six main SC challenges that blockchain technology directly address are: (1) Traceability, (2) Dispute Resolution, (3) Cargo Integrity Data Security, (4) Digitalization, (5) Compliance and (6) Trust Stakeholder Management. To identify the SC challenge that when targeted as objective in the announcement cause highest increase in returns compared to others, we classify the BC-SC announcements based on the SC objective targeted by the firm, as highlighted in Subsection 4.4.1. Then we compute the mean Cumulative Abnormal Returns (CAR (-2,2)) for each group.

5.2.1 Univariate analysis

Table 5.2 shows the results of the mean cumulative abnormal returns for six main SC challenges. The CAR results for the five-day period are significantly positive for all the groups at 1% significance level. However, when comparing the cumulative abnormal return CAR (-2,2) of each SC objective against the remaining objectives, Digitalization(8.5%), Dispute Resolution (12.1%)and Trust stakeholder management (7.1%) have significant high positive cumulative return , whereas Traceability(4.23%), Compliance (4.06%) and Cargo Integrity & Data Security(6.24%) events exhibit low positive cumulative returns when compared against the rest of SC challenges' CAR values. Our results suggest that the stock markets have different responses to different SC objectives targeted by BC-SC announcements. Some of the targeted objectives are mentioned in a small subset of the announcements and yet they caused positive impact represented by the CAR values and their associated positive to negative ratios. For example, BC-SC announcements stating Dispute resolution as one of the main objectives for adapting BC for their supply chains, represent only 11 out of the total 104 announcements, yet those announcements caused a positively significant mean CAR (-2,2) of 12.85% compared to 6.40% representing mean CAR(-2,2) for all other objectives combined.

TABLE 5.2: Abnormal and Cumulative Abnormal Returns of the Market Model for all BC-SC announcements

Supply Chain Objective	Traceability	Others	Dispute Resolution	Others
Sample Size	75	29	11	93
Mean CAR	0.0423***	0.1451***	0.1285***	0.064***
Patell test p-value	6.48E-08	4.97E-10	5.75E-06	1.59E-11
No. of +ve : -ve Returns	48:27***	26:3***	10:1***	64:29***
Sign Test p-value	0.005063	2.00E-05	6.56E-03	1.73E-04

Supply Chain Objective	Digitalization	Others	Compliance	Others
Sample Size	41	63	79	25
Mean CAR	0.085***	0.0616***	0.0406***	0.1664***
Patell test p-value	5.75E-12	5.95E-06	2.50E-08	1.07E-09
No. of +ve : -ve Returns	36:5***	38:25*	52:27***	22:3***
Sign Test p-value	1.50E-06	0.069248	2.92E-03	1.72E-04

Supply Chain Objective	Cargo Integrity Data Security	Others	Trust Stakeholder Management	Others
Sample Size	13	91	38	66
Mean CAR	0.0624***	0.072***	0.071***	0.0707***
Patell test p-value	0.0091	1.33E-13	4.62E-08	1.168E-08
No. of +ve : -ve Returns	8:5	66:25***	30:8	44:22***
Sign Test p-value	0.421224	1.00E-05	2.49E-04	0.0053

Two-tailed test: ***, **, and * indicate significance at 1%, 5%, and 10%, respectively.

5.3 Multivariate analysis

In this section, we perform a cross-sectional linear regression analysis to investigate whether the stock market reacts uniquely to various targeted SC challenges. In most of the announcements the firms state multiple objectives (out of the highlighted six in subsection 4.4.1) as their targets for using BC and how they achieved those targets. The dependent variable is the event day abnormal return AR_{it} or multi day cumulative abnormal return $CAR_i(t1, t2)$ calculated in Section 4.1. To represent the different SC objectives, six indicators are created. $Traceability_i$ equals one if a firm is targeting traceability as an objective for using BC for its supply chains, and zero if traceability is not one of the objectives. The same convention is followed for the remaining SC objectives represented by indicators $DisputeResolution_i$, $CargoIntegrityDataSecurity_i$, $Digitalization_i$, $Compliance_i$, and $TrustStakeholder_i$. The reason there are six indicators created and not one representing the objective containing six options to select from, is that each announcement in our sample, could have more than one objective.

In addition, various firm- and industry-related control variables are used to ensure the robustness of the model. In previous studies, the same variables were used by (Bai, Gao, and Sarkis, 2021; Jacobs and Singhal, 2014) to control for parameters like external competitive environment factors, firm and industry characteristics, that can cause variation in the overall market reaction. We use $FirmLeverage_i$ to account for the firm financial leverage, and it is calculated as the ratio of total debt to the market value of equity. $TotalAssets_i$ is also used, to quantify the economic worth of each firm in the sample, it is calculated as the natural log of total assets at the end of the fiscal year prior the BC-SC announcement. To control for industry-related factor; $IndustryROA_i$ is added to the model to indicate the industry performance and is defined as the median return on assets (ROA) of the sample firm's for each industry. This variable is also captured at the fiscal year end prior to the BC-SC announcement; each industry includes all firms that have the same 2 digit SIC industry code as that of the sample firm. Two external market competitive environment characteristics are considered. The Herfindahl index HHI_i is used to quantify the industry competition level. $Dynamism_i$ is an indicator for market dynamism and is utilized to reflect sales volatility of each industry. It is calculated as the standard error of the five-year regression slope of industry sales, divided by the five-year average sales. In addition, we include one industry dummy $IndustryDummy$, which uses two-digit SIC codes, and one time-year dummy$YearDummy$.

Table 5.3 presents descriptive statistics and correlation for both the analysis variables (BC-SC intended objectives) and the control variables. The Pearson's correlation matrix shows there could be some collinearity (dependence between two set of variables: (Traceability and Compliance) and (Digitization and Trust Stakeholder Management) having correlation coefficients 0.475 and 0.497 respectively. Both coefficients are statistically significant at 1% level. This raises a question should one of these independent variable be removed as it's effect is already evaluated via its corresponding peer in the pair. To answer this question, we conduct a variance inflation factor (VIF) test to assess multi-colinearity in the regression model. The variance inflation factor (VIF) identifies correlation between independent variables and the strength of that correlation.It is considered an effective approach for multicollinearity assessment because it overcomes some of the drawbacks of the Pearson's correlation approach, for instance, Pearson's correlation matrix has a limitation of establishing relationship between only two independent variables at a time (Vu, Muttaqi, and Agalgaonkar, 2015). Thus, once the cross-sectional regression model is established, VIF values have to be checked to eliminate independent variables causing multi-colinearity.

TABLE 5.3: Descriptive Statistics and Correlation Matrix for the Objectives and Control Variables in Our Analysis

Variables	Mean	Standard Deviation	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Traceability	0.724	0.449	1												
2. Dispute Resolution	0.105	0.308	-0.067	1											
3. Cargo Integrity Data Security	0.124	0.331	0.232**	0.155	1										
4. Digitalization	0.390	0.490	-0.161	0.236**	0.055	1									
5. Compliance	0.771	0.422	0.475***	-0.332	-0.002	-0.169*	1								
6. Trust StakeholderManagement	0.381	0.488	0.090	0.116	0.003	0.497***	0.100	1							
7. Firm Size	8.028	1.015	0.200**	-0.106	0.047	-0.203**	0.223**	0.021	1						
8. Firm Leverage	-1.258	33.730	-0.081	0.019	0.025	-0.120	-0.044	-0.124	0.016	1					
9. Median Industry ROA	4.360	0.693	0.046	-0.160	0.009	0.023	0.090	0.171*	-0.097	-0.046	1				
10. Industry Dynamism	1.516	4.135	-0.033	-0.068	-0.100	0.240**	0.089	0.259***	-0.240**	-0.068	0.219**	1			
11. Industry Competition	0.356	0.260	0.070	-0.051	-0.027	-0.065	0.051	-0.072	-0.050	0.001	0.126	-0.004	1		
12. Industry Dummy	33.533	17.414	0.031	-0.163	0.122	-0.052	0.013	-0.086	-0.030	0.021	0.201**	0.182*	0.202**	1	
13. Year Dummy	0.610	0.490	-0.014	-0.045	0.123	0.120	0.076	-0.136	0.083	-0.061	0.055	0.102	-0.089	0.103	1

Two – tailed test: ***,** and * indicate significance at 1%, 5% and 10% respectively.

Equation 5.9, is the basic linear model used to evaluate the impact of multiple BC-SC objectives, where Abnormal Return (AR) and Cumulative Abnormal Return (CAR) are used as the dependent variables one at a time.

$$\begin{aligned} AR_i/CAR_i = \beta_0 + \beta_1 Traceability_i \ + \beta_2 DisputeResolution_i + \beta_3 CargoIntegrityDataSecurity_i \\ + \beta_4 Digitalization_i \ + \beta_5 Compliance_i \ + \beta_6 TrustStakeholder_i \\ + \beta_7 FirmSize_i + \ \beta_8 FirmLeverage_i + \beta_9 IndustryROA_i \\ + \beta_{10} HHI_i + \ \beta_{11} Dynamism_i \ + \ \beta_{12} Industry_i + \ \beta_{13} Year_i + \varepsilon_i \end{aligned} \tag{5.1}$$

Table 5.4 presents the cross-sectional regression results based on equation 5.9. Given the theoretical and empirical literature that we outlined in our development of H2, the lack of a significant association between the abnormal returns (especially on the event day - Day 0), and all 6 SC objectives is surprising. Although, there are few exceptions such as the having a significant coefficient for $Disputeresolution_i$ when fitted against the CAR (Day -2 to 0), representing the first half of the event window, still this behaviour is unexpected. Given the observed adjusted R^2 values in 5.4, that range between -3.61% and 6.96%, the OLS model represents the data poorly and is not a good fit. R^2 compares the fit of the chosen model with that of a horizontal straight line (the null hypothesis). Thus, to explore this issue further we had to validate that all Ordinary Linear (OLS) regression assumptions are met and based on that determine whether the OLS model represents the collected data sample sufficiently.

TABLE 5.4: Cross-sectional regression analysis on the market reaction of all BC-SC announcements

	Variable	VIF	Day -2 to 0	Day 0	Day 0 to 2	Day -2 to 2
Intercept	*0*		-1.64E-01** (-2.154)	-8.79E-02(-1.626)	6.82E-02(0.848)	1.31E-01 (-1.439)
Traceability	$Traceability_i$	1.48	1.62E-02 (0.903)	7.65E-03(0.602)	1.41E-02(0.746)	-5.22E-03 (-0.244)
Dispute resolution	$DisputeResolution_i$	1.30	4.97E-02**(2.024)	2.80E-02(1.611)	-8.50E-03(-0.328)	3.67E-02 (1.253)
Cargo Integrity Data Security	$CargoIntegrityDataSecurity_i$	1.19	7.42E-03(0.339)	1.85E-02(1.195)	1.51E-02(0.654)	1.20E-02 (0.458)
Digitalization	$Digitalization_i$	1.74	-8.92E-03(-0.499)	-1.01E-02(-0.799)	-5.10E-03(-0.271)	-2.71E-02 (-1.274)
Compliance	$Compliance_i$	1.57	1.56E-02(0.793)	1.53E-02(1.094)	-3.88E-02*(-1.868)	-3.87E-02 (-1.647)
Trust Stakeholder Management	$TrustStakeholder_i$	1.70	-4.67E-03(-0.263)	-1.22E-04(-0.01)	9.44E-03(0.505)	2.77E-02 (1.311)
Total Assets	$TotalAssets_i$	1.24	7.38E-03(1.016)	2.52E-03(0.49)	-8.45E-03(-1.104)	-1.04E-02 (-1.204)
Firm Leverage	$FirmLeverge_i$	1.04	-4.39E-05(-0.219)	-5.32E-07(-0.004)	1.71E-05(0.081)	-1.88E-05 (-0.078)
Median Industry ROA	$IndustryROA_i$	1.16	1.64E-02(1.589)	1.25E-02*(1.716)	1.45E-02(1.331)	-3.13E-03 (-0.255)
Industry Competition	HHI_i	1.47	2.31E-06(0.749)	2.00E-06(0.914)	3.04E-07(0.093)	2.10E-06 (0.57)
Industry Dynamism	$Dynamism_i$	1.31	-3.81E-03**(-2.08)	-2.11E-03(-1.625)	7.00E-04(0.362)	-1.99E-03 (-0.911)
Industry Dummy	$Industry_i$	1.44	4.29E-04(0.938)	4.87E-05(0.15)	-1.34E-04(-0.277)	0.0009588* (1.758)
Year Dummy	$Year_i$	1.22	1.34E-02(0.895)	7.12E-03(0.673)	9.11E-03(0.578)	1.18E-02 (0.662)
N			104	104	104	104
Model F-value			1.59*	1.36	0.72	1.27
Adjusted			6.96%	4.26%	-3.61%	3.30%

According to (Poole and O'Farrell, 1971), the fundamental assumptions which must be satisfied if the classical linear regression model is to be totally valid are:

1. Linear relationship: There exists a linear relationship between the independent variable, x, and the dependent variable, y.

2. Mean of ϵ does not depend on observed Xs, in other words is equal to zero.

3. The number of observations is greater than the number of Xs

4. Normality: The residuals of the model are normally distributed.

5. Homoscedasticity: The residuals have constant variance at every level of x.

The first 2 assumptions can be verified by looking at the graph in figure . By plotting the fitted values against the model residuals/errors, we can see:

- ***The linearity assumption of the model is almost met***; this assumption basically means that Y (Cumulative Abnormal Returns from Day -2 to Day 2) values can be expressed as a linear function of x variables (the 6 SC Objectives). This can be verified by performing residual analysis on the error terms of the model. By plotting the fitted values against the model residuals/errors, we see that the linearity assumption is almost met, as the red line (which is just a scatter plot smoother, showing the average value of the residuals at each value of fitted value) is nearly flat. This tells us that there is no discernible non-linear trend to the residuals (with few outliers at both ends as exceptions).

- ***Mean of ϵ does not depend on observed Xs, in other words is equal to zero***. From the same plot of fitted values versus residuals we can see that scatter plot smoother red line is around the zero values at almost all fitted values, with the exception to the outliers at the boundaries.

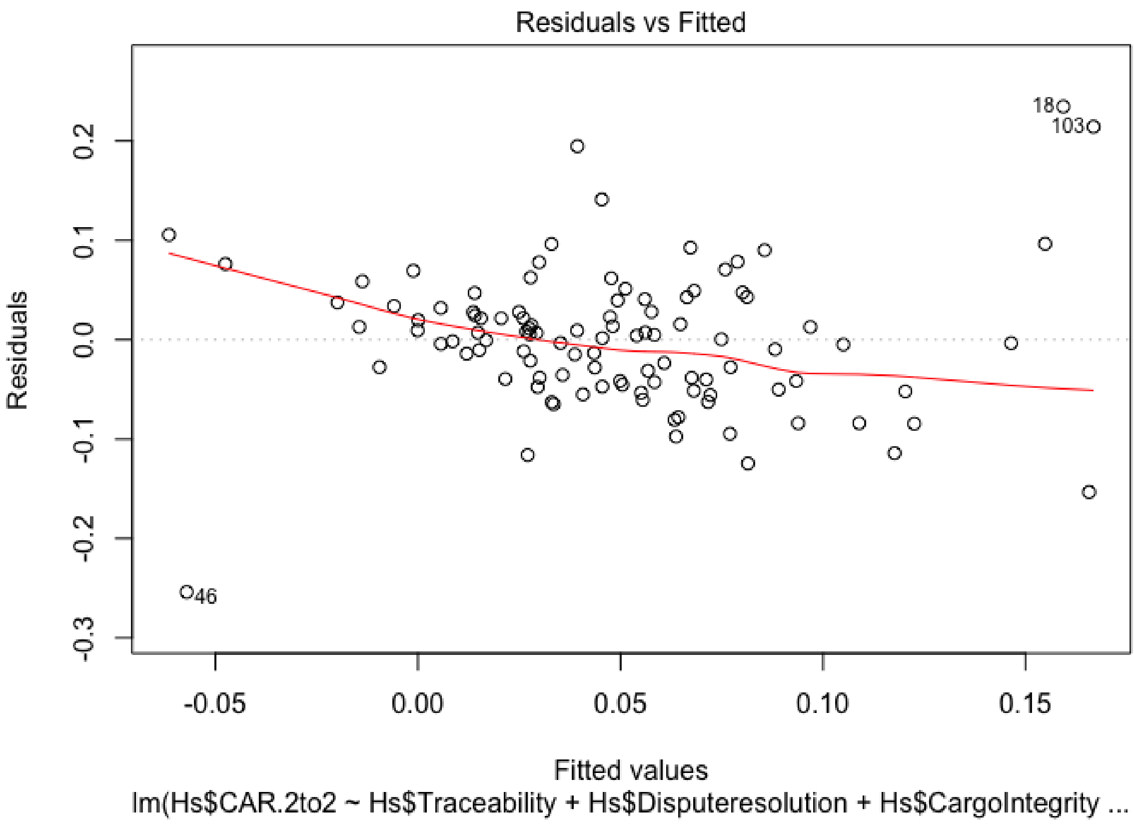

FIGURE 5.2: Linear Model Residuals vs Fitted Values

The third assumptions, ***the number of observations is greater than the number of Xs*** can be easily verified by checking the data. It is fulfilled in this model as we have 104 observations which is far greater than the number of X variables, which are 13.

The fourth assumption,***The residuals of the model are normally distributed*** can be interpreted from the quantile-quantile plot of the ordered standardized error of the model (on Y-axis) and the expected/theoretical residual (which is basically what we expect the residuals to be if they were normally distributed) As observed in figure 5.3, the std errors follow the theoretical quantiles on most of the points with few outliers.

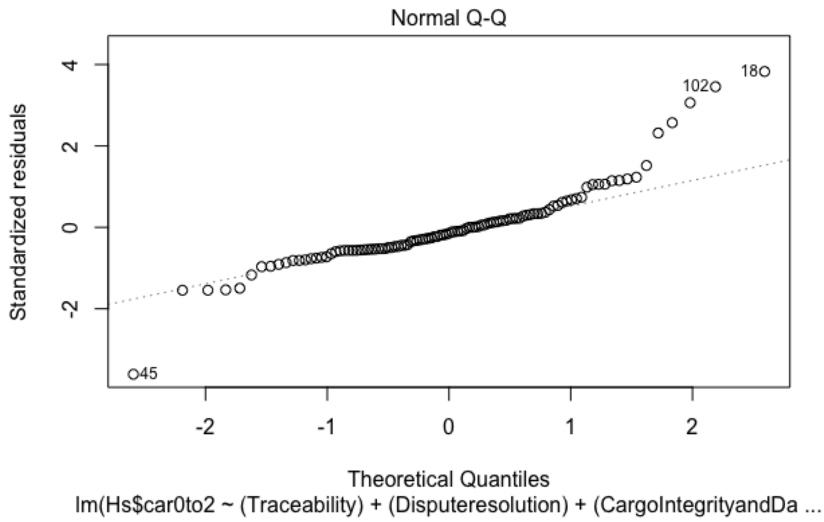

FIGURE 5.3: Quantile-Quantile (q-q) plot of the Regression Model

Another way to check the normality of the residuals is by plotting a histogram of the model residuals and check if they follow a bell shape or close one or not. When this was conducted, the output was as shown in figure 5.4. The Model residuals follow almost the Normal distribution bell shape pattern, with minor difference.

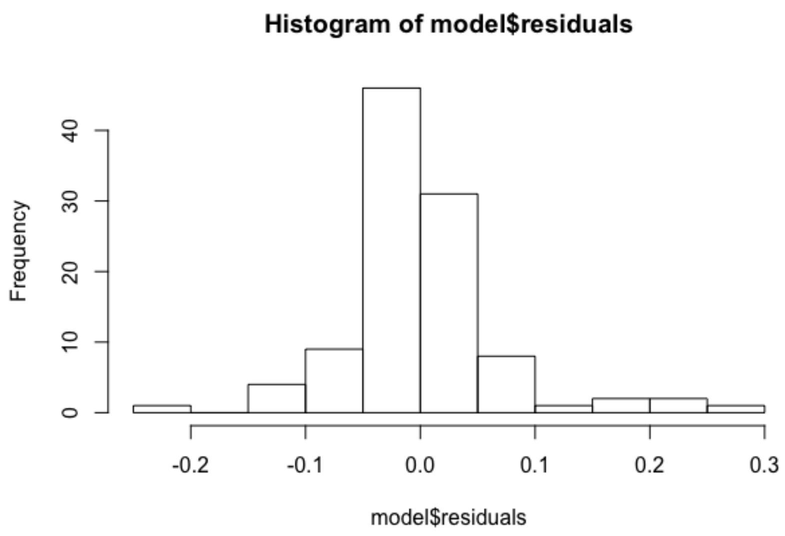

FIGURE 5.4: Model Residuals

The fifth assumption, ***Homoscedasticity of residuals or equal variance,*** the residuals appear to be unequally variable across the entire range of fitted values. There is some indication of non-constant variance. To confirm, Breusch-Pagan test for heteroscedasticity (Breusch and Pagan, 1979)(the regression contains unequal variance) is conducted.The test assumes that the variance of the errors is a function h of a number of regressors, which are the Xs (independent variables) present in the initial regression model (Equation 5.9). Equation 5.2 shows the general form of the variance function.

$$var(y_i) = E(e_i^2) = h(\alpha_1 + \alpha_1 x_i^2 + ... + \alpha_S x_{iS}) \tag{5.2}$$

The variance $var(yi)$ is constant only if all the coefficients of the regressors x in Equation 5.2 are zero, which provides the null hypothesis of our heteroskedasticity test shown in Equation 5.3.

$$H_0 : \alpha_2 = \alpha_3....\alpha_S = 0 \tag{5.3}$$

Te relevant test statistic is 2, given by Equation 5.4,

$$\chi^2 = N \times R^2 \sim \chi^2_{(S-1)} \tag{5.4}$$

where R^2 is the one resulted from Equation 5.9, N is the number of observations in the model (104).

When applying the Breusch-Pagan test function to determine a critical value of the χ^2 distribution for a significance level and $S1$ degrees of freedom. Our test yields a value of the test statistic χ^2 of 4.71, which is to be compared to the critical χ^2_{cr} having S1=103 degrees of freedom and $= 0.05$. This critical value is $\chi^2_{cr} = 3.84$. Since the calculated χ^2 exceeds the critical value, we reject the null hypothesis of homoskedasticity, which means there is heteroskedasticity in our data and model. Alternatively, we find the p-value of test statistic χ^2 was also calculated, p = 0.029972, which is less than significance level of 0.05.

Thus, the classical linear model, also referred to as the OLS model, fulfils all the assumptions, except the homoskedasticity (constant variance) assumption. The non-constant variance could also be the reason why all the coefficients of interest in the model are not significant. Thus, to verify this assumption, Weighted least squares linear model could be used to try to fit the data better.

5.3.1 Weighted Least Squares (WLS) Model

Since a key assumption of OLS regression is violated, and heteroscedasticity is confirmed in the residuals. The results of the regression in model 5.9 became unreliable. One way to handle this issue is to instead use Weighted Least Squares (WLS) regression (Willett and Singer, 1988), which is the OLS model in equation 5.9 multiplied by weights throughout. The weights are defined as the reciprocal of each error variance σ^2, so if the error (ϵ), is (multivariate) normally distributed with mean vector 0 and non-constant variance-covariance matrix as in equation 5.5, then the diagonal matrix containing these weights would look like 5.6. This way observations with small error variance are given more weight since they contain more information compared to observations with larger error variance. Weighted least squares has several advantages over other methods, including: It is suitable to extract maximum information from small data sets, in addition it is one of the approaches for data points that have varying quality, while maintaining the same assumptions of the OLS linear model.

$$\begin{pmatrix} \sigma_1^2 & 0 & ... & 0 \\ 0 & \sigma_2^2 & ... & 0 \\ 0 & 0 & \sigma_3^2 & 0 \\ 0 & 0 & ... & \sigma_n^2 \end{pmatrix} \tag{5.5}$$

The diagonal matrix containing these weights would look like:

$$\begin{pmatrix} w_1 & 0 & ... & 0 \\ 0 & w_2 & ... & 0 \\ 0 & 0 & w_3 & 0 \\ 0 & 0 & ... & w_4 \end{pmatrix} \tag{5.6}$$

To assess the cross-sectional variation of the market reactions to BC-SC announcements, given the variations in the sample causing heteroscedasticity effect, the new model used would be:

$$\begin{aligned} w_i * (AR_i/CAR_i) = w_i * (&\beta_0 + \beta_1 Traceability_i \ + \beta_2 DisputeResolution_i + \beta_3 CargoIntegrityDataSecurity_i \\ &+ \beta_4 Digitalization_i \ + \beta_5 Compliance_i \ + \beta_6 TrustStakeholder_i \\ &+ \beta_7 FirmSize_i + \ \beta_8 FirmLeverage_i + \beta_9 IndustryROA_i \\ &+ \beta_{10} HHI_i + \ \beta_{11} Dynamism_i \ + \ \beta_{12} Industry_i + \ \beta_{13} Year_i + \varepsilon_i) \\ where \ w_i = 1/\sigma^2 & \end{aligned} \tag{5.7}$$

Table 5.5 presents the cross-sectional regression results from the new model based on equation 5.8.

TABLE 5.5: Cross-sectional regression analysis on the market reaction of all BC-SC announcements(using Weighted Least Squared)

	Variable	VIF	Day -2 to 0	Day 0	Day 0 to 2	Day -2 to 2
Intercept	β_0		-0.25(-1.806)	-0.109(-1.156)	0.073 (0.847)	-0.083(-0.464)
Traceability	$Traceability_i$	1.20	-0.13***(-6.064)	-0.085***(-5.713)	-0.052***(-3.809)	-0.166***(-5.882)
Dispute resolution	$Disputeresolution_i$	1.07	0.17***(3.663)	0.098**(3.085)	0.080**(2.743)	0.208***(3.435)
Cargo Integrity Data Security	$CargoIntegrityDataSecurity_i$	1.45	0.15***(4.492)	0.106***(4.713)	0.076***(3.695)	0.225***(5.242)
Digitalization	$Digitalization_i$	11.77	-0.04(1.229)	-0.021(-1.067)	-0.019(-1.062)	-0.054(-1.432)
Compliance	$Compliance_i$	6.78	-0.03(-0.725)	-0.027(-0.917)	-0.020(-0.776)	-0.005(-0.090)
Trust Stakeholder Management	$TrustStakeholder_i$	1.11	0.07**(2.731)	0.051**(2.783)	0.012(0.743)	0.097**(2.805)
Total Assets	$TotalAssets_i$	3.59	0.02*(2.607)	0.012*(1.798)	-0.002(-0.338)	0.009(0.713)
Firm Leverage	$firmLeverge_i$	9.86	1.25E-05(0.028)	4.07E-05(0.132)	2.64E-06(0.009)	8.116E-05(0.139)
Median Industry ROA	$IndustryROA_i$	3.50	1.90E-03(0.135)	-0.002(-0.213)	-0.009(-0.977)	0.002(0.117)
Industry Competition	HHI_i	1.45	1.20E-05**(2.897)	7.09E-06*(2.463)	-1.14E-06(-0.432)	1.451E-05**(2.65)
Industry Dynamism	$Dynamism_i$	1.19	-0.01***(-3.982)	-0.006**(-3.176)	-0.005**(-3.261)	-0.009***(-2.645)
Industry Dummy	$Industry_i$	1.65	2.94E-03***(5.226)	0.002***(5.049)	-0.001*(-2.155)	0.004***(5.118)
Year Dummy	$Year_i$	1.45	-0.12***(-6.351)	-0.084***(-6.547)	0.029*(2.465)	-0.174***(-7.125)
N			104	104	104	104
Model F-value			61.07***	54.70***	16.920***	59.14***
Adjusted			88.30%	87.03%	66.60%	87.90%

Before interpreting the results, we assessed the Variance Inflation factor (VIF) to check for multicollinearity. Following (Rogerson, 2015)approach, where VIF value of 5 is used as a reference for the presence of the multicollinearity phenomenon. VIF is calculated as $VIF_j = 1/(1 - R_j{}^2)$, where $R_j{}^2$ is the coefficient of determination of the regression of $\bar{x}_j$ on all other independent variables in the data set $[x_1, x_2, \ldots, x_{j1}, x_{j+1}, \ldots, x_m]$.Thus, when $VIF = 5$, R_j^2 is found to be 0.8, which means that, 80% of the variable x_j can be represented by the other independent variables highlighting the possibility of multicollinearity. Applying this to our new model VIF results, $Compliance_i$ and $Digitalization_i$ are equal to 11.77 and 6.78 respectively, which shows that more than 80% of those independent variables are already represented by other variables in the model. Given the Pearson correlation results from 5.3, the independent variable representing $Compliance_i$ is $Traceability_i$ and similarly the one representing $Digitalization_i$ is $TrustStakeholder_i$. Thus, variables representing compliance and digitalization are considered redundant explanatory variables and are excluded from the independent data set (by adapting backward elimination analysis) to enhance the accuracy of the Weighted Least Square Model(Vu, Muttaqi, and Agalgaonkar, 2015). Now, the developed model including the optimized variable-set includes only the significant variables and eliminates the redundant variables as shown in table 5.6.

Multiple important results appear from day -2 to 2 cumulative abnormal returns. First, the four significant variables representing the objectives (Cargo Integrity & Data Security, Dispute Resolution and Trust and Stakeholder Management) for using BC for supply chains are all positive and statistically significant at the 1% level except Traceability. This result directly negates our argument for H2. Instead, the Column (7) in table 5.6 shows that firms targeting traceability as the main objective will exhibit significantly lower abnormal stock returns, using $CAR[-2, 2]$, ($\beta_1 = -0.166, P < 0.001$) when compared to the remaining objectives. This was confirmed by the uni-variant analysis in table 5.2, however the uni-variant analysis results did not provide the effect of combination of objectives against the others, which is the case in most of the announcements in our sample. Second, the results shows the different responses of CAR to the targeted objectives. The univarient analysis results suggested that the stock markets have different responses to the different SC objectives targeted, however those different responses were not yet quantified. On the other hand, the multi variant analysis results, as a set of standardized coefficients (s), represent an estimate for the change in CAR from day -2 to day 2 relative to the presence (objective set to 1) or absence (objective set to 0) of the combination of $Traceability, DisputeResolution, CargoIntegrityDataSecurity$ and $TrustStakeholderManagement$ objectives. A standardized beta coefficient compares the strength of the effect of each individual independent variable (i.e. each Objective) to the dependent variable (CAR/AR). So, by comparing the beta coefficients, we can rank the strength of SC objectives in terms of the increase in Cumulative abnormal returns, as follows:

1. Cargo Integrity and Data Security ($\beta_3 = 0.234$)

2. Dispute Resolution ($\beta_2 = 0.218$)
3. Trust & Stakeholder Management ($\beta_4 = 0.132$)
3. Traceability ($\beta_1 = -0.185$)

This ranking puts Cargo Integrity & Data Security on the top of the list of BC-SC targeted objectives, as shown in table 5.6, where ($\beta_2 = 0.234$, $p < 0.001$). Followed by Dispute Resolution and Trust & Stakeholder Management Third, all the resulted coefficients that are positive and in the same range ($\beta = [0.234 - 0.132]$), which suggests that if a company introduces BC to address one of the positive significant objectives, the cumulative abnormal return will be positively impacted with small variation from one objective to the other. However, as per this model, as more targeted objectives are aimed for using BC, a more positive market reaction is expected, except for Traceability. This indicates that extensive use of BC for resolving multiple supply chain challenges, particularly the top 3 ones mentioned above, will lead to a significantly higher abnormal return. In addition, this result is entirely in sync with companies' choices on how to use BC technology. As highlighted in section 4.4.1, the majority of the companies in the sample announced more that one use for BC to enhance SCs, only 15% of the sample represented companies targeting a single use for BC-SC.

TABLE 5.6: Cross-sectional regression analysis on the market reaction of all BC-SC announcements (using WLS Model after eliminating Multi-collinearity)

	Variable	VIF	Day -2 to 0	Day 0	Day 0 to 2	Day -2 to 2
Intercept	0		-0.176(-1.405)	-0.060(-0.693)	0.031(0.396)	-0.009
Traceability	$Traceability_i$	1.60	-0.139***(-7.568)	-0.089***(-7.007)	-0.056***(-4.823)	-0.185***(-7.663)
Dispute Resolution	$DisputeResolution_i$	1.04	0.171***(3.765)	0.099**(3.142)	0.081**(2.814)	0.218***(3.622)
CargoIntegrityandDataSecurity	$CargoIntegrityDataSecurity_i$	1.42	0.151***(4.712)	0.109***(4.91)	-0.079***(-3.886)	0.234***(5.505)
TrustandStakeholderManagement	$TrustStakeholder_i$	1.38	0.098***(5.599)	0.068***(5.574)	0.027*(2.461)	0.132***(5.711)
Total Assets	$TotalAssets_i$	3.36	0.022*(2.381)	0.010(1.59)	-0.004(0.623)	0.004(0.359)
Firm Leverge	$FirmLeverge_i$	1.11	-1.741E-06(-0.004)	3.28E-05(0.107)	1.01E-05(0.036)	5.57E-05(0.095)
Median Industry ROA	$IndustryROA_i$	2.36	-1.581E-03(-0.115)	-0.004(-0.439)	-0.007(-0.779)	-0.003107
Industry Competition	HHI_i	1.39	1.262E-05**(3.109)	7.340E-06*(2.611	-1.41E-06(-0.55)	1.59E-05**(2.968)
Industry Dynamism	$Dynamism_i$	1.18	-0.010***(-4.088)	-0.006**(-3.24)	-0.005**(3.349)	-0.009**(-2.788)
Industry Dummy	$Industry_i$	1.60	0.003***(5.411)	0.002***(5.189)	-7.93E-04*(-2.265)	0.004***(5.395)
Year Dummy	$Year_i$	1.95	-0.112***(-6.229)	-0.080***(-6.425)	0.026*(2.266)	-0.169***(-7.082)
N			104	104	104	104
Model F-value			72.15***	64.67***	72.15***	69.66***
Adjusted R^2			88.27%	87.07%	88.30%	87.90%

Two-tailed test: ***, **, and * indicate significance at 1%, 5%, and 10%, respectively.

5.4 Market Reaction to Firms using Industrial BC Consortium

Our sample of BC-SC announcements includes 3 categories each representing a BC type whether Public, Private or Consortium as explained in section 4.4.2, we differentiate these groups and use cross-sectional regression analysis to analyze differences in market reaction associated with a group of interest and that is Industrial BC Consortium. Using the same approach followed in the previous section, to evaluate market reaction against BC-SC objectives, we use both Cumulative Abnormal Return (CAR) and Abnormal Returns as our dependent variable in the weighted regression model, previously used and proved to better fit the data sample. To align BC-SC announcements with the Industrial BC Consortium adaptations, we use three-day CAR (Day -2 to 0), three-day CAR (Day 0 to 2), five-day CAR (Day -2 to 2) as well as one-day AR (Day 0). We construct a new indicator variable for the subcategory of Industrial BC Consortium announcements. $IndustrialConsortium_i$ is assigned label "Yes" if the company/companies in the BC-SC announcement are part of an industrial BC Consortium and that is clearly mentioned in the announcement content. Likewise, a label "No" is assigned to $IndustrialConsortium_i$ if the company is not part of an Industrial BC Consortium;using a public or private BC platform instead. So, to assess cross-sectional variation in the market reactions in response to Industrial BC Consortium, we use the following model:

$$\begin{aligned} w_i * (AR_i/CAR_i) = {} & w_i * (\beta_0 + \beta_1 IndustrialConsortium_i + \beta_2 Traceability_i \\ & + \beta_3 DisputeResolution_i \beta_4 CargoIntegrityDataSecurity_i \\ & + \beta_7 TrustStakeholder_i + \beta_8 FirmSize_i + \ \beta_9 FirmLeverage_i + \beta_1 0 IndustryROA_i \\ & + \beta_{11} HHI_i + \ \beta_{12} Dynamism_i \ + \ \beta_{13} Industry_i + \ \beta_{14} Year_i + \varepsilon_i) \\ where\ w_i = 1/\sigma^2 & \end{aligned} \tag{5.8}$$

and again σ^2 is: the variance of the error (ϵ), of the OLS model below:

$$\begin{aligned} AR_i/CAR_i = {} & \beta_0 + \beta_1 IndustrialConsortium_i \ + \beta_2 Traceability_i \ + \beta_3 DisputeResolution_i \\ & + \beta_4 CargoIntegrityDataSecurity_i \ + \beta_7 TrustStakeholder_i \\ & + \beta_8 FirmSize_i + \ \beta_9 FirmLeverage_i + \beta_1 0 IndustryROA_i \\ & + \beta_{11} HHI_i + \ \beta_{12} Dynamism_i \ + \ \beta_{13} Industry_i + \ \beta_{14} Year_i + \varepsilon_i \end{aligned} \tag{5.9}$$

Table 5.7 shows the regression results. The Cumulative abnormal CAR return results during the event window from Day -2 to 2 along with Abnormal Return on the event Day AR_0 in columns 3-6 of table 5.7, serve as the dependent variable. The coefficient of $IndustrialConsortium_i$ when CAR (Day -2 to 0) is used as dependent variable, is 0.105 and statistically significant at the 1% level. Similarly, in column 4 and 6, the coefficients are 0.074 and 0.117 respectively, and both are statistically significant at the 1% level. The only non-significant result was the coefficient when CAR (Day 0 to 2) was used as the dependent variable in the regression model. The results indicate that the stock market react more positively to Industrial BC Consortia when compared to public and private BC solutions that are not part of any Industrial collaborations. Also, the positive consequences are observed before the announcement date (Day 0). The statistically significant coefficient at 1%level, for CAR (Day -2 to 0), show that there is a positive response to industrial BC announcements 2 day prior the announcement day, suggesting that such announcements are sometimes leaked to the market.

TABLE 5.7: Cross-sectional regression analysis on the market reaction to capture the effect of Industrial BC Consortium

	Variable	Day -2 to 0	AR_0	Day 0 to 2	Day -2 to 2
Intercept	β_0	-0.22(-0.508)	-0.114(-1.60)	-0.057(-0.745)	-0.071(-0.508)
IndustrialConsortium	$IndustrialConsortium_i$	0.105***(4.054)	0.074***(5.047)	0.025(1.588)	0.117***(4.054)
Traceability	$Traceability_i$	-0.062**(-3.355)	-0.038**(-2.894)	-0.036*(-2.538)	-0.087**(-3.355)
Disputeresolution	$DisputeResolution_i$	0.05(1.336)	0.019(0.699)	0.04(1.375)	0.071(1.336)
CargoIntegrityandDataSecurity	$CargoIntegrityDataSecurity_i$	0.031*(1.882)	0.021(1.03)	0.014(0.647)	0.075*(1.882)
TrustandStakeholderManagement	$TrustStakeholder_i$	0.020(1.609)	0.012(0.881)	0.004(0.278)	0.043(1.609)
Total Assets	$TotalAssets_i$	0.015*(0.13)	0.007(1.159)	-6.09E-05(-0.01)	-0.001(-0.13)
Firm Leverge	$FirmLeverge_i$	-5.38E-05(-0.02)	-5.07E-06(-0.023)	2.13E-05(0.089)	-8.58E-06(-0.02)
Median Industry ROA	$IndustryROA_i$	0.003(0.035)	0.002(0.202)	-0.002(-0.246)	-5.90E-04(-0.035)
Industry Competition	HHI_i	-4.42E-06(-1.149)	1.96E-06(0.75)	-7.52E-08(-0.027)	-5.93E-06(-1.149)
Industry Dynamism	$Dynamism_i$	-0.008**(-2.018)	-0.004(-2.723)	-0.004*(-2.117)	-0.006**(-2.018)
Industry Dummy	$Industry$	0.002***(4.128)	0.001(3.835)	-4.77E-04(-1.248)	0.003***(4.128)
Year Dummy	$Year$	-0.045***(-3.45)	-0.032(-2.664)	-0.013(-0.98)	-0.082***(-3.453)
N		104	104	104	104
Model F-value		14.68***	13.58***	2.951**	13.75***
Adjusted R^2		61.22%	59.21%	18.37%	59.54%

Two-tailed test: ***, **, and * indicate significance at 1\%, 5\%, and 10\%, respectively.

To investigate the market reaction trends when it comes to Industrial BC adaptations, the average abnormal return for the group of companies in the announcements that adapt Industrial BC Consortium as a solution for supply chains, were plotted from Day -5 to Day 10 as shown in figure 5.5. An examination of figure 5.5 reveals that in the overall sample, most of the actions in CAR happen between day -1 and day 1. Industrial BC consortium firms category have higher pre-announcement CARs, with the largest jump from day -1 to day 0. This confirms our findings in Table 5.7. Category "Others" exhibit a similar pattern of smaller magnitude compared to "Industrial BC Consortium" category, with a noticeable jump from day 0 to day 1.

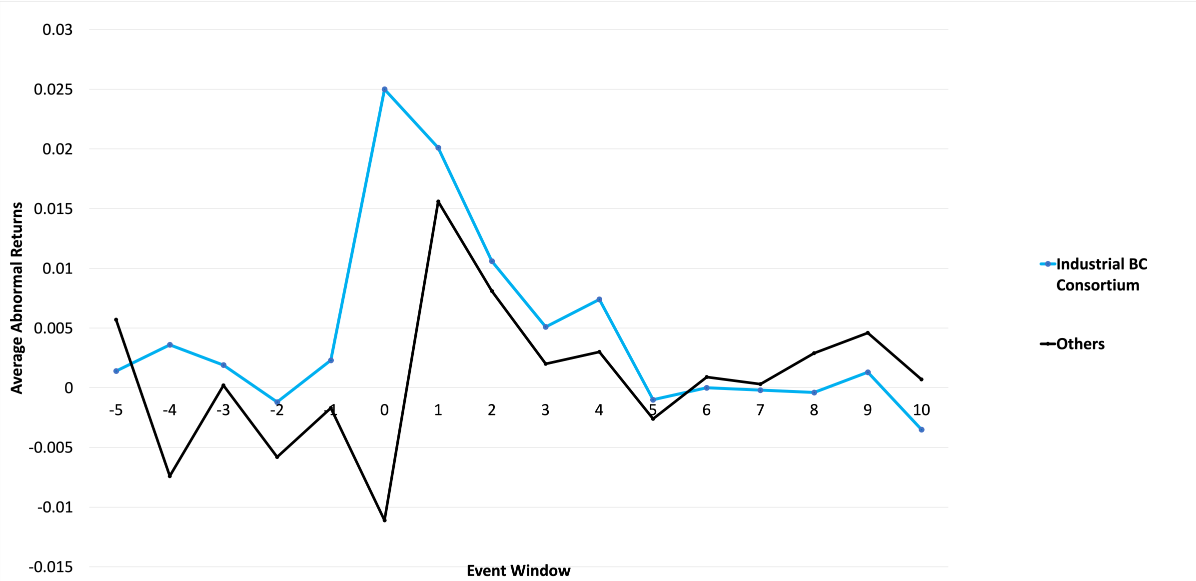

FIGURE 5.5: Average Abnormal Return by BC Type

5.5 Market Reaction to BC-SC announcements based on Firms' characteristics

This section will cover the results of market reaction to BC-SC with respect to some key firm - specific characteristics. We examine this issue from three aspects, the size of the firm within the market, the timing of investing in BC-SC; whether the firm took this decision early before other competitors or later after the topic became safer and (3) how much RD expense is invested by the company. The first firm characteristic of interest is the firm size. To verify H4, stating that *"**Smaller firms making BC-SC announcements will show more positive impact on stock prices than larger firms**"*, we use the four quartiles of the market capitalization (in USD Billions) as highlighted in Section 4.4.3 to see how the firm size (from the 1^st to 4^th quartile) affects the market reaction (represented by the dependent variables: CAR and AR respectively). We measure firm size by $FirmSize_i$, which could take one of the four pre-defined categories based on the market capitalization of the firm(Cahill et al., 2020). The second firm characteristic of interest is the R&D Intensity which is represented by $RDIntensity_i$. The greater the $RDIntensity_i$, the more the firm has invested in innovation projects such as BC technology, to compete with the market. Also, this implies a stronger competitive position of the firm compared with its peer firms. The model to assess cross-sectional variation in market reactions to different firm characteristics is formulated as

$$
\begin{aligned}
w_i * (AR_i/CAR_i) = w_i * (&\beta_0 + \beta_1 IndustrialConsortium_i + \beta_2 Traceability_i \\
&+ \beta_3 DisputeResolution_i + \ \beta_4 CargoIntegrityDataSecurity_i \\
&+ \beta_5 Digitalization_i + \beta_6 Compliance_i + \beta_7 TrustStakeholder_i \\
&+ \beta_8 FirmSize_i Category2 + \ \beta_9 FirmSize_i Category3 + \\
&\beta_{10} FirmSize_i Category4 + \ \beta_{11} RDIntensity_i + \ \beta_{12} Earlyvslate_i \\
&+ \beta_{13} TotalAssets_i + \beta_{14} FirmLeverage_i + \beta_{15} IndustryROA_i \\
&+ \beta_{16} HHI_i + \ \beta_{17} Dynamism_i \ + \ \beta_{18} Industry_i + \ \beta_{19} Year_i + \varepsilon_i) \\
where\ w_i = 1/\sigma^2 &
\end{aligned}
\tag{5.10}
$$

Table 5.8 shows the regression results of the model in equation 5.10. To interpret the Firm Size parameter, we see that the coefficients, using both CAR values (Day -2 to 2) as well as AR0, are positive and statistically significant at 1% level. The interesting observation is that the coefficients for all the categories are in the same range in terms of magnitude. For instance, when using CAR (-2,2) as the dependent variable, the coefficients for firm size from Category 2 to Category 4 are 0.118, 0.139, 0.107 respectively. This suggests that the firm size in this sample is not a differentiating parameter when it comes to the impact BC-SC announcements have on the stock returns of the announcing firms. This result is also linked to the listed firms used in the sample, as the market capitalization ranges from $2.3 Trillion to $1.46 Billion, which is still considered a representation of the large firms in the market. Thus, the result suggests that the same positive performance is achieved as long as the firm Market Cap. lies within this sample range.

As for the R&D Intensity, all the models used show positive and statistically significant coefficients. For instance, the model using Abnormal Return on the announcement date (AR_0) as the dependent variable, has a positive coefficient of 0.60. This suggests that firms with higher R&D Intensity experience greater positive reaction to BC-SC announcements. Consistent with (Jaffe, 1988), a higher degree of R&D in a firm's vicinity, leads to higher productivity rate which is eventually reflected in shareholders' wealth.

As for the use of $Earlyvslate_i$ parameter, we expected early adaptors of BC-SC solutions to receive a comparatively higher positive stock market reaction, but could not find support to verify H6, ***"Firms that are early adopters of Blockchain initiatives for SCs will show more positive impact in stock prices than firms that are late adopters."***. As shown in table 5.8, the coefficients for $Earlyvslate_i$, are all non-significant with the exception of the model using CAR (0,2) as dependent variable, shown in column 5, the coefficient shows positive market reaction for late adaptors (contrary to the expected) at a 5% significance level.

TABLE 5.8: Cross-sectional regression analysis on the market reaction of all BC-SC announcements

	Variable	Day -2 to 2	Day -2 to 0	Day 0 to 2	AR_0
(Intercept)	β_0	-0.113(-0.844)	-0.240*(-2.309)	0.044(0.539)	-0.131(-1.954)
IndustrialConsortium-Yes	$IndustrialConsortium_i - Yes$	0.084**(2.724)	0.077**(3.259)	0.026(1.396)	0.055***(3.602)
Traceability	$Traceability_i$	-0.043(-1.661)	-0.036(-1.826)	0.004(0.247)	-0.023(-1.839)
Disputeresolution	$DisputeResolution_i$	0.102*(2.145)	0.082*(2.236)	-0.080**(-2.749)	0.042(1.763)
CargoIntegrityandDataSecurity	$CargoIntegrityDataSecurity_i$	0.018(0.457)	-0.006(-0.193)	0.011(0.434)	-0.004(0.193)
Digitalization	$Digitalization_i$	-0.010(-0.302)	-0.018(-0.733)	0.018(0.893)	-0.017(-1.058)
Compliance	$Compliance_i$	-0.048(-1.261)	-0.004(-0.138)	-0.014(-0.594)	-0.002(-0.117)
TrustandStakeholderManagement	$TrustStakeholder_i$	0.041(1.404)	0.016(0.706)	-2.291E-03(-0.127)	0.012(0.837)
FirmSize-Category2	$FirmSize_i - Category2$	0.118***(4.224)	0.086***(4.016)	-0.074***(-4.333)	0.065***(4.654)
FirmSize-Category3	$FirmSize_i - Category3$	0.139***(4.769)	0.088***(3.899)	-0.035(-1.987)	0.069***(4.798)
FirmSize-Category4	$FirmSize_i - Category4$	0.107***(3.565)	0.083***(3.601)	-0.039*(-2.153)	0.054***(3.644)
R&D Intensity	$RDIntensity_i$	0.950***(3.853)	0.700***(3.676)	0.036(0.237)	0.604***(4.919)
Earlyvslate	$Earlyvslate_i - late$	-0.022(-0.741)	-0.025(-1.087)	0.043**(2.330)	-0.014(-0.916)
TotalAssets	$TotalAssets_i$	0.001(0.118)	0.014(1.702)	0.004(0.579)	0.007(1.242)
Firm Leverge	$FirmLeverge_i$	1.54E-06(0.004)	-3.740E-05(-0.128)	-2.575E-05(-0.111)	-3.277E-05(-0.174)
Median Industry ROA	$IndustryROA_i$	-0.007(-0.448)	-0.002(-0.169)	-0.002(-0.266)	-0.003(-0.367)
Industry Competition	HHI_i	8.05E-06(1.727)	6.88E-06(1.912)	-3.75E-06(-1.311)	3.656E-06(1.576)
Industry Dynamism	$Dynamism_i$	-0.006(-1.954)	-0.007**(-3.344)	0.003(1.986)	-0.004*(-2.615)
Industry Dummy	$Industry_i$	0.002***(3.561)	0.002**(3.403)	-5.136E-04(-1.333)	0.001**(3.219)
Year Dummy	$Year_i$	-0.0617**(-2.865)	-0.032(-1.91)	0.013(1.012)	-0.023*(-2.135)
N		104	104	104	104
Model F-value		15.69***	14.88***	3.259***	16.13***
Adjusted R^2		72.86%	71.72%	29.22%	73.43%

Two-tailed test: ***, **, and * indicate significance at 1%, 5%, and 10%, respectively.

The small significant level for CAR(0,2), is still an interesting observation that we wanted to investigate further. Thus, an interaction variable is introduced to the model. We examine whether the market reaction to early/late adaptors is moderated by the firm's industry. To test this, we estimate the following regression model:

$$
\begin{aligned}
w_i * (AR_i/CAR_i) = w_i * (&\beta_0 + \beta_1 IndustrialConsortium_i + \beta_2 Traceability_i \\
&+ \beta_3 DisputeResolution_i + \ \beta_4 CargoIntegrityDataSecurity_i \\
&+ \beta_5 Digitalization_i + \beta_6 Compliance_i + \beta_7 TrustStakeholder_i \\
&+ \beta_8 FirmSize_i Category2 + \ \beta_9 FirmSize_i Category3 + \\
&\beta_{10} FirmSize_i Category4 + \ \beta_{11} RDIntensity_i + \ \beta_{12} Earlyvslate * Highlevel.Industry_i \\
&+ \beta_{13} TotalAssets_i + \beta_{14} FirmLeverage_i + \beta_{15} IndustryROA_i \\
&+ \beta_{16} HHI_i + \ \beta_{17} Dynamism_i \ + \ \beta_{18} Industry_i + \ \beta_{19} Year_i + \varepsilon_i) \\
where\ w_i = 1/\sigma^2 &
\end{aligned}
\tag{5.11}
$$

where $Earlyvslate * Highlevel.Industry_i$ is the interaction between early adaptors and the Industry the firm is part of. $Highlevel.Industry_i$ is defined by grouping SIC Codes in table 4.3 - Panel B, for example, firms that have SIC codes between 20 and 39 are the manufacturing firms, while those between 40 to 49 are the transportation sector firms. Similarly, the firms that have SIC code between 10 to 14 are representing the mining industry, and 50 to 59 for the Retail/wholesale Trade and so on.

Table 5.9 presents the parameter estimates (t-values in parentheses) for the regression model

TABLE 5.9: Comparing the Parameter Estimates (t-statistics) from Regression Results from equations 5.11 and 5.10

		Interaction model (Equation 5.11)	Hypothesized model (Equation5.10)
		Day -2 to 2	Day -2 to 2
(Intercept)	β_0	-0.073(-0.584)	-0.094(-0.647)
IndustrialConsortium-Yes	$IndustrialConsortium_i - Yes$	0.103***(3.855)	0.086**(2.83)
Traceability	$Traceability_i$	0.002(0.094)	-0.045*(-1.764)
Disputeresolution	$DisputeResolution_i$	0.103*(2.517)	0.107**(2.282)
CargoIntegrityandDataSecurity	$CargoIntegrityDataSecurity_i$	0.007(0.201)	0.032(0.789)
Digitalization	$Digitalization_i$	-0.002(-0.05)	-0.011(-0.333)
Compliance	$Compliance_i$	-0.039(-1.175)	-0.031(-0.820)
TrustandStakeholderManagement	$TrustStakeholder_i$	0.019(0.671)	0.043(1.402)
FirmSize-Category2	$FirmSize_i - Category2$	0.092***(3.718)	0.119***(4.354)
FirmSize-Category3	$FirmSize_i - Category3$	0.113***(4.378)	0.140***(4.823)
FirmSize-Category4	$FirmSize_i - Category4$	0.129***(4.892)	0.119***(4.008)
RD Intensity	$RDIntensity_i$	0.579*(2.49)	0.926***(3.593)
Earlyvslate-late	$Earlyvslate_i$	-0.081(-1.26)	-0.022(-0.728)
Industry high level - Manufacturing	$Industry.high.level_i - Manufacturing$	-0.055(-1.105)	0.057(1.346)
Industry high level - Mining	$Industry.high.level_i - Mining$	-5.794E-04(-0.012)	-0.005(-0.098)
Industry high level - Retail	$Industry.high.level_i - Retail$	0.023(0.321)	0.081(1.318)
Industry high level - Transportation	$Industry.high.level_i - Transp.$	-0.007(-0.084)	0.128*(2.263)
TotalAssets	$TotalAssets_i$	-4.174E-04(-0.045)	-1.670E-03(-0.157)
Firm Leverge	$FirmLeverge_i$	1.491E-04(0.434)	-4.497E-05(-0.117)
Median Industry ROA	$IndustryROA_i$	-0.007(-0.5)	-0.006(-0.395)
Industry Competition	HHI_i	3.606E-06(0.826)	8.384E-06(1.694)
Industry Dynamism	$Dynamism_i$	-0.004(-1.448)	-0.004(-1.188)
Industry Dummy	$Industry_i$	8.251E-04(0.857)	3.260E-04(0.303)
Year Dummy	$Year_i$	-0.049*(-2.578)	-0.058**(-2.689)
earlyadaptors:industry.high-level	$Earlyvslate_i\$late * industry.high.level_i\$manufacturing$	0.181**(2.453)	
earlyadaptors:industry.high.level	$Earlyvslate_i\$late * Industry.high.level_i\$Mining$	-0.028(-0.396)	
earlyadaptors:industry.high.level	$Earlyvslate_i\$late * Industry.high.level_i\$Retail$	0.027(0.284)	
earlyadaptors:industry.high.level	$Earlyvslate_i\$late * Industry.high.level_i\$Transportation$	0.161(1.535)	
N		104	104
Model F-value		17.15***	15.69***
Adjusted R^2		80.74%	72.86%

Two-tailed test: ***, **, and * indicate significance at 1%, 5%, and 10%, respectively.

in Equation 5.11. The results indicate that the coefficients for $Earlyvslate_i$ and $Highlevel.Industry_i$ are still insignificant. However, the coefficient for $Earlyvslate.Highlevel.Industry_i$ is statistically significant (at the 5% level).

Column 3 in table 5.9 show the regression results from Equation 5.11. Few interesting observations are noticed from introducing the interaction variable, first When the firms are not early adaptors (i.e., $Earlyvslate_i$= late) and the firms are part of the manufacturing sector (i.e.,$Highlevel.Industry_i$ = Manufacturing) , the abnormal returns are increasing in CAR (slope is 0.181) and statistically significant at 5% level. Second, the remaining industries don't show similar significance. This suggests that late adaptations of BC-SC, specifically in the manufacturing industry, are received with a significant positive response on the market. The other industries do not experience such positive response, and the market reaction to both early and late BC adaptations is the same.

Chapter 6

Discussion, Implications and Future Research

Blockchain technology adaptation for supply chain management has been addressed extensively via theoretical lens (Nabipour and Ülkü, 2021; Nandi et al., 2020). However, only few studies addressed BC-SC adaptations using a quantitative approach especially from a financial perspective. Our study employs an event study approach to examine the impact of BC-SC announcements on the announcing firms' market reaction, represented by both Abnormal and Cumulative abnormal returns. The news/firms announcements covered multiple industries across 20 different countries in the period between 2016 to the first half of 2021. We empirically show that there is a significant positive market reaction to all the BC-SC announcements. Specifically, an abnormal return of 1.45% is observed on the announcement day, showing investors positive reaction to the announced initiatives. In addition, we address BC-SC adaptations based on project and firm characteristics such as, targeted objectives, type of BC network used and firm specific characteristics like firm size, innovation strength and adapting BC on an early stage. We find that firms that use BC to maintain cargo integrity and data security have more positive market reaction when compared to other objectives, like eliminating intermediaries or resolving disputes. Also, interestingly, firms that adapt BC for traceability purposes along the SC, have lower positive market reaction. We find that firms that are part of an industrial BC Consortium like Mediledger or IBM Food Trust experience a stronger positive market reaction. Then looking deeper into the firms characteristics, we find that firm size is not a differentiating factor for market reaction, as all firm size categories showed a positive significant reaction in the same range. In terms of innovation, we find that firms with high R&D Intensity exhibit stronger positive market reaction. Based on literature indicating better performance for early adapters of innovative initiatives, we hypothesized that early adapters for BC-SC initiatives are associated with higher stock returns. Contrary to the expected, late adapters showed more positive market reaction and only for the manufacturing industry. One possible explanation is that BC-SC initiatives are still considered early adaptations by investors (Hoek, 2019). The other explanation is that the manufacturing industry has been growing fast in this area showing multiple success stories, encouraging investors to trust the technology (Abeyratne and Monfared, 2016).

6.1 Implications for Research

Our findings contribute to the growing literature of using blockchain for supply chain efficiency. As it addresses the literature stating that BC-SC is beneficial for the overall performance of the adapting firm (Chang, Chen, and Lu, 2019; Wang, Han, and Beynon-Davies, 2019). Although BC adaptations are still considered in their early stages, the investors interest can be a good indication for upcoming expansions and potential. Thus, our empirical study is conducted by the means of event studies. In comparison with a recent event study (Cahill et al., 2020) examining the impact of multi-purpose adapting of BC technology, our abnormal return of 1.45% on the announcement day is considered a subset of the study's average abnormal return of 5.3% on the announcement day.

Extending to the existing literature, we empirically evaluated project - specific factors like: the targeted SC objectives and the type of BC network adapted by the announcing firm. Our findings empirically confirm the theoretical studies addressing the role of BC in addressing supply chain challenges like traceability, dispute resolution, cargo integrity& data security, and Trust among stakeholders. We found that greatest positive reaction is observed when Cargo Integrity and Data Security aspects are targeted by the announcing firm. This empirically emphasizes the theoretical work supporting the use of BC to improve product safety and security, and reduce illegal counterfeiting (Hoek, 2019; Toyoda et al., 2017; Pun, Swaminathan, and Hou, 2021). On the other hand, the least positive market reaction is observed when BC is used for traceability purposes (Song, Sung, and Park, 2019; Feng Tian, 2017; Fernández-Caramés et al., 2019). This finding challenges the theoretical work studies that consider tracing products as the main objective for BC-SC initiatives. Also, it confirms one of the BC challenges: "*Interoperability*". It is the ability to share information for operational and transactional purposes across various different blockchain networks (pwc, 2018). The challenge lies in creating a salable network that can rely messages between the different BC networks with trust. This is considered the next major wave of innovation that may create extended value in the scope of decentralised internet (Accenture, 2018). The second project-specific factor was the BC type. We found that announcing firms that are part of an industrial BC like MOBI, Pharmaledger or IBM Food Trust experience a more positive market reaction, when compared to firms using public or private BC networks. This empirically supports the existing "collaborations for innovation" literature (Lefebvre, De Steur, and Gellynck, 2015; Ferraris, Santoro, and Bresciani, 2017), and extends the BC-SC literature with respect to collaborations/consortia in specific.

Prior conceptual work has argued that firm characteristics play a critical role for IT business value and for supply chain management. However we are among the few event studies that leverage the divers firm characteristics in our sample, which allows us to provide empirical evidence on how the firm size, innovation and early or late adaptation of BC-SC affect the stock market reaction. We find that firms with high R&D intensity have more positive market reaction. This comes in alignment with the literature stating that firms address that address the low R&D

investment challenge, particularly in the scope of BC achieve better market performance (Sun, Fan, and Hong, 2018). Accordingly, we emphasize the importance of R&D investment in both overcoming novel technological innovation challenges and enhancing the financial performance of the firm. From a firm size prospective, and contrary to what we hypothesized, we find that the firm size is not a differentiating factor in the market reaction. Firms within the market capitalization range of $2.3 Trillion to $1.46 Billion have the same positive performance, no extra positive response is observed among the four quartiles represented by this sample. A possible reason for this is that our sample includes listed firms only, which is still a representation of large firms in the market, compared to non-listed firms or startups. Another interesting observation is the comparison of early vs late BC-SC adaptation among the announcing firms. First, we find that no significant market reaction is captured, unless this factor is evaluated with respect to the firms industry. Second, we find that late adapters of BC-SC projects in the manufacturing industry have more positive market reaction compared to early adapters in the same industry. This extends the existing literature, by introducing the link between the industry and the time of adapting, and emphasizing that manufacturing industry is the only industry were the timing makes a significant difference. One explanation for this is that manufacturing supply chains have been going through fundamental changes to embrace digitisation (Industry 4.0) using key enablers like 3D printing, automation, machine learning, SC digitisation, and blockchain (Xu, Xu, and Li, 2018). Thus, manufacturers see the potential of blockchain in addressing issues like security and intellectual property protection (Deloitte, 2021).

6.2 Implications for Management

The fundamental question is how beneficial these empirical findings are to companies. First, we find that the positive market reaction to BC-SC announcements on the short-term accentuates the general potential for BC and its use in supply chain management. Accordingly, we encourage firms' decision makers to introduce BC-SC pilots to elicit the technology benefits and benefit from investors' interest in it.

Second, our findings suggest that the determination of the SC areas that require BC involvement is key factor. While BC technology may seem like the solution to all SC challenges from theoretical prospective, there are certain application areas where it unfold more potential than others. Our findings help managers determine these application areas, where the benefits from adapting BC-SC are maximized. For instance, we recommend decision makers to adapt BC for SC areas that require data Cargo verification and security. It seems beneficial to focus first on using BC-SC to secure already existing data and cargo verification systems. Also, an investment to achieve interoperability among BCs is recommended, to achieve efficient and secure traceability of goods among different BC networks.

Third, our findings suggest that firms that are part of an industrial BC consortium, (working on an existing BC network that is controlled by a group of authorities) have a more positive market reaction compared to firms using public or private (in-house) networks. Accordingly, we encourage practitioners to be a participant in BC-SC consortium. This setup enables BC usage without the need to build the entire platform. Instead, the firm will be focused on self development and accordingly contribute the knowledge exchange with partners over time. Also, looking at the usage of private or public BC networks, we see a positive market reaction but smaller than that associated with BC Consortium. One explanation is that the choice of BC network type relies primarily on the business need. In some cases, the firm needs the BC capabilities for internal purposes like in the case of the collaboration NEC and Cisco, aiming to verify the authenticity of Cisco's equipment (Insights, 2020b). However, investors might anticipate the limited use and the small room for scaling up this project and outweigh the benefits form a firm joining a BC-SC consortium. Similarly, the use of public BC networks, where all participants have visibility on the data exchange, which accordingly raise the security and data privacy concerns.

Fourth, our analysis of the firm characteristics affecting the valuation of BC announcements may support decision makers in better understanding which of their firms' characteristics are considered an opportunity and areas of internal investment they can focus on. For instance, the positive market reaction based on firms' with high R&D Intensity, shows the importance of internal investment in R&D resources when adapting a BC-SC solution. It also reflects the importance of having a knowledge reference or database, which comes in sync with the initial recommendation of joining a BC-SC consortium, where knowledge exchange among partners is one of the key goals.

Fifth, the early vs late adaptation comparison is important to decision makers particularly in the manufacturing industry. Our findings suggest that market reacts more positively to BC-SC announcements in the recent announcements only for the manufacturing industry. This doesn't only reflect the potential BC has among manufacturing SCs, but also how the technology has gained the shareholders' trust over the years. Thus, we encourage manufacturing SCs practitioners to initiate their BC-SC pilots and join forces with other stakeholders on a manufacturing consortium.

6.3 Limitations and Future Work

Like any empirical study, there are limitations perceived in this study. By addressing these limitations we were able to allocate four potential areas for future research. First, the event study approach used captures the overall firm performance in response to the BC-SC announcement over a short period of time. The overall performance is a "big picture" indicator of the positive response BC-SC announcements have on the market, what's more specific is operational performance. Thus, as the number of announcements increase over time, researchers should explore options to evaluate the operational performance of the firm when BC-SC announcements are public. Second, the long term impact of such announcements was not addressed in this study, due to the nature of the event study approach and due to the limitation in data when it comes to BC-specific information published by the listed firms. So, it is recommended that researchers conduct long-term empirical study to evaluate the long term impact of using BC-SC on shareholders wealth and profitability. Third, the sample size used in this study could be expanded in the future as more announcements become available, this would increase the statistical accuracy of the results. Fourth, this study addressed the impact of firms joining an industrial BC-SC consortium, however, some of the announcements showed that the firm is part of more than one consortium due to its diverse portfolio, or each consortium is adapted for a certain objective. It would be interesting to study such setups in comparison to firms that are part of one consortium only. This would require a larger number of data points representing firms that use multiple consortia.

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