BLOCKCHAIN AND SUPPLY CHAIN MANAGEMENT

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CHAPTER 1

Blockchain in supply chain management: recent developments and key issues

1.1 Introduction

Today's supply chains (SCs) are highly complex. They deal with many different variations of products that move through multiple parties. Coordinating SCs is a challenging task. Most of the world's major companies run computerized enterprise resource planning and supply chain management (SCM) software to manage their SCs. They use technologies such as connected manufacturing equipment and radio frequency identification (RFID) to track products from their origins until they reach the recycling bins.[1]

Despite this, SCs today face many challenges.[2] Often shocks associated with supply and demand disruptions cannot be predicted with a reasonable level of accuracy. It is thus difficult for firms to take proactive actions and minimize the effects or disruption from a crisis.[3]

SCs also lack visibility. According to a 2019 study conducted by Cointelegraph Consulting and Swiss blockchain firm Insolar, 70% of firms' SCs have "visibility gaps."[4] Due to the complexity of SCs, most firms find it difficult to trace the products beyond their immediate suppliers.[5] An analysis of conflict minerals reports submitted to the US Securities and Exchange Commission in 2014 and 2015 found that only 1% of filing companies claimed that their minerals were conflict free.[6] This means that the other 99% of the firms had no information about the origins of their minerals. Inventory managers and other decision makers lack information related to location, status, and other variables about products, components, and materials. It is also difficult to pinpoint accountable parties in case of frauds and other violations.

As an upshot of all these, most SCs are highly inefficient. About one-third of all food produced worldwide is wasted.[7] According to the

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USDA, total food waste in the United States accounts for at least 30% of the food supply. One estimate suggested that a 1% reduction in foodborne diseases can lead to 700 million from increased productivity in the United States, the economy. The increase will result from the reduction in illness and lost productivity.[8]

Another challenge is that in the nonblockchain world, firms' claims cannot be effectively verified. For instance, Apple argues that it "has been mapping its cobalt supply chain to the mine level since 2016."[9] However, there is currently no way to determine the truth or falsity of such a statement.

Blockchain has the potential to effectively address many of the challenges facing SCs. This technology can create SCs with a high degree of adaptability, proactivity, reliability, responsiveness, and accountability. It provides a high degree of data visibility. Since a transaction is confirmed by many participants of a network, it increases SC transparency and real and perceived accuracy of transactional data.[10] Blockchain can also improve the methods of communication and exchanging information.[11]

Thus, blockchain arguably is the missing element in these hyperdigitized SCs.[12] Additionally, blockchain can help firms meet various SC goals that other technologies have not been able to achieve. Some have touted blockchain as the biggest innovation in computer science.[13] Others consider this technology to be "the biggest disruptor to industries since the introduction of the Internet."[14] The World Economic Forum considers blockchain to be among six computing "mega-trends" that are likely to shape the world in the next decade.[15]

SC activities are thus viewed as among the ones that are most likely to be transformed by blockchain. There are different mechanisms that lead to blockchain's benefits in SCs which can be better understood by looking at blockchain-led reduction in the cost of verification and the cost of networking. Regarding the cost of verification, blockchain makes it possible to verify information about past transactions and attributes of the transactions as well as the current ownership in a digital asset. As to blockchain's effect on reducing the cost of networking, various parties can start a self-sustaining process and operate a marketplace. It is not necessary to assign control to a centralized intermediary. This is possible because blockchain can verify the state at a low cost. Economic incentives can be targeted to reward valuable activities from a network perspective. They include contribution of resources needed to operate and scale the network and secure a decentralized stage. The digital marketplaces that result from

such collaborations would allow the participants to make joint investments to create shared digital assets.[16]

Moreover, in light of the poor performance of most blockchain projects on result demonstrability, a McKinsey.com article asserted that blockchain's value creation potential lies mainly in three areas.[17] These areas fit squarely into SCs. First, in applications such as SCs, blockchain can address problems related to inefficiency, opacity, and fraud. Second, in some sectors, blockchain can help modernize value by helping the digitization process, simplifying value creation process, and facilitating collaboration. Some specific areas include smart contracts in the global shipping industry, trade finance, and payments applications. Third, blockchain is being used in SCs by some firms to enhance reputational value by demonstrating their ability to innovate. Indeed some of the most promising blockchain applications outside finance are expected to include those in SCs, power and food/agriculture. These use cases are believed to deliver real return on investment (ROI) at the early stage of blockchain development.[18]

This introductory chapter provides a general introduction to blockchain's promise to transform SCM. We also present definitions and explanations of some of the key terms used in this book.

1.2 Blockchain as a promising tool for SCM

1.2.1 Blockchain's growth

According to the International Data Corporation (IDC), worldwide spending on blockchain solutions would reach US$4.1 billion in 2020, which is 50% higher than in 2019. IDC expects that the market for blockchain solutions will reach US$17.9 billion in 2024.[19] IDC has attributed this rapid growth to the COVID-19 pandemic, which exposed many vulnerabilities and weaknesses in SCs, financial services, and other industries. Companies are increasingly recognizing that blockchain and distributed ledger technology (DLT) can play key roles in addressing these vulnerabilities. Key mechanisms include improving visibility and increasing efficiencies across SCs.[20]

As of 2018, there were over 1000 blockchain focused startups in the world. Well-known consultancies such as Accenture, Deloitte, and PwC have released studies highlighting its potential.[21]

Blockchain has proved invaluable in a wide range of applications, including finance, SC, and governance. For instance, the Chinese city of Beijing is reported to use blockchain for 140 government services.[22]

1.2.2 Blockchain in supply chains

Probably the most important use of blockchain to date has been in SCM. In order to justify this observation, we look at the annual Blockchain 50 list published in February 2020 by Forbes. The list consists of the world's biggest brands with over US$1 billion in annual revenue that are using blockchain. The list was first introduced in April 2019.[23] An analysis of the Netherlands-based market intelligence platform for blockchain and DLT firm Blockdata found that six of the Blockchain 50 companies specifically developed SCM-use cases (Fig. 1.1).

Market research and business consulting firm Allied Market Research estimated that the global SCM market will increase to US$37.41 billion in 2027 from US$15.85 billion in 2019. The integration of blockchain in SCM software is expected to be a major factor behind the rapid growth of SCM market.[24]

Blockdata also found that companies in the Blockchain 50 were more likely to use blockchain for traceability and provenance, which are closely related to SC, compared to payments and settlement.[25] Blockdata's analysis indicted that 15 had used blockchain solutions in traceability and provenance, whereas 13 had used such solutions for payments and settlements.[26]

While other technologies make it possible to trace and track products, blockchain will lead to confidence and trust in wide range of products such as fresh produce, raw materials, and diamonds. When goods change hands,

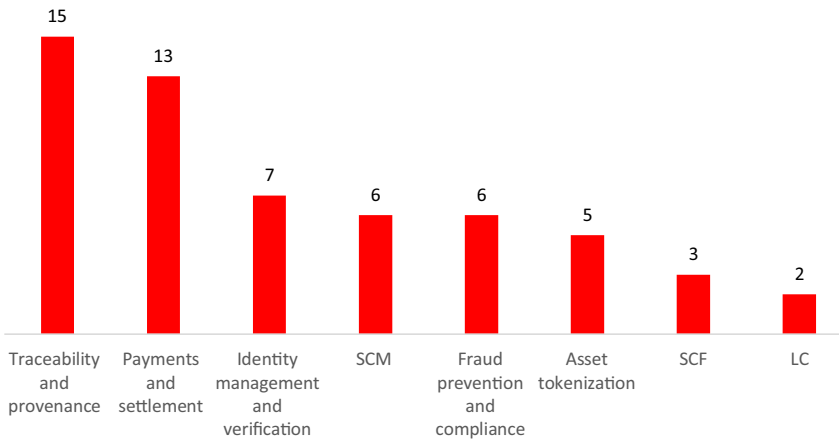

Figure 1.1 No. of products related to various use cases offered by Blockchain 50. *(Data source: Blockdata.)*

relevant records can be added. Reports related to inspections and deliveries can be uploaded, and payments can be released automatically when the conditions are fulfilled. PwC has identified provenance as the No 1 use case of blockchain and estimated that by helping organizations to verify the sources of their goods and track their movement and enhancing SC transparency, the technology has the potential to increase the global GDP by US$962 billion by 2030.[27]

Some companies with blockchain-based traceability solutions included in the list were IBM, Nestle, Foxconn, Honeywell, Walmart, Amazon, BMW, and Mastercard. Blockdata's analysis found that 10 of the products were already in production and five were in the pilot phase. Use cases were found in diverse industries such as agriculture, mining, aerospace, food, and automotive.

CEO and founder of traceability-as-a-service provider Circulor,[28] Doug Johnson-Poensgen noted that SC is among applications that can really benefit from blockchain and DLTs. SCs have many features that cannot be solved with huge database alone. Complex global SCs have no central authority. They need commercial confidentiality of data and an immutable record of transactions. Johnson-Poensgen went on saying that raw materials have the potential business problem that would most likely scale with blockchain.[29]

According to Frost and Sullivan's report Automotive Industrial Internet of Things Growth Insights, published in October 2018, 84% of Chief Information Security Officers reported that the "biggest challenge" they were facing was the "lack of visibility" across their SCs.[30] Blockchain can help companies make their SCs more visible, transparent, and collaborative (see In Focus 1.1: Jyoti - Fair Works using blockchain to map supply chains).

SCs entail flows of various categories of crucial resources such as physical goods, information, and finance (e.g., payments). The last two categories of nonphysical flows play supporting roles in SCM.[32] Blockchain deployment can improve the flows of both nonphysical layers: nonfinancial information and financial information. Blockchain-based SCM may incorporate additional useful nonfinancial information related to different attributes of an object, such as shape and color as well as environmental conditions such as temperature and humidity. SC-related data also may be collected continuously rather than at discrete intervals. Second, information in traditional SCs flows only in backward and forward directions. Some blockchain-based SC systems have nodes such as certification agencies and regulators, which were not a part of the information flows in traditional SCM. Third, blockchain-based SC

In Focus 1.1 Jyoti - Fair Works using blockchain to map supply chains

Jyoti - Fair Works is a German "fair fashion" label. It works with South Indian NGOs Jyothi Seva Kendra Trust and Nava Chetana Kendra to improve disadvantaged women's lives. As of early 2020, it employed 20 seamstresses. It claims to provide living wages, professional training, education, healthcare, and microloans to its employees.

Jyoti - Fair Works uses blockchain provided by Düsseldorf, Germany-based startup Retraced (https://retraced.co/en), to demonstrate that its apparel, footwear, jewelry, and other fashion brands have been sourced in ethical and sustainable manner. Retraced is a participant in the Oracle for Startups program, which is powered by Oracle Blockchain Platform. Jyoti - Fair Works uses Retraced's application to map its SC data that include details about cotton growers, textile manufacturers, fabric dyers, designers, and seamstresses. The system helps Jyoti to update order, delivery, and production schedules.

The system also creates, prints, and affixes QR codes to physical and digital garment tags. A blouse is posted on Jyoti - Fair Works's website or shipped to a retailer comes with QR code. Consumers can scan the QR code to see details such as a local farmer grew the cotton organically, it was processed without utilizing hazardous chemicals at a textile factory, it was dyed using environmentally friendly plant-based extracts, it was woven into biodegradable fabrics, and it was cut, sewn, and embellished by a fair trade artisan.[31] Jyoti invites suppliers to download Retraced's app and create a user account.

When Jyoti places an order, the app prepopulates with details regarding the materials needed to produce blouses. After a supplier accepts the order, it is added to the chain so that its activities can be tracked. Jyoti has all the details about the cotton such as when the cotton is shipped from the farm, processed into yarn, and dyed, woven into fabric, and sent to the sewing workshops to stitch the finished garments.

systems make reasonable efforts to ensure the veracity of the information entered in the system. For instance, SC participants cannot use fake custom clearance certificates since such certificates are directly uploaded by relevant government agencies. In some cases, it is also possible to evaluate the veracity of the information recorded in blockchain databases. If a farmer claims that they have planted organic palm trees in a certain plot of land and the information is entered into a blockchain records, interested participants such as certification agencies can visit the site and compare data recorded in the blockchain against the real-world situation. The record can also be confirmed

with other sources of information such as satellite imagery. There is thus a strong disincentive for an SC participant to provide false information in a blockchain system.

1.2.3 Current status of blockchain deployment in SC

A number of blockchain-based solutions have been launched to facilitate international trade. In August 2018, Maersk and IBM announced that the two companies jointly developed a blockchain-powered shipping solution TradeLens (https://www.tradelens.com/). The goals of TradeLens are to bring various parties involved in international trade together, support information sharing among them, and enhance transparency.

As of March 2020, TradeLens network consisted of 150 members. That included five of the world's top six ocean carriers—APM-Maersk, Mediterranean Shipping Company (MSC), China Ocean Shipping Company (COSCO), Hapag-Lloyd and Ocean Network Express (ONE).[33] Together they represent over half the world's container cargo capacity. By March 2020, the platform had processed 15 million containers.[34]

There are a number of other similar initiatives. In November 2018, nine ocean carriers and terminal operators—COSCO Shipping Lines (China), Compagnie Maritime d'Affrètement and Compagnie Générale Maritime (CMA CGM), Evergreen Marine, Hong Kong-based Orient Overseas Container Line (OOCL), Yang Ming, DP World, Hutchison Ports, PSA International and Shanghai International Port, and CargoSmart—announced that they would form a consortium to develop a blockchain-based platform, Global Shipping Business Network (GSBN). The blockchain software will be created by CargoSmart, which is a software company funded by Hong Kong-based container shipping and logistics service company OOCL.[35] OOCL is a founding member of GSBN. Likewise, in the early 2018, it was reported that AB InBev, Accenture, APL, Kuehne + Nagel, and a European customs organization tested a blockchain solution to exchange documents.[36] While these companies are mainly based in developed countries, some of them have significant operations in the developing world. In addition, we discussed above some blockchain-based solutions used in international trades in which most of the participants and beneficiaries are developing world-based.

1.2.4 Diverse value proposition across industries

Blockchain's value proposition is higher for goods with relatively high information costs.[37] Note that information costs are related to due

diligence, when individuals or companies need to evaluate the prudence of an investment or an activity. Some example of such products include perishable agricultural goods,[38] high-end manufactured products,[39] and drugs and pharmaceutical products.[40,41]

According to BIS Research's report titled "Global Blockchain in Agriculture and Food Market - Analysis and Forecast, 2018–28," the global market for blockchain in agriculture and food was US$41.9 million in 2018, which will increase to US$1.4 billion by 2028,[42] A study of Cointelegraph and VeChain suggested that blockchain will trace US$300 billion worth of food products by 2027.[43]

1.3 Definitions and explanations of the key terms

1.3.1 Blockchain and distributed ledger technology

A DLT is a decentralized database managed by a number of participants. In such a database, there is no central authority to act as an arbitrator. The distributed nature of the logs of records increases transparency and reduces the chance that the database is manipulated. It is also more challenging to hack or attack the database.

Blockchain is a DLT that has additional features. In a blockchain, the records related to transactions are shared by means of blocks that form a chain. Every block in a blockchain's online ledger has a timestamp, a hash pointer to link it to the previous block. Put simply, a hash is a type of cryptographic signature that closes the blocks. The next block starts with that same "hash," which can be viewed as a type of "wax seal."[44]

To sum, blockchains thus can be viewed as a secure distributed and decentralized digital ledger or database created by a network of computers, which stores continuous blocks containing transaction information in a secure and verifiable manner. The interaction among the computers is facilitated by purposefully designed software in order to get the computers to agree (or achieve consensus) as to what data to add and store on the database.[45]

1.3.2 Consensus mechanism

In a shared ledger, it is important to have an efficient, fair, and secure mechanism in order to make sure that only genuine transactions occur and participants agree on the ledger's status. A consensus mechanism performs this task by defining a set of rules to decide the various participants' contributions. The goal is to achieve the necessary agreement on a data value or the network's state.[46]

1.3.2.1 Proof of work

In a Proof of Work (POW) protocol, all users can compete to verify transactions. Major drawbacks of such protocol include high energy consumption and longer processing time.

1.3.2.2 Proof of stake

In a Proof of Stake (PoS) consensus model, only a small group of nodes can validate transactions. A node's power to validate transactions or responsibility to maintain the public ledger is proportional to the number of virtual currency tokens associated with the node.[47] For instance, a node that owns 5% of the currency available theoretically can validate only 5% of the blocks. It is viewed as a low-cost and low-energy consuming alternative to the POW algorithm.

1.3.2.3 Proof of Authority

The Proof of Authority (PoA) consensus model relies on a limited number of trustworthy block validators, which are preapproved. It is viewed as a modified form of PoS, in which a validator's identity rather than the role of stake is important. The nodes responsible for validating transactions are selected based on certain rules.[48]

1.3.3 Characteristics of blockchain

Three key characteristics of blockchain have been identified—decentralization, immutability, and cryptography-based authentication.[49]

1.3.3.1 Decentralization

Blockchain's value proposition is arguably embedded in the decentralization feature. By supporting decentralized models, blockchain can make sustainability-related activities more transparent and hence help produce trust. Blockchain eliminates the need for a trusted third party in the transfer of value and thus enables faster, less expensive transactions. Even those who are skeptical of the potential of blockchain in many other fields and applications are optimistic in its trust-producing capabilities.[50]

1.3.3.2 Immutability and append-only database

In an append-only database, new data can be appended, but existing data are immutable.

The data in a blockchain are immutable, and in the context of SCs this is an extremely effective feature. The term immutable comes from object-oriented programming, in which data structure and operations or

functions that can be applied are defined by programmers. Immutable means that once an object has been created and is recorded in a software code, it cannot be modified. Blockchain-based transactions are thus indelible and cannot be forged. The immutability feature makes transactions on blockchain auditable, which can improve transparency. A party can be given controlled access to relevant data. For instance, blockchain's distributed ledger model would allow regulators and authorities to access key data and information.[51]

1.3.3.3 Cryptography-based authentication

To ensure that only authorized users can access the information, blockchain systems use cryptography-based digital signatures in order to verify identities of participants. Users sign transactions with a private key. Such a key is generated when a user creates an account. The private key is typically a very long and random alphanumeric code. Using complicated algorithms, blockchain systems also create public keys from private keys. Public keys make it possible to share information. This feature makes it possible to measure and track relevant outcomes. For instance, if a coffee retailer claims that living wages are being paid to coffee farmers, the accuracy and truthfulness of such claims can be assessed by checking the payments to digital wallets that are assigned to the farmer.

1.3.4 Types of blockchain

There are, broadly speaking, three kinds of blockchains: permissionless (public), permissioned (private), and hybrid.

1.3.4.1 Public blockchain

A permissionless blockchain is an open platform. In a way, permissionless blockchains are like a shared database. Anyone can join. Everyone can read everything. However, a user cannot control who can write. Some examples include Bitcoin and Ethereum (see In Focus 1.2: The Minespider protocol built on Ethereum). The Ethereum network is a public blockchain–based open software platform, in which each node can be discovered by and known to other nodes in the network. It has its own cryptocurrency known as Ether.

1.3.4.2 Private blockchains

Private or permissioned blockchains, on the other hand, are restrictive. Access must be granted by some authority.[76] Permissioned blockchains can be designed to restrict access to approved actors such as SC partners.

In Focus 1.2 The Minespider protocol built on Ethereum

Berlin, Germany-based Minespider was founded in 2018. As of April 2020, it had operations in Switzerland and Brazil. In April 2019, Volkswagen and Minespider announced a pilot project to track carmaker's lead supply used in batteries.[52] The point of origin of lead could be a mine or a recycling facility. The blockchain pilot planned to gather data from various tiers of suppliers that deliver more than a third of the company's lead supply.[53]

The Minespider protocol

The Minespider protocol, which is built on Ethereum, has two layers: a certificate layer and a blockchain layer. The blockchain layer is used to record the amount of metal produced by responsible sources and owners of the metal. The certificate layer stores other relevant data such as certificates of origin, authorizations, production limits, and Chain of Custody.[54] For instance, digital "certificates" are created at mines or recyclers, which are encrypted with the company's public key and posted on a public blockchain.[55] As to the rationale of the public protocol approach, the company pointed out the risk that a large player with can create a monopoly on the global mineral SC tracking initiatives using private, permissioned blockchains.[56]

Companies can use Minespider platform to create "digital passports" for their raw materials, which help them track where the materials have come from as well as the conditions under which they were produced. When minerals are sold, new owner is added to the certificate and reencrypted with the new owner's public key. This makes sure that only the owner can access the SC data. At the same time, the data are in a verifiable and immutable public database, which enables SC transparency. This allows companies to verify environmental and social sustainability of their materials. Depending on the sensitivity, Minespider passports separate data into three different layers: publicly visible, visible to members of the same SC, or private.[56] It uses nested encryption to make sure that a company's sensitive data remain private on a public blockchain.[56] In a nested encryption, what is referred to as "onions of encryption" may be used in order to optimize security and functionality.[57] The idea is that a stronger encryption slows performance. Thus, one or more onions of encryption are used to encrypt each data item. The outer layers provide stronger security, whereas the inner encryption layers provide higher degree of functionality.[58]

As another example, the blockchain-based SC platform VeChain's VeChainThor is described as a public blockchain[59] (see In Focus 1.3: VeChain's public blockchain for supply chain management). VeChain was started in 2015 as a subsidiary of the Shanghai-based Blockchain-as-a-Service (BaaS) company, BitSE.

In Focus 1.3 VeChain's public blockchain for supply chain management

Epitome of China's global ambition

VeChain represents the epitome of China's ambition to internationalize Chinese technological solutions. In April 2019, the Cyberspace Administration of China (CAC) released the first list of 197 companies that were approved to conduct business with blockchain.[60] There were only two virtual currency projects in the list: VeChain Token (VET) and ParcelX (GPX). However, ParcelX (GPX), which planned to be a crypto-based parcel delivery service, had not yet been launched.[61]

In early 2020, China's largest state-controlled media company, China Media Group (CMG), also known as the "Voice of China," which focuses on radio and television broadcasts, promoted VeChain. The CMG published several videos about VeChain as a part of the first state-run 5G app Yangshipin. Yangshipin had about 100 million downloads in early 2020.[62]

As of early 2020, VeChain had developed more than 40 enterprise applications on its platform.[63] VeChain is a cofounder of the Belt and Road Initiative Blockchain Alliance (BRIBA) established in December 2019. The BRIBA aims to contribute to the Belt and Road Initiative (BRI) by leveraging blockchain.[64] Note that the BRI is a global development and industrial initiative proposed by the Chinese government in 2013.

How VeChain works

VeChain aims to simplify SCM.[65] In VeChain food traceability platform, for instance, each product is assigned a unique ID. The information is stored on the blockchain and also attributed to the product with an Near-Field-Communication (NFC) chip, RFID tag, or QR code (https://boxmining.com/vechain/). Sensors are used to track the products at different stages of the SC. At any point of the SC, distributors, retailers, or consumers can interact with the chip, tag, or code. Doing this, companies can access to information about how the products are handled. Consumers can verify the products they bought are legitimate and handled appropriately. Sensors are used to measure various indicators related to a product and record information at every stage of the SC. The information is linked to the product's identity. VeChain designs the sensors and manufacturers such as Bosch and Qualcomm produce them.

When consumers scan a QR code, they will be directed to a website that displays detailed information about the product such as its journey from the origin to the store. Each transaction has a timestamp. Information about the supplier and logs of temperature measurements in the SC is recorded. The QR code also has information about the blockchain transaction ID, which shows where all relevant data are stored on the VeChainThor blockchain.[66] Additional information about appropriate ways to use and store the product can also be provided.

In Focus 1.3 VeChain's public blockchain for supply chain management—cont'd

Using VeChain's ToolChain, a company can become ToolChain Admin Center and build systems to handle transactions on the VeChainThor blockchain. VeChain says that no strong technical background is needed to use ToolChain. Companies can upload product descriptions, features, photos, and videos. ToolChain Admin Center also manages which SC participants can write information on to the VeChainThor blockchain. A ToolChain Admin can predefine the events to share in the blockchain and control and assign what different companies can do. It is also possible to see the transaction generated by the product's journey.[67]

Proof of authority consensus

VeChain uses PoA consensus. Its 101 Authority Masternodes work as validators. Anonymous nodes are not allowed. Disclosure of identity is required to become an authority Masternode.[68]

It employs so-called native fee delegation feature, which means that the party that benefits from traceability covers the costs of using the network. Consumers and partners that interact with VeChain-powered DApps do not need to hold VET or VTHO. They do not need to pay to write transactions or use the network for other purposes as long as associated gas costs are sponsored, which are specified by the developers.[69] As of July 2020, VeChainThor was reported to handle 100,000 transactions daily to track SCs of fashion, food safety, and sustainability.[70]

VeChain utilizes a dual-token economic model. VET is the primary token, which is used to represent value on the network. The utility token VTHO is a "gas" currency, which is required to send transactions or perform actions on the network (https://boxmining.com/vechain/).

VTHO can address issues related to price fluctuations. For instance, if network activity grows and the price of VTHO increases due to higher market demand, it is possible to reduce the cost of a transaction in VTHO terms. In this way, transaction cost in dollar terms can be stable.[71]

Expanding to international markets

In November 2019, VeChain reached into an agreement with logistics, SC, and import solutions provider ASI Group to implement cross-continental logistics and trading solution using VeChainThor blockchain.[72] Together with the global quality assurance and risk management company DNV GL, VeChain announced Foodgates.[73] The plan is to develop a platform to monitor products along the value chain (e.g., cow selection, slaughter, packaging, and shipping to the supermarket/buyer for beef products).

Continued

In Focus 1.3 VeChain's public blockchain for supply chain management—cont'd

Italian startup Tokenfarm aims to introduce 4R technologies such as Blockchain, Artificial Intelligence, the Internet of Things, and 5G networks to the agrifood industry.[74] Tokenfarm is an initiative of Confederazione Nazionale Coltivatori Diretti (Coldiretti), which is Italy's main farmers' organization that has over 1.6 million members. In July 2020, Coldiretti and food firm Princes signed a 3-year contract to track the value chain of Italian tomatoes. Every year, Princes plant processes 300 million kilograms of tomatoes pass involving 300 companies, 17 cooperatives, and 6 associations of producers.[75] The blockchain pilot is powered by VeChain's ToolChain.

Private blockchains arguably have more promising applications in SCM.[77] Doug Johnson-Poensgen, CEO of Circulor, explained that the company originally prototyped its solution on Ethereum but switched to Hyperledger Fabric (see below). The switch was due to Circulor clients' prejudice against public blockchain. Potential uses were concerned that maintaining commercial confidentiality could be difficult to configure in a public blockchains.[78]

1.3.4.2.1 Hyperledger

Hyperledger is a private, permissioned blockchain that has no native cryptocurrency. It is an open-source collaborative effort, which was created in 2016 by 30 members including IBM, Accenture, BNY Mellon, Intel and Digital Asset Holdings to advance the use of blockchain across various industries. Over half of the companies in the Forbes Blockchain 50 list of February 2020 used Hyperledger.[79]

The Linux Foundation leads the Hyperledger Consortium, which had more than 250 members in July 2018.[80] Hyperledger has three categories of membership: premium, general, and associate. Consortium members include IBM, Intel, Accenture, American Express, Daimler, JP Morgan (premium), Lenovo, SAP, Tencent Cloud (general), Yale University, University of California, Los Angeles (UCLA), and Cambridge University (associate). These members are working together to develop platforms, tools, methodologies, processes, and solutions for enterprise blockchain.

As of August 2020, a premium membership, which comes with benefits such as right to appoint representatives to the Hyperledger Governing

Board, members-only Premier Legal Committee, and vote representative to the Marketing Committee, costs US$250,000. The fees for general membership varied from US$5000 to US$70,000 depending on the size of the company and existing membership in the Linux Foundation. Pre-Approved nonprofits, open-source projects and government entities are eligible for an associate membership with no charge (https://www.hyperledger.org/about/join).

Hyperledger Fabric is one of key projects developed under Hyperledger. Its codebase or the collection of source code to build Hyperledger Fabric's system, application, or software component comes from three sources: (a) Hyperledger, owned by Digital Asset, formerly called Digital Asset Holdings, (b) IBM's open-source blockchain platform, Open Blockchain, and (c) Blockchain technology company Blockstream's Lib-Consensus, derived directly from Bitcoin Core (a descendant of the original Bitcoin software client, that is, distributed to end users of Bitcoin for installation), which provides the Consensus Layer's part of the code to establish the criteria for a valid block.[81]

Hyperledger Fabric is a modular blockchain system, which allows organizations to develop products, solutions, and applications based on blockchain. Key components such as consensus and membership services work on a plug and play basis. It thus allows organizations to conduct confidential transactions without the need of a central authority.

To take an example, Düsseldorf, Germany-based startup Retraced leverages Oracle's Hyperledger Fabric blockchain (see In Focus 1.1: Jyoti - Fair Works using blockchain to map supply chains). One example has been in the creation of a digital ecosystem for sustainable clothing brand CANO.[82] Retraced's solution collects SC-related information from Cano. The information is made available for consumers with a near-field communications chip and QR codes that are embedded in products sold by Cano. Customers scan their Mexican leather shoes (also known as Huaraches) or apparels with an app to gain different insights that demonstrate sustainable and fair practices. The information provided includes the type of leather used, processes used to manufacture the leather, and the artisans. Cano can trace each product from creation to end-consume. The information collected can help make SC more efficient.[83]

Hyperledger Fabric performs better than well-known cryptocurrencies and public blockchains in terms the speed at which transactions are completed (Fig. 1.2). For instance, as of the early 2018, Hyperledger Fabric deployed in a single cloud data center had a throughput of over 3500

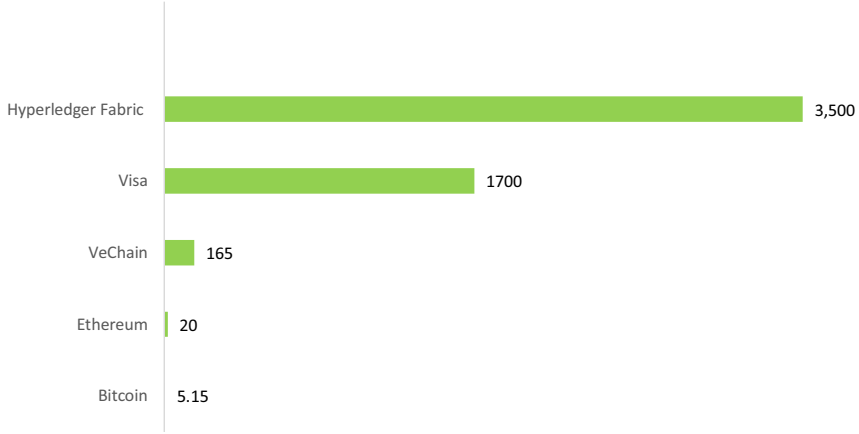

Figure 1.2 ***A comparison of throughputs of various blockchains and Visa (TPS).*** *(Data are from the following sources:* For Bitcoin, Ethereum and Visa: *earian, L. MIT's blockchain-based 'Spider' offers 4X faster cryptocurrency processing.* ComputerWorld*; 2020. https://www.computerworld.com/article/3518893/mits-blockchain-based-spider-offers-4x-faster-cryptocurrency-processing.html;* For VeChain: Brown C. VeChain 11 times faster than Ethereum – Mainnet update. Crypto News Flash; 2020. *https://www.crypto-news-flash.com/vechain-11-times-faster-than-ethereum/; For* Hyperledger Fabric (early 2018, deployed in a single cloud data center). IBM Behind the architecture of hyperledger fabric. IBM; 2018. *https://www.ibm.com/blogs/research/2018/02/architecture-hyperledger-fabric/.)*

transactions per second (TPS) with latency rate of less than one second. This compares favorably with the public Ethereum's 10 to 30 TPS and Bitcoin ledgers' 3.3 to 7 TPS.[84]

1.3.4.3 Hybrid blockchains

In hybrid blockchains, businesses use permissioned chains to transact in the background. Using an application programming interface (API), the transactions are connected to a public blockchain, which would allow consumers and others to engage in transaction such as transferring money or accessing information about products in SCs.[88]

A consortium blockchain can be viewed as a hybrid of public and private blockchains. In such a blockchain, a group governs the network rather than a single entity. Nodes in the network have various types of privileges. Some can control the consensus process. Others participate in transactions. Consortium blockchains are often attractive for entities operating in the same industry. Firms can leverage blockchain to enhance workflow efficiencies, share information and resources, accountability, and

promote transparency.[89] One example is R3's open-source blockchain platform Corda. As of August 2020, R3 had more than 300 participants from multiple industries (https://www.r3.com/about/).

1.3.5 Smart contract

Implementing smart contracts is among blockchain's most transformative applications. Smart contracts execute automatically when certain conditions are met. Computerized protocols and user interfaces are used to execute a contract's terms[90] and to "formalize and secure relationships over public networks".[91] A smart contract assures a party with certainty that the counterparty will fulfill the promises. In SCs, for instance, a smart contract system can be established to track products, which automatically determines ownership rights. Such a system can also be employed to release payments automatically when products are delivered.[92]

By implementing "business logic" in SCs into smart contracts, cost savings can be realized with blockchain. Additional cost savings can be achieved subsequently by removing intermediaries and employees.[93] Computer codes perform the tasks that needed intermediaries before (see In Focus 1.4: BlocRice uses smart contract to benefit Cambodian rice exporters).

In Focus 1.4 BlocRice uses smart contract to benefit Cambodian rice exporters

According to Oxfam, which is the confederation of 20 independent charitable organizations, the agriculture sector employs 60% of Cambodia's workforce, and many farmers lack contracts with their clients.[94] In April 2018, Oxfam launched the blockchain project, Blockchain For Livelihoods From Organic Cambodian Rice (BlocRice) in Cambodia. It uses smart contracts to improve Cambodian small-scale rice farmers' bargaining and negotiating power and digitally connect SC participants.[95] Agricultural cooperatives are parties to the contracts.[96] Key parties involved in the smart contracts include organic farmers and rice exporters in Cambodia and buyers based in the Netherlands. The term of the contract is that the exporter will pay farmers the market price, plus a premium.[97] Such a condition would guarantee a market for the rice and reduce some uncertainties for farmers.[97]

The project

It started with organic rice farmers in Preah Vihear province in the central north of Cambodia. The province is known for organic rice. Farmers town 1–2 ha of

Continued

In Focus 1.4 BlocRice uses smart contract to benefit Cambodian rice exporters—cont'd

land in average and produce 2.5–3 tons per year.[98] BlocRice project's phase I started with 50 farmers from the Reaksmei cooperative in one agricultural community in the province. Other parties were rice exporter AmruRice and rice-cake producer SanoRice. The communication consultancy Schuttelaar and Partners and the Dutch affiliate of the international Oxfam organization and Oxam Novib facilitated the process.[99] By selling directly to SanoRice, middlemen were eliminated.

The 50 farmers who participated in the BlocRice pilot project had agreed to provide 100 metric tons of rice. Since a late-season drought had led to reduction of rice production, they could deliver only 92.5 tons. The shipping took place in two containers to the Netherlands in March 2019.

Benefits to farmers

Each farmer receives a digital identity, which can be used to see details such as shipment weights and prices by logging into a website. The information is available in both Cambodian and English.[100]

The BlocRice application allows farmers to see the database using their smartphones. In this way, they are informed about prices and other contract terms. Farmers enter their planting and harvest data, which help AMRU Rice and SanoRice to predict about future yields.

Rice farmer and president of the cooperative Lyvoeung Chum noted that BlocRice provided more predictable prices compared to selling to traders. The farmers participating in BlocRice received US$0.24 per kilogram, and an additional US$.05 premium. The premium amounted to about US$100 for most of the farmers that participated in the first phase of BlocRice.[101]

Plans to expand the project

By July 2020, the project was expanded to 500 households in two communities in Preah Vihear province.[99] The goal is to expand to 5000 farmers by 2022.[94]

Future plans include making more data available. These include data related to weather forecasts, rice varieties, and farming practices in order to help smallholders to improve their yield and profitability forecasts.[100]

Current challenges

Many challenges remain. In 2019, 10%–20% of the farmers had smartphones. Some farmers are illiterate, lack Internet access, and a mobile data plan. Oxfam's BlocRice Project Manager Phay Cheth discussed about the potential to develop an app with audio to help illiterate farmers. Solutions are also being explored to develop apps that would allow farmers to update data offline, which can be uploaded when the devices are connected to the Internet.

The solution provides only a small improvement. Farmers suffer other forms of uncertainties such as those related to weather. The availability of risk sharing

In Focus 1.4 BlocRice uses smart contract to benefit Cambodian rice exporters—cont'd

and transfer mechanisms such as farm insurance is critical to improve the livelihood and development of farmers. A Multigrain Organic Rice Cake in a US Walmart store (3.53 oz) cost US$2.18 in July 2020 (https://www.walmart.com/ip/Great-Value-Organic-Rice-Cake-Multigrain-3-53-oz/117643524), which translates to US$21.78 per KG. This is more than 75 times of what was paid to the Cambodian farmers.

A stated benefit is that the system can improve farmers' bargaining position. Also it is arguably a cheaper social certification mechanism compared to alternatives such as FairTrade.[102]

The first blockchain to implement smart contracts was Ethereum, which is also the most widely used smart contract platform.[103,104] Ethereum has a built-in programming language that allows to define smart contracts and provides decentralized applications.

Smart contracts are installed in each node of the Ethereum network. While Bitcoin stores data related to transactions, Ethereum stores diverse types of data such as those related to finance, industry, legal, personal information, community, health, education, and governance. These data can be accessed and used by computer programs known as decentralized applications (DApps) that run on Ethereum. Software developers can choose their own "rules" for ownership, transactions formats, and other aspects (https://www.stateofthedapps.com/whats-a-dapp). Ethereum can thus be customized to offer unique solutions to special needs. It is mainly used to develop B2C applications. In Ethereum, computers connected in an open and distributed network provide the processing power needed to run a smart contract. The computers in the network also verify and record transactions in the blockchain.

The owners of the computers are awarded with Ether tokens for their contributions. Ethereum can be viewed as the first shared global computer. Bitcoin, on the other hand, is considered to be the first accounting ledger that can be shared globally.[105] Ethereum needs what is referred to as Ethereum Gas in order to execute transactions or smart contracts.

1.3.5.1 Advantages of blockchain-based smart contracts

Regarding how smart contracts are written and executed, three key challenges have been identified in the nonblockchain world. First, there is the

lack of transparency. For instance, when smart devices automatically perform actions on a user's behalf, the user may not be able to audit the encrypted information that is sent from the device to the cloud. The user's private data could also be sent. Second, it is possible that a piece of the application is controlled by a single entity. Some infrastructures that support the functioning of the IoT devices may not be available when they are needed. For instance, a smart contract may involve charging credit cards after a user refuels. But the credit card information might be stored by a cloud service, which may not be available. For instance, during early 2015—early 2017, cloud downtimes of major cloud services providers AWS, Microsoft, and Google were 448 min, 1652, and 506 min, respectively.[106]

Third, trust is critical in IoT applications involved in the exchange of goods or services. The production of trust may add financial overhead and/or may involve risks related to the violation of trusts. For instance, a vendor may leak credit card information or the credit card company may collude with a party if a dispute arises.[107] Blockchain-based smart contracts can address these shortcomings.

A blockchain-powered smart contract can be executed either "above" the blockchain or "on" the blockchain. In the former, the software program runs outside the blockchain and feeds information to the blockchain. In the second case, the software program is coded into blocks.[108]

In many smart contracts that are executed "above" the blockchain, effective communication between the underlying IoT infrastructure to facilitate reliable and secure processing of IoT data is critical.[109] When blockchain and IoT are integrated into a smart contract framework, the concerned parties need to decide where interactions would take place. Three possibilities can be envisaged: (a) inside the IoT; (b) a design that involves IoT and blockchain; and (c) through blockchain. Especially the first approach requires reliable IoT data and low latency in IoT interactions.[110] For instance, in IBM's blockchain trial project involving the transport of fruits from India to the UAE and juice from the UAE to Spain, data related to temperatures and other conditions of fruits and juice are reported by Du's IoT devices are validated by IBM's Watson AI. If these conditions meet those specified in the smart contract, the Spanish bank, Santander would release the payments. The bitcoin blockchain is found to be insufficient to implement smart contracts. In order to address the drawback of bitcoin, new blockchain platforms have emerged that come with integrated smart contract functionality.[110]

A rich ecosystem is developing around Ethereum to facilitate smart contracts. For instance, the security company Quantstamp has launched a security-auditing protocol for smart contracts. The protocol is written in Solidity, which is Ethereum's contract-oriented programming language for writing smart contracts. Quantstamp examines smart contracts through verification software and "Bug Finders" Quantstamp's process, however, is extremely labor-intensive. Source codes need to be reviewed, and specifications must be written manually.[111]

1.3.5.2 The roles of oracles in smart contracts

Access to reliable information about the conditions specified in a contract is a key challenge because the smart contract has no way to know about events that occur outside the blockchain environment. Most smart contracts thus require access to data related to real-world conditions. Such conditions could be temperature, payment completion, price changes, delivery of raw materials at a warehouse, or anything that is associated with the smart contract. So-called oracles provide data related to real-world conditions that are needed to enforce smart contracts. Oracles are the only way by which smart contracts interact with data outside the blockchain.[112] Oracles often charge a fee for performing a service.

Oracles thus have a critical role to play in the successful integration of smart contracts in the real world. At the same time, they create complexity. A key challenge is to provide authentication, security, and trust in oracles.[113] Among the key requirements, the data sources used by oracles to send to smart contracts must be credible.[114] For instance, if the term of a smart contract involves the temperature of a location, a priori choice needs to be made as to which source to believe when two or more sources provide different temperatures.

In order to determine whether a given event has occurred, a smart contract may query one or more oracles. Smart contract developers often do not trust a single oracle due to the inherent risk that the oracle may be wrong and/or act unfaithfully.[115] Aggregation of data from multiple oracles is likely to lead to a more accurate view of the data supplied and the real-world conditions specified in the contract.[116]

Oracles often use cryptographic protocols in order to provide evidence that the data they provided have not been altered since they were obtained. Some well-known data sources such as Google or the Yahoo Finance API are not considered to be good to act as oracles because they do not provide

cryptographic proof of what was returned to a given query at a point of time in the past.[117]

Oracles that can be utilized in smart contracts come in various forms. Some important forms of oracles include software oracles and hardware oracles. Software oracles are typically online sources of information such as temperature readings, and the price of various financial assets. The significance of software oracles lies in the fact that they are connected to the Internet, which allows them to supply the up-to-date information required to execute smart contracts.

Hardware oracles, on the other hand, are tasked with sending data to smart contracts when certain events occur in the physical world. Prominent examples of hardware oracles are IoT devices. To take an example, in SCM, if an object that has a sensor attached to it arrives at a warehouse, the data can be sent to a smart contract.[114]

There are several platforms that tack the oracle problem. For instance, blockchain-based middleware, ChainLink identifies and authenticates data before a smart contract is triggered. Its on-chain interface has three components: (a) The Reputation Contract stores and tracks metrics related to oracle service providers; (b) The Order-Matching Contract extracts data parameters related to a service level agreement. It also takes bids from oracle providers; (c) The Aggregating Contract collects responses from oracle providers and calculates the final collective result.[116]

Many potential challenges of oracles need to be considered. As mentioned, oracles may charge a fee for their services. However, when the outcome of a prediction market has a high value, the opportunity cost of collusion may increase. In such a case, an oracle may find an incentive to collude with a bad actor.[115]

Second, the ideal situation would be to rely on multiple oracles. However, this is easier said than done. In niche areas, sufficient number of oracles may not exist. For high-value smart contracts, the probability of the consensus being manipulated could be too high.[117]

Third, the information presented by an oracle could have been hacked. In order to address this, oracles might provide cryptographic proof to ensure that the content of the data is untampered. However, there is also the possibility that a hacker could target the data source feeding the oracle.[117]

Finally, errors can occur with even the most reputable companies. It is thus important to ensure that smart contracts are being executed based on correct information.[117]

1.3.6 Token and tokenization

Put simply, a cryptographic token (or simply a token) is a digital unit of value that is programmable and recorded on a blockchain or other distributed ledger protocols.[118] Smart contracts are used to manage cryptographic tokens.[119] In order to access a token, the private key for the address that holds the token is required. The token can only be authorized with the private key.

When a blockchain is used to issue a token, the issuance is recorded on the blockchain ledger. The blockchain also keeps a ledger of all movements of the token.[120] Tokens can be fungible or nonfungible (see: In Focus 1.5: Tokenization of minerals and metals).

In Focus 1.5 Tokenization of minerals and metals

Blockchain can be used to tokenize minerals and metals. Due diligence data that are submitted by participating SC actors can be used in the creation of the tokens.[121] Fungible as well as nonfungible tokens can be used to represent metals such as gold. We illustrate NFT below:

Let us assume that a responsible gold mine is interested in selling gold to customers. After extracting gold, they melt it into a semipure alloy of gold known as doré bars. Each bar is weighed, and a NFT to represent the bar is created. A doré token containing a unique ID is put on a tag that is attached to the doré bar. A link to due diligence data about the company producing the bar is also attached. When the doré bars change ownership, the associated NFTs are passed to the new owner.

When a doré bar reaches the refiner to create 1 oz gold bars, new gold tokens are created for each refined gold bar. Each new token is linked to the corresponding old doré token to have a record of where the bar came from. The old tokens representing the doré bars are frozen, which means that they cannot be traded any bar. When the gold bars are stored in a vault, each will have a unique ID. The owner can sell them on the open market, or redeem for the specific gold bar represented by an NFT.

There are some challenges to overcome for NFTs to track the metal. First, each bar of metal needs to be linked to an NFT. When the material is processed, which leads to a change in its form, it is difficult to determine which 1 oz gold bar is from which doré bar. Second, the system would work only when good data are provided to the blockchain.[122]

1.3.6.1 Fungible token

Fungible tokens are identical. That is, one token cannot be distinguished from another. They are also divisible and interchangeable.[123] Some common examples of a fungible token are payment tokens such as Bitcoin, Monero, Ether, and other cryptocurrencies.

Utility tokens, which are often used for fundraising in an Initial Coin Offering (ICO), are also fungible. The tokens that investors buy in an ICO can be used to buy goods or services offered by the token's issuer. It may also represent voting rights in decision making. Such tokens are also called coins or cryptocurrency assets. The most widely used utility token is the Ethereum-based ERC-20, which is a technical standard used for smart contracts. ERC-20 token keeps track of token owners at a given point of time.[124] An ERC20 token can be created with less than 100 lines of codes.[125] Tokens built on Ethereum need to conform to the standard.[126] Before ERC-20 was created, each cryptocurrency had its own system in order to verify account balances and initiate transfers.

1.3.6.2 Nonfungible token

A nonfungible token (NFT) can be viewed as the digital representation of an asset that is scarce.[123] NFTs that are powered by blockchains can fight counterfeiting. Buyers are likely to be confident that they will actually get what they have paid for. NFTs often have three characteristics:[127]

(a) Uniqueness: Metadata are used to describe factors that make an asset different from other assets. A permanent record which cannot be altered or erased describes the asset represented by an NFT represent. (b) Rarity: NFTs are attractive to represent scarce assets. (c) Indivisibility: Most NFTs cannot be divided up into smaller denominations. The whole item must be acquired, held, and transacted.

In July 2020, the blockchain-based diamond-exchange platform Icecap launched a bid/ask trading marketplace for diamond investors. Using the Ethereum ERC721 standard, Icecap assigns diamonds NFT tokens. Each ERC721 token is unique and thus is referenced on the blockchain with a unique ID. It is possible to determine the owner of a token with the ID.[128]

Its diamonds are certified by the Gemological Institute of America (GIA) and verified by the Gem Certification and Assurance Lab (GCal).[129] Each diamond is graded based on carat, color, and clarity. Each token represents the rights to a single specific piece of diamond that is stored in a vault. These tokens can be traded in crypto marketplaces such as OpenSea.io.[130]

1.3.6.3 Security tokens

Security tokens, which are registered securities in a jurisdiction where they are issued, share characteristics of both fungible and nonfungible tokens.[131] Such tokens function as investment contracts and represent complete or fractional legal ownership in an asset such as real estate asset, company, artwork, etc. Security tokens are more heavily regulated by the governments compared to utility tokens.[118]

1.3.6.4 Tokenization and tradeability

Blockchain-based tokenization can facilitate SC tradeability. Note that tokenization of a physical or digital asset in blockchain involves issuing a security token that represents the asset.[132] For instance, blockchain-based tokens can represent physical assets. Tokens that are tradeable can represent the stake a shareholder holds in a given asset (e.g., real estate, automobiles, and digital assets). Users can transfer ownership without moving the physical asset.[133]

1.3.7 Traceability

Traceability entails following a product's path along the direction of the upstream SC to its origin, while tracking involves following the downstream SC, that is, from raw materials to the end product.[134] The lack of traceability in traditional SCs is mainly due to data silos. That is, SC data are accessible by one participant but are isolated from other SC participants. In order to be able to trace ingredients across multiple tiers of an SC, data must be shared in a tamper-proof way and must be accessible to relevant parties.[135]

The above issues are important due primarily to the fact that consumers highly value transparency and traceability. A study conducted by the SaaS company Label Insight in 2016 found that 94% of consumers were likely to be loyal to a brand that offers complete transparency. The company's 2016 Transparency ROI Study also found that 73% of the respondents were willing to pay more for products that have completely transparent SCs.[136] Similar findings have been reported in recent studies. A survey conducted by IBM found that 73% of consumers surveyed placed importance on traceability of products and 71% of them would pay a premium for it.[137] Blockchain's key features such as decentralization and immutability make it an ideal tool to improve SC traceability[138] by addressing various shortcomings of traditional SCs.[139] Despite traditional SC information systems' capability to uniquely identify products, they perform poorly in traceability.

The importance placed on traceability in SCM is also apparent in scholarly literature. An analysis of 613 academic articles related to blockchain use in logistics and supply chain management (LSCM) indicated that "traceability" was the fourth most used title word (after blockchain/blockchain technology, supply chain/supply chain management, and applications) and fifth most used keyword (after blockchain/blockchain technology, supply chain/supply chain management, smart contract, and IoT).[140] Indeed, early academic papers focusing the use of blockchain in LSCM mainly dealt with traceability and product provenance.[141]

Various types of transformation parameters can be used in blockchain-based traceability.[142] In a single item traceability, consumer can see history of the item as moves along the SC. Blockchain can be combined with RFID or QR codes?[143] Single item traceability is appropriate for expensive prescription products such as life-saving drugs.[144]

In a batch traceability system, batch-managed products are tracked and traced from raw materials to finished goods. SAP Global Batch Traceability (GBT) allows companies to create a "product batch genealogy." To do so, batches of products are tracked and linked them with business activities (e.g., purchase orders, production orders and deliveries) throughout an SC.[145]

Mass Balancing methodology takes into account the materials or masses that enter and leave a system. This approach is widely used in fields such as chemical engineering. The systems and solutions provider for aseptic packaging SIG requires its supplier to purchase certain amount of certified plant-based feedstock for a given amount of polymer output.[146] Certified mass balance systems are used to verify the amount of bio-based feedstock that goes into the manufacturing of polymers.[147]

1.3.8 Mainnet and testnet

Mainnet is used to describe a blockchain protocol that is fully developed and deployed for actual cryptocurrency transactions with value. That is, such transactions are broadcasted, verified, and recorded on a blockchain.[148] The term testnet, on the other hand, is used to refer to a blockchain protocol or network, that is being used by programmers and developers to test smart contracts and DApps.[45]

Testnets and Mainnets are often operated by different networks. One group of computers agrees to work together to form a Testnet network. Another group agrees to serve as the Mainnet network.[149]

1.3.9 Interoperability in blockchain networks

In order to benefit from the network effect in the multichain environment, where many blockchain networks are present, it is important for different blockchains to work together. This means that industry collaboration and common standards for interoperability[150] play a critical role to realize the full potential of blockchain.[151]

Two main blockchain interoperability approaches can be suggested: APIs and network-of networks model.[152] Many APIs can be coordinated with an API Mashup, which categorizes and reveals all APIs as one API for the user.[153] "Mashup" APIs can bring blockchain networks and solutions together using a "mashup" application. Organizations interact with one API rather than an API for every network. Capabilities included are defined in data models and smart contracts. The API serves as "the glue that joins various networks together."[152] A drawback is that they cannot organize interoperability in the long run.[154] To take an example, China's Blockchain Service Network (BSN) project aims to integrate six public blockchains: Chainlink, Ethereum, Nervos Network, Iris Network, NEO, and Tezos.[155] The state-backed[156] BSN provides APIs to websites. It aims to build an ecosystem of decentralized applications (DApps) on public blockchains, which will be managed, launched, and operated with blockchains that are available on BSN. Using BSN tools, developers can develop interoperable DApps.[155] The developers can run nodes and applications with BSN's resources such as data storage and bandwidth.[156] Benefits for users include BSN's cheap services, interoperability with other Chinese enterprise blockchains. They can also access financial data from China UnionPay, which is normally not accessible to foreign-based blockchain firms.[157]

Network-of-networks model involves finding a blockchain solution that many blockchain networks can use so that the industry networks to converge around the solutions.[158] It is the most efficient and scalable way to build interoperability.[152] Some companies have made efforts in this area. Circulor is working with blockchain startup Everledger in order to make data interchange interoperable. The goal is to ensure that different solutions in a multiprovider environment can "talk" to each other.[159] Both Circulor and Everledger utilize the Oracle's blockchain platform (OBP). Circulor, Everledger, and Oracle were reported to be working on interoperability involving a series of standards for a number of applications including the battery SC.[160] Oracle is a BaaS provider and the OBP is based on

Hyperledger Fabric. OBP sets up, manages, and maintains the blockchain platform for enterprises.[161]

1.4 Concluding comments

Blockchain is transforming itself from a hype to reality. It is a promising tool for SCM. Blockchain helps to improve collaboration and communication among various parties involved in an SC and gives more control over SC activities. SC partners are often far away from each other and a member may not know most other members. For instance, a manufacturer often has no information about raw material producers. The COVID-19 pandemic has been an opportunity to reset the outdated SCs that are predominantly paper-based. In a digitized SC, blockchain's integration makes it possible for each member to know the identities and actions of all other participants.

Data are viewed as more reliable and accurate because they are recorded in a blockchain only if other participants in the value chain agree. It can also eliminate duplicate entries and provide a single, scalable record system. Blockchain-based systems make it possible to include transaction details such as amount that has been paid to each member in the value chain and socioeconomic characteristics such as the gender of a farmer. Verifiable information would create more interests and encourage active participation among consumers. In this way, it is also possible to translate traceability and sustainability data into a positive impact on smallholder farmers. They can be motivated to produce more sustainably and rewarded for their efforts.

1.5 The roadmap of this book

Including this introductory chapter, there are nine chapters in this book organized in three parts. The first three chapters in Part I present key issues and concepts related to blockchain in SCs. In Chapter 2, we examine the current challenges in meeting key SC objectives and provide detailed descriptions of how blockchain can help firms achieve these objectives. Chapter 3 provides an analysis of how many of the trust-related challenges in modern SCs can be overcome by combining blockchain with other advanced technologies.

The three chapters in Part 2 give an overview of the impacts of blockchain on major industries and activities. Chapter 4 evaluates blockchain's potential to address various challenges in the food and beverage

industry SCs. Chapter 5 focuses on blockchain's impacts on the healthcare and pharmaceutical industry, which has been among the highest priority sector to apply blockchain in major economies across the world. Chapter 6 gives special consideration to blockchain-led transformation that is likely to occur in SC and trace finance.

In Part 3's final three chapters, opportunities, challenges, and implications are discussed and the way forward is suggested. In Chapter 7, we highlight the opportunities, barriers, and enablers of blockchain adoption in SCs. Chapter 8 delves into policy, legal, and ethical implications. Discussion, conclusion, and recommendations are provided in Chapter 9.

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CHAPTER 2

Blockchain's roles in meeting key supply chain objectives

2.1 Introduction

In order to emphasize the importance of blockchain as a tool to achieve various supply chain (SC) goals and objectives, the proponents of this technology offer an example of the 2015 *E. coli* outbreak at Chipotle Mexican Grill outlets. The crisis left 55 customers ill. The company suffered a reputation loss due to negative news stories, restaurant shutdowns, and investigations. Sales reduced dramatically, and its share price dropped by 42%. The roots of the problem lie partly in the reliance of *Chipotle* and other food companies on multiple suppliers to deliver parts and ingredients. There is a severe lack of transparency and accountability across complex SCs. Food companies such as Chipotle are not in a position to monitor their suppliers in real time. It is, thus, impossible for Chipotle to prevent the contamination or contain it in a targeted way after it is discovered.[1] Chipotle's value proposition is centered on fresh and locally sourced ingredients. The nonblockchain methods of securing the Chipotle food supply chain are expensive and cumbersome. The process involves manual verification and massive record keeping.

In situation such as the one faced by Chipotle, blockchain can reduce the workload and ensure traceability. Besides the obvious value of traceability, huge benefits can be reaped in terms of reduced labor costs and food wastes. According to IBM, blockchain can reduce the average product recall cost by up to 80%.[2] At a broader level, according to the US Department of Agriculture, food recalls lead to 133 billion pounds of food wastage in the United States annually.[3] Blockchain adoption in SCs can reduce or even eliminate this wastage.

The above examples can be generalized to any industry such as aircraft, metals and mineral, electronics, or drugs. In short, blockchain-led total value chain visibility can offer huge gains to operations for any firm.[4] For

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instance, deliberate SC frauds alone cost businesses 5% of their revenues or US$3.7 trillion per year worldwide.[5] Such frauds can be detected and prevented with blockchain. These benefits may accrue to all the parties involved in the SC such as farmers, retail warehouses, and individual stores.

As another benefit, by eliminating middlemen such as auditors, efficiency can be increased, and costs can be lowered. Individual suppliers can perform their own checks and balances on a near real-time basis.[6]

Blockchain also provides an accurate way of measuring product quality during transportation. For instance, by analyzing data on the travel path and duration, stakeholders in a SC can know whether the product was in a wrong place or whether it remained in a location for too long. This is especially important for refrigerated goods, which cannot be left in warm environments. This value proposition is even more appropriate for countries such as China, where meat smuggling has led to serious health risks and a significant loss in tax revenue. In this way, blockchain-based solutions may give consumers more confidence that the products are genuine and of high quality and make them significantly more willing to purchase the brand.

Despite traditional SC information systems' capability to uniquely identify products, they perform poorly in traceability. Note that traceability entails following a product in the upstream of an SC to its origin, while tracking involves following in the downstream direction of an SC, that is, from raw materials to the end product.[7] The lack of traceability in traditional SCs is mainly due to data silos. That is, some SC data are accessible by some participants but are isolated from other SC participants. In order to be able to trace ingredients across multiple tiers of an SC, data must be shared in a tamperproof way and must be accessible to relevant parties.[8]

Blockchain can, thus, effectively facilitate track-and-trace applications. This technology allows companies to document the chain of custody of their products. They can prevent leakage in SCs, fight fake and counterfeit items and frauds, pinpoint suppliers that are at risk, or should be replaced. Blockchain also makes it easy to comply with regulatory requirements and create transparency around firms' sourcing activities.[9]

In some industries, blockchain adoption in SCs is no longer a choice but a necessity. An article in *Financial Times* published on September 9, 2020 reported that carmaker Volvo discontinued at least one supplier from its network due to noncompliance with its demand to connect to blockchain networks. Volvo plans to expand its monitoring to heavy components in order to reduce carbon dioxide (CO_2) emissions throughout its SC network.[10] Thus, in such cases, being part of blockchain network is matter of a firm's survival.

This chapter gives detailed descriptions of how blockchain can help firms meet various supply chain management (SCM) objectives. Specifically, it looks at the following SCM objectives: (a) Reducing costs; (b) Assuring quality of products; (c) Increasing speed; (d) Increasing dependability; (e) Reducing risks; (f) Facilitating sustainable practices; and (g) Enhancing flexibility.

2.2 Supply chain objectives

Logistics and Supply Chain Management (LSCM) play a key role in a firm's ability to deliver customer value.[11] Among the key goals of an effective LSCM involves getting the product in the right condition, in a timely manner and at the lowest possible costs.[12] Measurement of SCM performance is often described in terms of objectives such as quality, speed, risk reduction[13,14], dependability, cost, and flexibility.[15]

In addition to the above objectives, prior researchers have addressed the role of SCM for sustainable products.[16] This trend is partly driven by consumers' increasing concern about the source of products they use such as food and beverages, pharmaceutical, and cosmetic.[17] Social and environmental issues such as those related to noise pollution, congestion, and carbon dioxide emissions have become increasingly important and prominent.[18] Researchers have also argued that sustainability-related issues in SCs, which often deal with natural environment and social causes, are less quantifiable.[19] In this regard, it is hoped that blockchain, in combination with other technologies, can help obtain more quantifiable and objective data to tackle these issues.

Global SCs are complex and face multiple uncertainties.[20] A major objective of SCM is also to reduce risks. Among the various risks that organizations face include relational risks such as a business partner's engagement in opportunistic behavior (e.g., cheating, distorting information).[13,14]

The sources of risks in SCs can be classified into two main categories, namely, atomistic or holistic.[21] In order to deal with atomistic sources of risk, a selected and limited part of the SC need to be looked at in order to assess risk. This approach is suitable for components and materials that are of low-value, less complex, and easily available. On the other hand, holistic sources of risk require an overall analysis of the SC. This approach is preferable for high-value, complex, and rare components and materials.[21]

To achieve the various objectives noted above, it is important to evaluate suppliers. Due to increased competition, globalization, and outsourcing, the number of players in a typical SC has increased

significantly. In response, firms have introduced supplier evaluation programs using environmental and social criteria.[22,23] Some use supplier self-evaluation, in which SC partners declare how they have tackled environmental and social issues.[24] To take an example, the global apparel retailer C&A requires its suppliers to respect its ethical standards which include fair and honest dealings with employees, subcontractors, and other stakeholders.[25] There are, however, implementation challenges due to the technical impracticality of assessing various stakeholders' sustainability practices.

2.3 The roles of blockchain in achieving various strategic supply chain objectives

Blockchain can help address many of the challenges facing modern SCs. Table 2.1 provides illustrative examples of how blockchain can contribute to key SCM objectives such as cost, quality, speed, dependability, risk reduction, sustainability, and flexibility (See: In Focus 2.1).

Table 2.1 The roles of blockchain in achieving various strategic supply chain objectives.

Supply chain performance dimension	Explanation/context	Example
Reducing costs	• Economic sense to generate a blockchain code even for small transactions. • Elimination of paper records. • Blockchain's traceability makes it possible to easily identify the source of a problem and engage in strategic removals of affected products instead of *recalling the entire* product line.	• Maersk: Significant costs savings by fully digitizing the documents in international SCs. • Walmart: 2.2 s to trace a product.
Assuring quality of products	• Verification of CoC discourages SC partners to use low quality and counterfeit ingredients. • Real-time feedback can improve product quality.	• Alibaba's "Food Trust Framework" aims to improve integrity and traceability of food SC in China. • Quality-related issues were down by 20% in Unilever's tea SC in Malawi.

Table 2.1 The roles of blockchain in achieving various strategic supply chain objectives.—cont'd

Supply chain performance dimension	Explanation/context	Example
Increasing speed	• Blockchain digitizes communications and other important processes; There is no need for paper documents to be stamped and approved. • The cryptodenominated international commerce.	• Maersk: A simple shipment required stamps and approvals from up to 30 people and included over 200 different interactions and communications. • Cryptocurrency as the means of payment to settle international transaction increasing in developing economies such as those in Africa and Latin America.
Increasing dependability	• Exerting pressure on supply chain partners to be more responsible and accountable for their actions.	• Gemalto's delivery of temperature-sensitive medicines from drug manufacturer to hospitals located in hot climates.
Reducing risks	• Only parties mutually accepted in the network can engage in transactions in specific touchpoints. • Can ensure that software file downloaded has not been breached.	• Validation of the identities of individuals participating in transactions (Maersk). • Foolproof method for confirmed identity can reduce cybersecurity-related risks (Lockheed Martin).
Facilitating sustainable practices	• Promotes transparency and ensure that middlemen and other actors in SCs do not engage in unethical behaviors.	• A project initiated by RecycleGO and DeepDive uses Hyperledger Fabric to identify the entire history of a plastic bottle: creation, collection, conversion back to raw material form, return back to the manufacturer to make another plastic bottle.
Enhancing flexibility	• COVID-19 has forced firms to search for blockchain solutions to increase flexibility.	• SMBC joined komgo and Contour to exchange documents required for LC.

In Focus 2.1 Maersk integrates blockchain in supply chains (SCs)

The Danish shipping company Maersk is the world's largest container carrier and accounts for 18%–20% of the global market.[26] Maersk has been a high-profile example of a company that has successfully tested the use of blockchain applications in international logistics. Maersk uses the solution to track its shipping containers around the world with attributes like global positioning system (GPS) location, temperature, and other conditions.[27]

For many years, Maersk had been looking for a better way to trace the goods it ships worldwide. For Maersk, the key problem was the "mountains of paperwork" required with each container. For instance, Maersk's storage room at Mombasa office, on the coast of *Kenya*, was reported to have shelves and shelves of paper records that date back to 2014.[28]

The chairman of IBM Europe, Erich Clementi, personally pitched blockchain to the top technology executive at Maersk. Maersk and IBM started working on a version of its software that would be open to everyone involved with every container. When customs authorities signed off on a document, they could immediately upload a copy of it with a digital signature. This allows everyone involved—including Maersk and government authorities—to see that it was complete. If there were disputes later, everyone could go back to the record and be confident that no one had altered it in the meantime. The cryptography involved would make it hard for the virtual signatures to be forged.[28] The solution is based on the Linux Foundation's open source Hyperledger Fabric.

In 2014, Maersk tracked a shipment of avocados and roses from East Africa to Europe in order to understand the physical processes and paperwork in cross-border trades.[29] In most cases, the containers can be loaded on a ship in a few minutes. However, it can be held up in port for many days due to a missing paperwork. The study found that a single container to handle a simple shipment of refrigerated goods from East Africa to Europe required stamps and approvals from up to 30 people such as those in customs, tax officials, and health authorities. That includes over 200 different interactions and communications among them.[26]

The goods inside the containers may spoil. It was noted that moving and keeping track of all the required paperwork may cost as much as the cost of physically moving the containers. *Frauds are rampant in* the global SC system. For instance, the bill of lading is often tampered with or copied. Criminals take goods from the containers. They also circulate counterfeit products, which results in billions of dollars in maritime fraud every year.

IBM and Maersk did a proof of concept (POC) in September 2016, which tracked a container of flowers from the Kenyan coast city of Mombasa to Rotterdam in the Netherlands. In the POC, the shipping cost was US$2000, and the paperwork was estimated at about US$300 (15% of the cargo's value).[26] The POC was considered to be a success. Maersk and IBM followed up by using the system to track containers with pineapples from Colombia, and mandarin oranges from California.[28]

In Focus 2.1 Maersk integrates blockchain in supply chains (SCs)—cont'd

Subsequently, a pilot project was completed in February 2017, which started with Schneider Electric's empty container in Lyon, France. It was then filled with goods from the plant in the location and sent to Rotterdam. In Rotterdam, the container was loaded onto a Maersk Line ship and transported to the Port of Newark in the United States. From there, it was sent to a Schneider Electric facility in the United States. The number of agencies that participated in the pilot gives an idea of the complexity of international shipping. The agencies included Customs Administration of the Netherlands, the US Department of Homeland Security Science and Technology Directorate, and US Customs and Border Protection. Maersk's SC solutions company Damco supported origin management activities of the shipment. Rotterdam and Newark were selected with guidance from Maersk. Maersk was able to bring in customs to test the solution.[26]

2.3.1 Reducing costs

According to a 2019 study conducted by Cointelegraph Consulting and Swiss blockchain firm Insolar, blockchain can reduce businesses SC-related costs by 0.4%–0.8%.[30] Blockchain deployment results in even higher cost savings in some niche areas. For instance, according to IDC, by 2023, a quarter of original equipment manufacturers (OEMs) will utilize blockchain to source spare parts. This will improve accuracy of usable parts by 60% and reduce costs by 45%.[31] Likewise, drinks company AB InBev and software company BanQu started the blockchain project with 2000 Zambian farmers and 1200 Ugandan farmers who supply cassava and barley. According to BanQu, companies that adopt blockchain can realize average SC savings of 15% and reduce their exposure to risks by 50%.[32]

Several mechanisms are available to ensure cost reduction with blockchain-based solutions in SCs (See In Focus 2.2). Among the most obvious cost components, manual paper-based processes and humans carrying documents such as air courier expenses are eliminated. For instance, Maersk found that, significant costs savings can be achieved by fully digitizing the documents in international SCs (In Focus 2.1).

An observation is that unlike many other Information and Communications Technology (ICT) systems such as radio-frequency identification

In Focus 2.2 Deploying blockchain, smart sensors, and digital twins in oil field supply chains to reduce costs

The blockchain-based solutions provider for Internet of Things (IoT) Filament has launched wireless sensors, called Taps, which allow communication with computers, phones, or tablets within 10 miles.[33]

Taps create low-power, autonomous mesh networks that enable companies to manage physical mining operations or water flows over agricultural fields. Taps do not rely on cloud services. Device identification and intercommunication is secured by a blockchain that holds the unique identity of each participating node.[34] One key application is likely to be in the next generation of the industrial network (the Industrial Internet). Filament's blockchain-based applications involve sensors connected in a decentralized system and use autonomous smart contracts. This means that devices communicate securely with each other, exchange values, and execute actions automatically. For instance, Filament's Tap can be attached to drilling rigs in remote locations. Based on predefined conditions, a rig might know that it requires a piece of machinery and, thus, sends a request to an autonomous drone.[35]

Data provided by sensors connected to a drilling rig may not accurately reflect the rig's behavior. Digital twins may address this challenge. One example of a company planning to use digital twins in oil SCs is Chevron Corp. The technology helps predict maintenance problems in its oil fields and refineries. The company's plan is to have sensors connected to most of its high-value equipment by 2024. By preventing the breakdowns of equipment, the company expects to save millions of dollars annually.[36]

(RFID), blockchain can be deployed without devices, reading hardware or any process to attach tags to cases or pallets. Marginal costs associated with blockchain are, thus, zero or low, if technologies such as IoT have already been used to detect, measure, and track key SCM processes.

Blockchain can also combine unit level (instead of batch level) entity identification. Firms can exploit zero or very low marginal cost economics of digital networks. It makes economic sense to generate a blockchain code even for small transactions. Even SC activities involving a small quantity of products such as dumping a few dozen pints of apples or blueberries into a juice press or pouring a mixture of liquid and solids into a strainer in order to remove the solids can be recorded in a cost-effective manner. Combining with data related to temperature, humidity, motion, chemical composition, or other relevant indicators that can be collected from IoT

devices or sensors on equipment, blockchain can cost-effectively confirm everything related to the SC history of food products.[4]

To take one example, Walmart has accelerated the adoption of the IoT. In October 2016, it filed patent application that describes the addition of IoT tags to products based on Bluetooth, RFID, infrared, Near-Field-Communication (NFC), and other technologies. The tags will monitor product usage patterns and automatically refill orders. The IoT tags can also track products' expiration dates and product recalls.[37]

An increasing reliance on the use of IoT applications is among the trends that will affect SCM. With IoT, RFID tags, sensors, barcodes, GPS tags, and chips, the locations of products, packages, and shipping containers can be tracked at each step. This allows an enhanced, real-time tracking of goods from their origins. By incorporating blockchain in this hyper-digitized space, significant cost-savings can be realized. To take an example, in early 2020, Auburn University RFID Lab, GS1 US, and major global retailers launched the Chain Integration Project (CHIP). The project completed a POC that demonstrated how blockchain can be combined with RFID in order to gather serialized product information. Three brands—Nike, PVH Corp., and Herman Kay—and two retailers—Kohl's and Macy's—had contributed live data to the project.[38] Three key challenges have been identified that are likely to be addressed by blockchain-based solutions: (a) reducing the high costs associated with claims and charge-backs; (b) facilitation of more widespread sharing of collected serialized data; (c) adopting innovative, consumer-centric business models that legacy systems have failed to meet.

Blockchain's traceability has important cost-saving implications for the retailer. In a trial, Walmart found that it took only 2.2 s to find out an individual fruit's weight, variety, growing location, time it was harvested, date it passed through US customs, when and where it was sliced, which cold-storage facility the sliced mango was held in, and for how long it waited before being delivered to a store. In crisis involving contaminated food products and defective auto parts, the affected company would be able to easily identify the source and engage in strategic removals of affected products instead of recalling the entire product line (In Focus 2.3). Blockchain also enables more effective response if tainted products are discovered. In this way, the company can keep buyers' confidence in other products and avoid the danger of consumers getting ill.[48]

In Focus 2.3 Toyota uses blockchain in supply chain management (SCM)

In 2009, Toyota announced a recall of four million vehicles due to faulty gas pedals.[39] The recall cost an estimated US$2 billion.[40] The company had received pedals from many suppliers. It lacked mechanisms to track the suppliers that were responsible for the faulty pedals. There was, thus, no way to know which cars had the defective pedals.[41]

Indeed, counterfeit, fake and knock-off parts are a pervasive problem that affects the automobile industry. One estimate suggested that about 250,000 airbags on US roads are fake.[42]

Many carmakers are realizing that these problems can be tackled with blockchain and DLTs. In June 2016, Toyota Financial Services joined blockchain consortium R3. It was the first automotive financial services provider to become a member of the consortium.[43]

In the same month, Toyota Financial Services and R3 Consortium announced their collaboration on R&D of blockchain applications for the auto industry. The goal was to test the use of distributed ledger technology (DLTs) in nonfinancial use cases.[44]

Subsequently, Toyota started using blockchain to track auto parts in various countries, factories, and suppliers and provide and share information on a real-time basis among manufacturers, finance companies, insurers, service providers, regulators, and customers.[45] IoT data from vehicle parts are integrated in a blockchain. It expects to reduce recall rates and fake products and increase consumer safety.

In April 2019, Toyota Motor Corporation and Toyota Financial Services Corporation launched Toyota Blockchain Lab. The automaker said, it aims to become a "Mobility Company." The Lab focuses on four areas:[46]

(1) Identity and access management: Toyota collaborated with blockchain start-up BUIDL to develop identity and access management application. Using blockchain-based decentralization, the identity of a user would not need to be verified again and again. Once verified, identity-related data can be securely shared. It is also more secure compared centralized systems to store personal information. It consists of personal ID platform and vehicle ID platform. Corporate users such as the Toyota Group and its affiliates can use the personal ID platform for a range of activities such as managing points and employee benefits and issuing digital certificate. The vehicle ID platform can be used for managing vehicle registration, maintenance records, and ownership records.[47]

(2) Managing the life cycle of a car: With blockchain, *actionable data can be* shared securely, used, and viewed throughout a car's life. Data related to ownership, mileage, and repair and other events can help to provide a car's real-time valuation.

In Focus 2.3 Toyota uses blockchain in supply chain management (SCM)—cont'd

(3) Supply chain: Blockchain is expected to strengthen SCs *in two different* ways. In its upstream SCs, it can track auto parts from various suppliers. In its downstream SCs, when it can track cars and parts to dealers and service companies. For instance, a consumer can verify the authenticity of a Toyota part.

(4) Tokenization of ownership: Toyota refers to this as "value digitalization." The goal is to tokenize car's ownership. Among other benefits, the data can used for leases and contract hire agreements.

2.3.2 Assuring quality of products

As noted above, blockchain can facilitate track-and-trace applications,[8] which can provide numerous ways to assure quality of products in SCs. Verification of Chain of Custody (CoC) is probably one of the key mechanisms, which discourages SC partners to use low-quality and counterfeit ingredients.

According to the Organisation for Economic Co-operation and Development (OECD), the global trade in counterfeit and pirated products was US$250 billion in 2008, which increased to about one trillion in 2016 or 2.5% of global imports.[49] China is the global capital of counterfeit products.[50] Over 80%of the world's fake products originate in China.[51] Many blockchain solutions in China focus on tackling this issue. To take an example, Alibaba's "Food Trust Framework" is a tool to improve integrity and traceability of food SCs to fight against low-quality and counterfeit products in China.

Blockchain solutions also allow faster response and quicker feedback.to SC partners, which can have a major impact on quality of products. For instance, the British–Dutch multinational consumer goods company Unilever utilizes blockchain technology Provenance's platform to connect with farmers. Among many benefits, Unilever has been able to address product quality issues in its tea leaf SC (See: In Focus 2.4).

2.3.3 Increasing speed

The speed with which various operations are performed can be increased with blockchain. Digitization of physical process and reduction in interactions and communications are important mechanisms to increase the speed.

In Focus 2.4 Unilever utilizes blockchain in tea leaf supply chain

Unilever is utilizing Provenance platform to ensure fair wages to farmers of tea leaf crops in Malawi. It also aims to promote quality control within its tea leaf SC. Provenance's blockchain ledger supports the validity of Unilever's sustainability and social impact credentials within the developing regions (provenance.org, UD). The data allow Unilever to expedite financing to processors and reduce overall costs of their SCs. Savings are, thus, reinvested into the small farmers' communities in programs that further educate the farmers about sustainable growing practices, thereby increasing their farming efficiencies and social impact within the area. The response times of Unilever's tea SC are "cut in half, and quality issues down by 20%".[52] Real-time feedback has also improved product quality control and relationship quality with their suppliers, processors, farmers, and customers.

The cryptodenominated international commerce, which has become increasingly common,[53] has also become a key force to increase the speed of SC activities. Small businesses in developing countries have reported that speed and efficiency can be greatly improved by making payments in cryptocurrencies rather than in major international currencies such as US Dollar and Euro. A Nigerian vendor of handsets and accessories, who sources his products from China and the United Arab Emirates, reported that his Chinese suppliers prefer payments in cryptocurrency. He started paying with cryptocurrencies, which increased his profits. This is mainly because he did not have to buy US dollars using the Nigerian naira or pay expensive fees to money-transfer agencies.

Due to such practical uses, which is unique to developing economies such as those Africa, Bitcoin's use has been reported to grow in these economies. For instance, according to US blockchain research firm Chainalysis, monthly cryptocurrency transfers of under US$10,000, which are typically made by individuals and small businesses, to and from Africa increased by more than 55% during June 2019–2020 to reach US$316 million.[54]

Chainalysis' analysis showed a similar pattern in Latin America. During June 2019–2020, Latin America sent US$25 billion worth of cryptocurrency and received US$24 billion.[53] Chainalysis' data showed that East Asia was Latin America's significant counterparty.[55] The blockchain

research firm's interviews with Latin America–based cryptocurrency operators indicated that many of the payments were commercial transactions between East Asia–based exporters and Latin American importers. A Paraguay-based cryptocurrency exchange explained that businesses in Paraguay import significant amount of goods from China. Some of them are then exported to other countries such as Brazil. Many of the importers make payments using Bitcoin because of the speed and ease with which they can settle the payments. Due to concerns related to money laundering, banks in Paraguay are reluctant to do businesses with most companies. The banking application process is complex, which requires many supporting documents and takes a long time. Moreover, even if a business's application to make a payment in international currencies is approved, wire transfers are costly. Moreover, by making payments in cryptocurrencies, they can avoid import taxes.[55]

2.3.4 Increasing dependability

Blockchain can provide various mechanisms to achieve a high degree of dependability. With blockchain, SC partners can expect a high level of dependability since immutable data related to measurement for various indicators such as quality and physical state such as temperature, moisture content, and location (e.g., with GPS) are available for verification. To take an example, digital security company Gemalto, which was acquired in 2019 by Thales, teamed up with an insurance company that covers the delivery of temperature-sensitive medicines from drug manufacturer to hospitals located in hot climates. Digital thermometers are used to record the temperature of drugs regularly. All relevant data are added on the blockchain ledger. Blockchain helps exert pressure on SC partners to be more responsible and accountable for their actions. The responsibility and accountability shift when the drugs move along an SC. Drugs are delivered in a state that meet regulatory requirements. Blockchain's "super audit trail" can address challenges associated with self-reported data provided by SC partners.

2.3.5 Reducing risks

Blockchain provides a range of mechanisms to address SC risks. In this regard, for one thing, there is a deep thirst for a foolproof method for confirmed identity of actors engaged in SCs as well as of IoT devices (See In Focus 2.2). The first of blockchain's direct benefits is that it provides a

possible solution to identity management.[56] Blockchain provides immutable information that can be made readily accessible to relevant SC partners, which helps to know who is performing what actions. Additionally, time and location of the actions can be determined. For instance, the identities of individuals participating in transactions can be validated. Especially, in permissioned blockchain, only parties mutually accepted in the network can engage in transactions in specific touchpoints. For instance, the IBM/Maersk platform is built on IBM's Hyperledger Fabric protocol, which is a permissioned blockchain (In Focus 2.1).

Blockchain facilitates valid and effective measurement of outcomes and performance of key SCM processes. Once the inputs tracking data are on a blockchain ledger, they are immutable. Other suppliers in the chain can also track shipments, deliveries, and progress. In this way, blockchain produces trust among suppliers and reduces risks.

Blockchain can also ensure that software file downloaded has not been breached, which is an extremely valuable application for some players. In 2017, the world's largest defense contracting firm, Lockheed Martin Aeronautics, announced plans to leverage blockchain in its operations. In order to integrate blockchain into its external software SC, Lockheed Martin teamed up with Virginia-based cybersecurity provider GuardTime Federal.[57]

GuardTime Federal is helping Lockheed Martin Aeronautics to integrate Keyless Signature Infrastructure (KSI) blockchain across the latter's external software SC.[58] Blockchain's role is to ensure data integrity by verifying that data in the network are not compromised. For instance, KSI's integration into digital-based manufacturing equipment allows the detection of unauthorized software when third-party routine maintenance is performed.[59] The KSI blockchain takes only fingerprints of the data and, thus, does not put all the data in the blockchain. Thus, data authentication is possible in a massive scale.[60,61]

As another example, the precision parts manufacturer Moog has launched a service called Veripart. As to the challenges that it wants to address, the director of Moog's additive manufacturing and innovation unit, James Regenor put the issue this way: "How can the maintenance crew on a US aircraft carrier have absolute confidence that the software file they downloaded to 3D print a new part for a fighter jet hasn't been hacked by a foreign adversary?" [1] This is a powerful argument in favor of blockchain's use in risk reduction.

2.3.6 Facilitating sustainable practices

IBM company's report "Meet the 2020 consumers driving change" based on the survey emphasized on "Trust but verify."[62] That is, shoppers want information on corporate sustainability policies. Consumers want brand to support recycling, invest in charitable causes, or take other actions to demonstrate social responsibility.[63]

Blockchain might be an important way for firms to demonstrate their sustainability-related practices (In Focus 2.5). For instance, some argue that by storing SC data in a tamperproof way in blockchains, firms can create a positive perception of products in terms of environmental and social sustainability.

Overall various mechanisms related to the deployment of blockchain and other technological advancements can help firms to *achieve triple bottom line (TBL) goals* and long-term sustainability. For instance, blockchain promotes transparency and ensure that middlemen and other actors in SCs do not engage in unethical behaviors.[67]

In Focus 2.5 RecycleGO and DeepDive aim to leverage blockchain to promote environmental sustainability

Recent estimates have put the total amount of plastics produced in 2020 at about 400 million tons, which is projected to double by 2050.[64] Only 9% of plastic products are recycled.[65] According to the World Economic Forum, about 40% of plastic is landfilled, and 32% is leaked into the environment. In order to change this situation, recycling service and technology provider RecycleGO and enterprise technology firm DeepDive Technology Group have initiated a multiphase project with a goal to transform the existing recycling SC using blockchain.

The CEO of DeepDive noted that data in the plastics recycling industry are fragmented and incomplete. Participants in the industry find it difficult to access relevant data. Blockchain is expected to help share secure data efficiently without the need of intermediaries.[66]

The project is built on Hyperledger Fabric.[64] Technologies such as IoT sensors and QR codes will also be employed to collect data.[66] In Phase 1, collaborators of the project will be able to identify the entire history of a plastic bottle: creation, collection, conversion back to raw material form, return back to the manufacturer to make another plastic bottle.

Promoting social sustainability in SCs is becoming a key aspect of many blockchain applications. By combining blockchain with other technologies such as IoT and big data analytics, firms can monitor and evaluate social sustainability performance of their SCs.[68] For instance, Bureau Veritas, which provides testing, inspection, and certification services, has developed blockchain-based consumer facing food traceability system (http://www.origin.bureauveritas.com//). Relevant participants share records and validate transactions. It provides information from continual verification rather than only samples. By flashing a QR code in-store, shoppers can see a product's history in order to make informed purchase decisions. One of the future goals of Bureau Veritas blockchain system is to eliminate forced and child labor from those SCs.[69]

A trend discussed above is that consumers are increasingly becoming concerned about the sources of products they use such as food and beverages, pharmaceutical, and cosmetic.[17] Using blockchain, it is possible to make indicators related to sustainability more quantifiable and more meaningful for consumers. End users can ensure the quality and accuracy of such information.[70] In this way, blockchain can enhance consumers' perception of a firm's sustainability practices.

By allowing consumers to monitor products, firms can make corporate social responsibility (CSR) governance more transparent. End users can have access to data that could help them determine whether the products they are about to buy have been produced in an environmentally sustainable manner and whether issues related to human right violations or child labor were involved in their SCs.[71]

Researchers have suggested that labeling can be used as an important tool to enhance consumers' perception of a firm's sustainability practices.[72] A problem with this statement is that firms may use false labels by misusing labeling programs related to production, process standards, and other aspects.[73] By exploiting the information asymmetry, manufacturers and retailers can increase profits by providing false information about their products.[74] These challenges can be addressed with the deployment of blockchain.

In this way, companies can reduce the risk of being accused of greenwashing or bluewashing. Note that the term bluewashing (or bluewash) is used to criticize the corporate "partnerships" with the United Nations (UN) under the UN Global Compact, which is a nonbinding pact to encourage businesses to adopt environmentally sustainable and socially responsible.[75] Critics have suggested that some corporations' association

with the UN under the Global Compact helps to improve their reputations, but due to their engagement in unsustainable water use practices, their sustainability-related claims are of little or no worth.[76] Some go even further to argue that some corporations that are notorious for human rights and environmental violations have shown a tendency "to 'bluewash' their image by wrapping themselves in the UN flag." [77]

2.3.7 Enhancing flexibility

Using blockchain, a higher degree of flexibility can be achieved in SCs. Flexibility can be defined as an SC's ability to adapt to the changing competitive environment in order to provide products and services in a timely and cost-effective manner.[78] Researchers have used range and adaptability to measure flexibility. Range is related to how existing resources can be combined to achieve a number of different states (e.g., levels, options, and positions). Adaptability can be defined as the ability to change from one state to another quickly and in a cost-effective way.[79] In international SCs, processes such as the letters of credit (LC) and bills of lading have very complex and intricate information flows.

The COVID-19 pandemic has acted as a jolt that has forced firms to search for solutions that can provide a higher degree of flexibility in such situations. Blockchain has been seen as an obvious option. Thus, COVID-19—led pressures have intensified the adoption of blockchain solutions. Berlin, Germany-based blockchain solutions provide Minespider reported that there has been an increased interest in its traceability services following the COVID-19 pandemic.[80]

Paper documents need to be physically exchanged, which is an extremely slow process (Fig. 2.1). This issue became especially apparent during the COVID-19 pandemic. Documents such as LC, bills of lading, invoices, and others are normally carried in the cargo holds of passenger aircraft. Most passenger flights could not operate during the COVID-19 pandemic. Millions of documents related to cross-border trade transactions were forced to find alternative means such as ships to reach their destinations. However, many of them could not be delivered to banks because they were closed. Due to the emergency nature of the situation, many banks started accepting scanned signatures and documents. While electronic documents show superior performance in terms of speed, their fraud proneness has been a big concern among banks and other players. Blockchain has a clear usefulness in relation to security.[82]

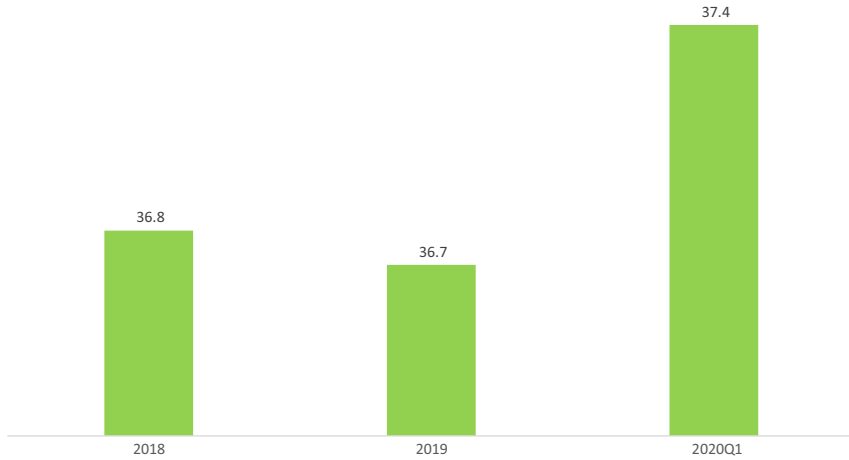

Figure 2.1 Average time to settle an invoice (days). *(Data from: Tradeshift Lin J, Lanng C. Here's how global supply chains will change after COVID-19. World Economic Forum; 2020. https://www.weforum.org/agenda/2020/05/this-is-what-global-supply-chains-will-look-like-after-covid-19/).*

As an example, in July 2020, Sumitomo Mitsui Financial Group (SMBC) announced that it would join blockchain consortiums komgo and Contour, which focus on LC. A major motivation to join the networks was COVID-19–led complexity in exchanging documents required for LC.[83]

Finally, a key observation of with respect to flexibility is that even if only a few participants in an SC use a blockchain-based solution, this will have a powerful effect. Due to the network effect, the power and impact of blockchain increases with more players' incorporation of such solution.[84]

2.4 Discussion and implications

From the above discussion, it follows that blockchain can help firms meet key SCM objectives. There is an interesting contrast here between the use of blockchain in the financial industry and SC activities. Matt Levine, a Bloomberg View columnist, asserted that users in the financial industry could get "a lot of the same benefits" from a regular old database.[85] He gave some examples to help illustrate this point. For instance, central banks keep "lists of who has what amounts of currency." In the United States, the Depository Trust Company (DTC), a clearing and settlement institution established in 1973, which is a member of the Federal Reserve, keeps a list of owners of stocks. In many cases, the problems that are encountered in

SC-related activities concern issues related to communications. For instance, it is important to obtain numerous approvals from various authorities. They need to be communicated efficiently and in the same format. This is exactly the problem solved by blockchain in SC. The problem that blockchain is solving in Maersk's case discussed above is "a messaging problem" more than "a database problem." It is argued that the shipping container example is different in the sense that whereas finance has trusted central intermediaries, shipping lacks such intermediaries. Due to the above-mentioned factors, it is argued that financial industry blockchain projects are "highly hyped." On the other hand, blockchain has a true potential to help firms meet various objectives.

Using innovation diffusion theory, it can be argued that blockchain has a higher relative advantage in SC activities compared to the banking and financial industry. Note that relative advantage can be defined as perceived benefits of a technology over previous technologies and the extent to which it is better than the idea it supersedes.[86] One view is that there is not much value in setting up proprietary centralized blockchains for financial purposes, which do the same thing less efficiently than existing databases. Due to the absence of other available alternatives to solve the communications problem in shipping, blockchain is likely to become an attractive and cost-effective option.[85]

As discussed above, one of the major impacts of blockchain is cost reduction. A caveat needs to be made about cost saving. Like many other technology projects, it may take a long time to materialize. For instance, Maersk expected that the costs are likely to reduce drastically, the blockchain-led savings are not expected to be known for 2 years or so until the technology is more widely used.[26] When the rules are in place, blockchain could automate many processes and enable them to run more efficiently.[87]

Blockchain solutions can also provide various mechanisms to assess and ensure quality and help address quality issues in SCs. Such solutions can provide data that can be used to assess useful, meaningful, and representative indicators for describing quality. There are substantial frauds related to counterfeit products such as medicines, fine wines, and luxury fashions. One estimate suggested that the value of fraudulent fine wine is about US$1 billion annually.[88] According to the technology enterprise Everledger, one-fifth of the sales of international fine wines are counterfeit.[89] Managing the risks of counterfeiting is, thus, important in a number of

economic sectors. Especially, industries that face the risks of counterfeiting are more likely to adopt blockchain in SC to assure quality of their products.

Blockchain improves dependability by exerting pressure on SC partners to be more responsible and accountable for their actions. Gemalto's case indicates that individual responsibility and accountability can be stipulated and warranted. Note that in a conventional or "centralized" ledger, a single authority acts as the "trusted third party." In a blockchain system, each user has its own verified copy of the distributed ledger. A user can immediately see transactions on the ledger.[90]

Security-related risks is an important consideration that may distinguish blockchain deployment in financial activities and SC. It was reported that the companies working with IBM were less worried about the security issues. Almost all of them were against an open system such as Bitcoin. The blockchain SC solution developed by IBM and Maersk is a permissioned blockchain. This is a closed group of participants that are known and have permission to participate in the transaction.[26]

The roles of other mechanisms to reduce risks deserve mention. Only parties that are mutually accepted in the network can engage in transactions in specific touchpoints. It is, thus, possible to maintain trust and security. Lockheed Martin's case indicates that cybersecurity-related risks can be reduced with blockchain.

Some determinants of blockchain adoption in SC are the number and capabilities of related actors involved and the extent of pressure faced by the firms to stay competitive. Partly because there is a challenge in bringing a large number of parties together, blockchain-based SC solutions are likely to be more appropriate for the technology and auto industries. Note that these industries exhibit shallow SC restricted to a small number of suppliers. Some consider garments industry as also a possible target. These industries have relatively shallow pool of suppliers, which is critical for blockchain platform's early stage of development. The oil industry, on the other hand, is reported to have up to 13 supplier layers.[91] That's not to say that oil industry is likely to lag other sectors in the adoption of blockchain in SC. Indeed, some argue that the oil trading sector may overtake the financial sector in blockchain implementation. This sector is dominated by a few big players (players with strong capabilities). Some of them are large conglomerates, and others are independent firms. They exhibit lower risk aversion than most financial institutions. If a few oil firms demonstrate positive results by moving their operations to blockchain platforms, others

may follow them in order to be competitive. Moreover, firms in this sector are facing pressure to stay competitive since the market is facing an environment of lower profits.[92] In 2010, 16 companies that traded energy, metals, and agriculture had aggregate revenues of US$1.1 trillion.[93]

A key application of blockchain is likely to be in verifying environmental and social sustainability. As noted above, some firms use self-reported response from suppliers to assess the way environmental and social issues are tackled. A problem with this approach is that there are no mechanisms to verify the claims that a supplier makes. Blockchain's "super audit trail" can address this concern. Blockchain also provides the flexibility of being able to go back and examine the contents of the record for all the relevant parties in case of disputes. Particularly, the coffee SC employs 25 million people directly, mostly in rural areas of emerging countries. Nongovernmental organizations (NGOs) and others that monitor the fair trade use "antiquated" techniques. Much superior and better results can be achieved with blockchain. In this way, blockchain has the potential to reduce unethical and illegal practices.

It is important for organizations to understand the problem they want to solve. This may require the cooperation of multiple participants.[87] A related point is that one entity's adoption of blockchain can have important impact on other SC entities. In some cases, companies can exert normative pressures on other SC members to influence their blockchain adoption. For instance, if a farmer registers food on blockchain, the distribution company that buys it from the farmer can also register. Everyone in the SC up to the grocer can do the same thing.

2.5 Concluding remarks

Blockchain facilitates valid and effective measurement of outcomes and performance of key SC processes. In general, the more important, the issue of traceability is to key stakeholders such as the government, consumers, and retailers, the greater should be the value of blockchain. For this reason, the food industry is most likely to be impacted by blockchain. The example of the 2015 *E. coli* outbreak at Chipotle Mexican Grill discussed above is illustrative of a widespread problem faced by food SCs. This example indicates that there is a deep thirst for dependable suppliers in the food industry. In this regard, a key element of blockchain-based model is that all the transactions are auditable, which is particularly important in gaining the trust of all interested parties. With blockchain, consumers know if the food

they are eating is right and authentic. Various measures can be used to increase transparency in fish and seafood SCs.

Blockchain can also help achieve robust cybersecurity measures and reduce cyber risks. Trust and security can, thus, be improved with blockchain. At the same time, more resources need to be devoted to addressing concerns such as participation of diverse SC members and enrichment of the existing blockchain ecosystem in order to realize the full potential of blockchain.

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CHAPTER 3

Amplifying the value of blockchain in supply chains: combining with other technologies

3.1 Introduction

Blockchain has currently solved the problem of third-party trust, which is the trust placed in intermediaries such as banks and brokers. But, the problems related to the first-party trust and second-party trust[1] still mostly exist in supply chains (SCs). For instance, the original record cannot be necessarily trusted and thus there is guarantee that blockchain-based systems lead to the creation of error-free or fraud-free records.[1]

Many of these challenges can be overcome by combining blockchain with other advanced technology, mainly the so-called Fourth Revolution (4R), also known as the Fourth Industrial Revolution (4IR) technologies. For instance, artificial intelligence (AI), which is arguably the most prominent 4R technology, is viewed to have a great potential to address trust issues in blockchain-based SCs.

In order to illustrate how AI can address trust issues in SCs, we consider blockchain in conflict mineral SC monitoring programs. It is pointed out that blockchain alone cannot address the "first mile" problem, which is the

[1] First-party trust is the trust that actors have in themselves. One example of this is the handling of private keys. As a relevant situation of this kind of trust, we can consider mishandling private keys. When a wrong party gets the keys, they can steal the assets. When the private keys are lost or forgotten, the assets are lost. Second-party trust is the trust placed in the entity that a party is transacting with (https://medium.com/hubtoken/hub-frequently-asked-questions-e6f4896310b8). The question here includes "who the party" is and whether thy behave in a way that is "agreed upon in the transaction", n.d. (https://medium.com/hubtoken/linkedin-cofounder-and-hub-ceo-eric-ly-delivers-keynote-presentation-at-ico-and-the-token-economy-4fef0c2a7aeb).

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most crucial step in assuring the quality of the ore.[2] Some have raised the question of trust at this point. For instance, blockchain systems can be corrupted if the government agents whose role is to tag bags collude with smugglers and enter incorrect data.[3]

In some cases, AI could be more trustworthy than human agents. It is envisioned that in the future, AI and other systems, and networks that autonomously sense, analyze information, and act will perform many of the activities that are currently performed by human agents such as government agents, inspectors, and certifiers.[4]

Another way to analyze blockchain's role in combination with other technologies is to look at its potential to add value in a hyper-digitized SC. Indeed, an encouraging trend is that SCs exhibit an extremely high degree of digitization; thanks to technologies such as cloud computing, big data, AI, and the Internet of Things (IoT). Consequently, physical objects can communicate with each other. Blockchain arguably is the missing element in this hyper-digitization.[5]

A related point is that blockchain should not be viewed as an all-encompassing platform. Its value and significance lie in combination with other technologies.[6] For instance, IoT devices are key data sources that can be shared with SC participants. AI can help make sense of the data. Blockchain can keep track of the data, so that transparency and visibility can be achieved. Technologies such as AI and the IoT also make it easy to switch to alternative providers when the existing suppliers are affected by disruption.[7]

Realizing the roles of key 4R technologies to enhance trust in blockchain-based systems, some established corporations have made significant investments in blockchain start-ups focusing on SC traceability. In July 2020, Volvo Cars' venture capital investment arm Volvo Cars Tech Fund announced an investment in blockchain traceability start-up Circulor.[8] Three other investors SYSTEMIQ, Total Carbon Neutrality Ventures, and Plug & Play also joined Volvo Cars Tech Fund in that round.[9] Circulor plans to use funds from new funding sources to train and improve its machine learning (ML) models, so that they can distinguish between children and adults with a high level of accuracy. With such a capability, the firm hopes to be able to use aerial imagery to determine whether a mining company has employed children in its operations.[10] These measures are likely to address trust issues in the gate for data before they enter the blockchain network.

In this chapter, we describe how many of the trust-related challenges in modern SCs can be overcome by combining blockchain with other advanced technologies, mainly the 4R technologies. Specifically, technologies such as AI, IoT, analytical fingerprinting, satellite imagery, machine vision, and digital twins are analyzed in terms of their potential of significant added value as well as complementary and synergistic effects they can produce by combining with blockchain.

3.2 Artificial intelligence and machine learning

AI is probably the most important 4R technology. AI systems can mimic and imitate human cognition to perform tasks that seemed to be possible only with human thinking and logic before. It entails simulating human intelligence by machines. The key processes involved are learning (acquiring information and understanding the rules for using the information), reasoning (applying the rules to reach conclusions), and self-correction. Economists view AI as among the four most important "general purpose technologies" (GPTs),[11] other three being steam engine, electric power, and Information Technology (IT). GPTs possess potential to transform household as well as business activities.[12] GPTs such as AI also facilitate complementary innovations and bring transformations and changes in business processes.[11]

ML is a type of AI that helps increase accuracy of software applications in predicting outcomes without explicit programming. The basic idea behind ML is simple; algorithms receive input data, and by using statistical analysis, they predict output values within acceptable ranges. ML processes are similar to those involved in data mining and predictive modeling, which also look for patterns in data in order to adjust program actions.

Before looking at the transformative potential that the combination of blockchain and AI can bring in SCs, we first briefly review the roles of AI. In supply chain management (SCM), AI plays a critical role in optimizing the flows of materials, components, and products in the long-haul international routes, the last mile delivery as well as in the warehouse. For instance, AI algorithms use historic SC information and real-time data to estimate time of delivery. Based on local conditions such as those related to traffic and weather, they can select optimal routes for vehicles and sequence deliveries. In the warehouse, AI-powered systems can map the capacity and availability of goods and assess the manpower needed.

Using AI shipments can be consolidated and rearranged more effectively. For instance, AI algorithms can group a large number of items by location, customer, season, mode of freight mode, and delivery timelines. They can also consider other prerequisites needed to transport medical and food products that are sensitive to temperature and humidity. By analyzing information related to damage claims and other liabilities based on SC actions, AI can provide critical insight into key problems. Such information can be used to assess risks and select an appropriate damage mitigation strategy and to reevaluate the rates charged for cargos with various levels of risks.[13] All these can lead to savings in transportation and warehouse and optimal use of capacity.

Combining AI with blockchain, it is possible to greatly improve SC traceability and transparency, which can lead to higher levels of trustworthiness.[14] Tamperproof data related to diverse indicators such as location, temperature, and humidity, which is stored in a blockchain ledger, can be valuable to various stakeholders. Especially, the pharmaceutical and food industries are likely to benefit if sensors are used to monitor physical conditions, such as temperature and humidit γ and the data that are read by the sensors are stored in blockchain. In pharmaceutical industry, medical devices and medicines need to be kept in strict regulatory-approved temperature parameters. In the food industry, blockchain in combination with IoT sensors can bring more opportunity. Temperature data can help to ensure and verify that perishable food products are stored at the optimum temperature range. This can benefit retailers, consumers, and other parties. If smart contracts specify certain temperature parameters and if there is access to reliable data for the complete duration, standards can improve.[15]

Blockchain can also prevent counterfeit, knock-off, and fake products from entering an SC. The pharmaceutical company Merck has been granted a patent that combines AI with blockchain to enhance SC integrity and eliminate counterfeit products. The process links physical objects to blockchains to create "crypto-objects". ML is used to create "fingerprints using unique features such as physical patterns, chemical signature, and DNA." Once the object becomes a crypto-object with a unique fingerprint, another layer of security can be provided with data such as time or location. The receivers of a crypto-object can compare the discriminating data with corresponding reference data. The later sets of data are stored in repositories with restricted access.[16]

Finally, AI can also effectively validate data to implement smart contracts. In a smart contract executed "above" the blockchain, the software

program runs outside and feeds information to the blockchain.[17] In most cases, the IoT provides the data. AI's analysis and intelligence conditions represented by the data meet the standards stipulated in the contract. For instance, IBM worked with the UAE's Dubai Customs and Dubai Trade, the telecommunications company Du, a letter of credit (LC) issuing bank Emirates NBD Bank, the responding bank, Santander, freight company Aramex, and an airline to use its blockchain platform, Hyperledger in international trades. The plan was to integrate it with IBM Watson's AI after completing the proof of concept (PoC). The PoC was designed to track the shipment of fruit from India to Dubai via a cargo ship. In Dubai, the fruit would be processed to produce juice and then exported to Spain by an airplane. To move the transactions to blockchain, Du tracked data via IoT-enabled devices. Aramex would ship the fruit, and an airline company would transport the juice.

3.3 Remote sensing and satellite imagery

In some cases, a higher level of trust in data entered in a blockchain ledger can be achieved by utilizing satellite data. For instance, the TaaS provider Circulor's mine-to-manufacturer traceability of Tantalum in Rwanda utilizes satellite data that verify the authenticity of mines. A registered mining company that has a concession can apply to use the system. The coordinates, the mine's operations, and its historical production are entered in the system. Satellite data are used to verify that the mine is working.[18]

Retailers are envisioning a future where drone package delivery system can be combined with blockchain. For instance, Walmart has shown interest in blockchain-based drones. In January 2019, the company filed a patent application entitled "Cloning Drones Using Blockchain" with the United States Patent and Trademark Office (USPTO). The patent was published in August 2019. The application for the patent described in detail how blockchain is used to transmit information such as drone identification numbers, flight heights, flight speeds, flight routes, battery information, and loading capacity to other drones. Such information can be shared between drones.[19] In May 2017, Walmart's another patent application for a blockchain-based drone package delivery system was also published by the USPTO.[20]

Blockchain and satellite imagery system can be combined to create a self-sustaining ecosystem to facilitate SC traceability and monitoring. For instance, blockchain-based smart contracts make it possible for owners of

satellites and those that need their services for SCM to engage in negotiation autonomously. Transactions can be completed based on criteria that are predetermined. They include the price a customer would pay for an image and can download when they need it. It is also possible for users, satellite owners, and the satellites to dynamically create new services, and the revenue can be used to pay for launching them, insurance premiums, and other costs.[21]

3.3.1 Global positioning system

Navigation applications such as global positioning system (GPS) deal with locational aspects of transactions. GPS relies on satellite technology to pinpoint an exact location. A minimum of three satellites that transmit a signal to a receiver are used.[22]

These applications can enhance SC chain visibility by providing key data and information that decision-makers need to prioritize their activities and take actions. In a trade finance transaction, for instance, data from SC systems, customs, as well as GPS data on shipments may be used to write and execute smart contracts.[23]

GPS can also provide information about the veracity of a claim. For instance, in the case of conflict minerals, the GPS feature in smartphones pinpoints exactly where the ore was tagged.[24] Likewise, the blockchain platform Tracr was launched by the diamond company De Beers in early 2018 to establish provenance, authenticity, and traceability in the diamond SC.[25] De Beers' program records GPS locations for each diamond found. The diamond is then placed in a tamperproof bag, which is QR-coded.[26]

3.3.2 Combining satellite images, blockchain, and AI

Some companies are also developing solutions involving satellite images, blockchain, and AI that reward sustainable farming practices. Two examples are presented below.

3.3.2.1 Oracle's partnership with the World Bee Project

One such example is Oracle's partnership with the World Bee Project to help farmers manage bee population and pollinator habitats. The plan is to take images of the farm with drones or satellites and utilize AI-based image recognition algorithms to evaluate whether the way a farmland is managed support bee colonies and other pollinators in a sustainable way.[27] Research has indicated that farms that allocate certain proportion of their land to plant flowering crops such as spices, oil seeds, buckwheat, and sunflowers can

increase crop yields by up to 79% due to efficient pollination from bees. An ecolabel certificate can be issued to farmers depending on the farm composition. The certification can be stored in a blockchain, so that all SC partners can see it (e.g., during the farm product's journey to the retailer).

3.3.2.2 Bext360

Another example of a company that combines satellite images, blockchain, and AI is Denver, Colorado-based start-up Bext360 in its coffee-tracking projects. For instance, Bext360's kiosks in Uganda evaluate coffee beans using its Bextmachines. A Bextmachine is a Coinstar-like device, which employs smart image recognition technology machine vision, AI, IoT, and blockchain to grade and track coffee beans. It takes a three-dimensional scan of each bean's outer fruit.[28] Bextmachines analyze farmers' coffee cherries and coffee parchment deposited at collection stations and sort them to assess quality. Farmers that supply bigger and riper cherries are paid more. Bext360's systems store data related to time, date, and location of transactions and amount of payment.

The bextmachines link the output to crypto tokens, which represent the coffee's value. New tokens are automatically created when the product passes through the SC. The values of tokens increase at each successive stage of the SC.[29]

Using a mobile app, relevant parties can negotiate a fair price. Farmers get paid immediately via the app. The app also determines the identity of the person selling the products. Using Bext360's API, intermediaries such as wholesalers and retailers embed the technology into their websites, marketing, and point of sales (POS). This level of transparency may not be possible without blockchain. In April 2018, the world's first blockchain-traced coffee tracked by Bext360's solutions was sold.[30] It also includes indicators related to sustainable sourcing and satellite images to show if producers are polluting water.[31] The combination of different technologies can help getting closer to the truth regarding sustainability practices.

3.4 Internet of things

The IoT is the network of physical objects or "things" (e.g., machines, devices and appliances, animals, or people) embedded with electronics, software, and sensors, which are provided with unique identifiers and possess the ability to transfer data across the Web with minimal human interventions.

According to Gartner, there are three components of an IoT: the edge, the platform, and the user. The edge is the location where data originate or are aggregated. Data may also be reduced to the essential or minimal parts. In some cases, data may be analyzed. The data then go to the platform, which is typically in the cloud. Analytics are often performed in the cloud using algorithms. A real-time data streaming decides if some actions need to be taken right away or if the data need to be stored for future use. The user engages in a business action.

There are three possible ways in which data that have been analyzed can move from the IoT platform to a user: (1) the user deploys an application program interface (API) to call or query the data, which specifies how software components of the user and platform should interact; (2) if the IoT finds a predetermined set of events, it can announce or signal to the business user; (3) it is possible to combine (1) and (2).[32]

By attaching IoT devices to items, real-time tracking can be achieved, visibility and traceability can be increased, and a logistics assessment can be carried out.[33] A 2015 report from Cisco and DHL estimated that by the next decade, IoT in logistics and supply chain management (LSCM) will generate $1.9 trillion in value.[34] A 2019 study by Juniper Research found that blockchain and IoT sensors would save $31 billion in food fraud worldwide by 2024.[35]

One major form of the IoT is to attach radio frequency identification (RFID) tags to the target items and connect RFID reader to the Internet to identify, track, and monitor the item in real time.[36] The IoT allows the virtualization of SCs. Food industry is likely to be a major sector that can benefit from IoT, RFID, and blockchain. Virtualization of a food traceability system provides relevant information to track food items and trace their history.[37] Sensor technologies can record and monitor state information and various parameters related to food quality such as temperature, humidity, and microbiological information.[38] These make it possible to use the Internet based on virtual objects to monitor, control, and optimize food SCs without physical observation of sites.[39]

To take an example, McDonald's major supplier Golden State Foods (GSF) prepares over 400,000 hamburgers per hour. RFID tags, IoT devices, and Hyperledger Fabric are used to track the location and temperature of its products and share data. When the products flow from GSF's protein plants to distribution centers and then to restaurants, all SC parties can see a journey in their dashboard including the temperature maintained.[40] All participants can monitor the products even after a delivery.

The system sends alerts if temperature and other conditions are likely to lead to spoilage of the patties. It also tracks the amounts of meat in different locations such as in a truck and a restaurant's freezer to optimize inventory and increase efficiencies.[41] Restaurants can make sure they use a product at the best time. Manufacturers and distribution centers can plan production and shipping schedules. Food wastes can be minimized.

Data from IoT devices can also be used to execute smart contracts. Sensors can tell a smart contract that a product has arrived.[42] In an insurance smart contract, the IoT can provide data related to the insurable events. For example, in case of robbery, using IoT data, it would be possible to check if the warehouse's door was locked. Likewise, if there is a warehouse fire, IoT devices from the fire detection systems could provide the latest data.[23]

3.5 Analytical fingerprinting

The Analytical Fingerprint (AFP) is a scientific tool, which can be employed to check the documented origin of tin, tungsten, and tantalum (3T) ore minerals. This technique involves comparing a sample from a shipment to reference samples stored in a database to test the claim regarding the documented origin of the mineral. AFP relies on the identification of geochemical features, that is, distribution of chemical elements in mineral deposits from a given location. In this way, AFP can evaluate the plausibility of claim regarding the origin stated in the documents of a shipment.[43]

Germany's national geoscientific agency that provides advice to the Federal Government in georelevant issues Federal Institute for Geosciences and Natural Resources [Bundesanstalt für Geowissenschaften und Rohstoffe] (BGR) started developing an AFP method since 2006.[44] The initiative was launched in response to calls by the United Nations (UN) for a scheme to verify the origin of conflict minerals mined in the DRC and neighboring countries. The BGR's recommendation is to apply AFP as an optional forensic tool to perform audits or risk assessments in the uppermost section of a mineral SC. Specifically, the BGR has suggested to perform AFP after extracting minerals from the mine sites and before homogenizing, that is, mixing the minerals in order to reduce the variance of the product supplied, for loading in a container for export. AFP can serve as a way to verify the integrity and credibility of other traceability schemes.[44]

Tantalum and Niobium (Ta–Nb), which belong to so-called transition metals due to their positions in the periodic table of elements, are almost

always found paired together. These two metals are difficult to separate due to their shared physical and chemical properties. Specifically, columbite ore, which is rich in niobium, and tantalite ore, which is rich in tantalum, form a solid solution series known as the Columbite–Tantalite series.[45] When intermediary minerals exist between two end-member minerals[2] that are isomorphous[46] (that is, the same crystal form because of identical molecular arrangement in spite of their different specific elements), a solid solution series is formed.[47]

Ta–Nb ores are extremely complex in terms of mineralogical and chemical composition. This is because columbite–tantalite solid solution series found in different parts of the world vary widely.[48] Moreover, columbite–tantalite solid solution series incorporates many additional elements.[48] The wide variations in Ta–Nb minerals and ores also provide opportunities to develop mineralogical–geochemical–geochronological–based fingerprinting schemes in order to determine their origins.[48] It was reported that as of 2008, over 350 samples of individual crystals and ore concentrates had been analyzed by BGR. More than 60% of them were from central and southern Africa.[48]

BGR's Frank Melcher's team analyzed columbite group minerals (CGM) and other mineral phases bearing Ta–Nb in order to identify major[49] and trace elements. They used an electron microprobe (EMP), also referred to as an electron probe microanalyzer (EPMA), which is an analytical tool used to determine chemical compositions of small volumes of solid materials in a nondestructive way. Specifically, the EMP they used was Cameca SX100 brand from CAMECA SAS, which is a France-based supplier of microanalytical and metrology instrumentation.[50] The CAMECA SX100 used in the analysis had a detection limits of 200 ppm for trace elements.

The team found different mineralogical and geochemical fingerprints' of minerals depending on the origin of a concentrate. For instance, bismutotantalite was found only in samples from Mozambique. Wodginite was frequently found in samples from Rwanda. Tapiolite was detected in concentrates from the DRC and Rwanda.[48]

[2] In an isomorphous (solid-solution) series, an endmember is one of the simple compounds (definition of end member: Mindat.org; n.d. https://www.mindat.org/glossary/end_member.

3.5.1 Current challenges

There are still several challenges that must be overcome for the use of AFPs in mineral SCs. A key challenge is that AFPs are more expensive compared to other techniques. Moreover, due to technological limitations, they are available only for some minerals.[2]

Another challenge concerns the lack of sufficient sample materials. In order to achieve a reasonable level of accuracy using geochemical fingerprinting to determine the source of their raw materials, databases need to be constructed with thousands of samples of known origin from around the world.[51]

3.6 Digital twin

A digital twin is "a virtual representation of an object, a service process, a product, or anything else that can be digitized." [52] For a physical entity, a digital twin is an exact digital replica or representation of the entity (physical twin) and includes the "properties, condition, and behavior of the real-life object through models and data." The digital twin possesses the capability to simulate actual behavior of the physical twin in the deployed environment. Digital twins, thus, give a real-time view of what is happening with physical assets such as equipment.

In order to create a physical object's digital twin, data from various sources are collected and synthesized. They include data related to physical characteristics, manufacturing, and operational data as well as insights from data analytics. Combining with AI algorithms, this information is integrated into a virtual model. With analytics, it is possible to get relevant insights regarding the physical asset.[53]

IoT sensors gather data from the physical object and send it to the digital twin, which can be used to optimize the product's performance.[54] The digital twin also acts as the virtual counterpart during the physical twin's product life cycle.[55]

It is argued that by creating an SC's digital twin, firms can achieve traceability and transparency of every operation carried out in the SC.[56] AI and ML are used to analyze the model of operations represented by the digital twin.[54]

Digital twins play a key role in augmented reality (AR), which involves the real-time integration of digital information with the user's

environment. The digital twin follows the product's location and movement. Images that are overlaid onto the real world using real-time sensor data and analytics can be used to perform product maintenance and services.[57]

The digital twin can be a reference point that can be used to check the blockchain information.[58] The blockchain platform for the lifestyle industry Lukso utilizes digital twin to create digital copies of physical goods such as jacket or a pair of shoes. The digital copies are stored on a blockchain. The tokenized assets are transferred along with their physical twin to prove an item's ownership. In this way, top fashion designers and other luxury merchants can display their collections and enhance their reputations in the digital world.[59]

As an example, in Helsinki Fashion Week (HFW) 2020, which was held from July 27 to August 1, viewers were able to purchase digital garments from the shows. They could have their images "dressed" in them. The HFW teamed up with Lukso to transfer the ownership.[60]

Among the most ambitious example is the planned Destination Earth (DestinE) of the European Union (EU) which is "digital twin" of the planet Earth. DestinE will start in 2021 and is expected to be implemented in 7–100 years' time. The initiative aims to develop digital model of the Earth that can monitor and simulate the natural activities such as those associated with the atmosphere, ocean, ice, and land as well as human activities with a very high degree of precision. The major goals of the project are to develop and test scenarios in order to enable more sustainable development and support the EU's environmental policies.[61] The hope is that it will be possible to forecast floods, droughts, and fires from many days or even years in advance. It is expected to enable policymakers to analyze the impacts of climate change on society of and assess the effectiveness of various climate policies.[62]

3.7 Computer vision and machine vision

Computer vision (CV) entails automatically capturing, processing, and analyzing image in order to provide useful results. Machine vision (MV) is a subset of CV, which involves CV's use in industrial environments.[63]

In the past, the use of CV and MV was extremely limited due to a number of constraints, such as requirement of highlight-controlled environments and expensive sensor technology, and reliance on restrictive feature detection technology.

Deep learning (DL)—based MV is expected to lead to new classes of applications.[64] For instance, robots and drones can go beyond "seeing" things. They can learn from their environment and respond.

Early CV techniques relied extensively on manual efforts to build rules-based classification techniques. Human beings needed to select relevant features of individual objects. For instance, the machine was needed to be explicitly told, "cats are made of legs, legs are made of thighs and paws, and paws are made of toes."[65] Each of the components of a cat needed to be codified as rigid rules. The CV system needed to detect the coded features within the image. This process is inflexible and difficult to change after codifying the components. The process is time-consuming, and for each new to be detected, codes needed to be manually entered. Traditional CVs perform poorly when the model needs to deal with a high number of classes. It is also difficult for them to handle images with low clarity.

The process is entirely flipped in DL models. In the cat example above, a deep neural network training process employs massive amount of data involving millions of labeled images of cats and millions of training cycles to teach the machine in a bottom-up approach until the machine learns how a cat looks. In this process, the algorithm extracts a cat's relevant features. Using this process, a model is produced, which can accurately classify a previously unseen image.[65]

3.8 Optical scanning technologies such as quick response codes

A quick response (QR) is a two-dimensional barcode or a machine-readable optical label. The label contains information about the item to which it is affixed. Japanese automotive SCs were using QR codes since the mid-1990s.[66] Thanks to blockchain-based SCM, QR codes have found new uses. QR codes are used to provide consumers with relevant information about the products, as well as engaging with and empowering them (In Focus 3.1: Chainvine utilizes blockchain, IoT devices, and QR codes to create "Intelligent Wine," and In Focus 3.2: Farmer Connect uses blockchain to connect farmers with consumers). For instance, consumers can scan a QR code of a food product to know the origin as well as the entire SC history. Firms can affix QR codes to physical as well as digital tags of products. Communication of such information can be an effective way to increase the seller's reputation.

In March 2019, the US Seafood company Bumble Bee Food announced a plan to use SAP's Cloud Platform Blockchain to allow

In Focus 3.1 Chainvine utilizes blockchain, Internet of things (IoT) devices, and QR codes to create "Intelligent Wine"

Establishing the provenance of old expensive wines is a difficult task. These are assets that have not been seen for many decades. Consumers only have scant pieces of information such as some uncorked bottles and reference books that contain old labels. This makes the fine wine marketplace a breeding ground for fake products.

The UK-based enterprise software solution and service provider Chainvine has collaborated with winemakers and merchants to address this problem using blockchain, IoT devices, and QR codes. A bottle of wine tracked on Chainvine's platform using these technologies is referred to as Intelligent Wine. First, a vineyard scans the QR and adds the bottles to Chainvine's blockchain. When vineyards sell the bottles, they are marked "in transit."

Chainvine worked with international law firm, Lewis Silkin to ensure that the platform complies with international regulations related to export and import.[67] As the wine shipment moves along the SC, customs agents and other government officials scan the QR codes attached to the bottles or cases to verify their regulatory compliance, which also creates an immutable digital record. Thus, no paperwork and documentation are required during fine wines' importation and exportation.

Sensors in the IoT devices monitor the bottles' locations and other conditions such as temperature and humidity. When the merchant receives the shipment, the bottles are scanned, and they become a part of the merchant's inventory. Wines can be marked as drunk, which prevents bottles' or labels' to fraudulently reuse, "recreate," and resell a vintage wine, which is rare. Chainvine can also access data about older bottles in existing blockchain-enabled wine databases.

In July 2019, Chainvine announced a partnership with fine wine merchant, IG Wine to use the platform. Chainvine's blockchain platform was used to track fine wine from the US-based exporter to the end customer in the United Kingdom.[67]

customers to scan a QR code to view the SC history of products. The information includes the origination of a fish, the time and date it was captured, size of the catch, transportation history, authenticity of the product, fishing and trade certification, and the freshness.[74] SC participants such as individual fishermen, tuna processors, and packers enter their own data on a real-time basis.[41]

Some companies have designed QR codes that can provide various users in SCs with a wide range of functionality and versatility. For instance, Danone's farm-to-fork dual-QR tracking utilizes blockchain, serialization,

In Focus 3.2 Farmer Connect uses blockchain to connect farmers with consumers

Farmer Connect uses blockchain to track the journey of coffee from bean to brew. It connects diverse actors in the coffee SC such as coffee growers, traders, roasters, and consumers. It is built on IBM's Food Trust SC ledger.[68]

They share data that benefit the coffee ecosystem and promote sustainability practices.[69] Traders and roasters can better understand impacts on coffee quality. Consumers are empowered since they can see their coffee's production journey. Customers can contribute to sustainability and quality practices. For instance, they can make donations and give tips that go to the coffee farmers.[70] Farmer Connect is an initiative envisioned by Sucafina, which is a now an independent company.[71]

Farmer Connect is reported to be working with the nonprofit Sovrin Foundation in order to create a self-sovereign identity for each player in the coffee industry. This is a new form of digital identity which enables users to own the security keys. In this way, they can control the way their business and banking account data are shared with industry players.[68]

Sucafina has offices in Belgium, Lebanon and the United Kingdom, and operations in five continents. It works with roasters around the world including countries such as Uganda, Burundi, and Rwanda. It utilizes blockchain to create and verify digital identities for farmers who may not have other forms of ID verification.[72] In July 2020, J. M. Smucker Company's 1850 Coffee brand teamed up with Farmer Connect to provide transparency in its 100% Colombian Coffee bagged offering. Consumers can trace their coffee back to its region of origin. They can scan a QR code on the bag of coffee, which will take them to the Thank My Farmer website. It provides detailed information such as where the coffee was grown, processed, and exported, and the location of its roast.[73]

and data aggregation technology (In Focus 3.3). Users can have the most recent and most detailed transactional data. Various participants have access to various types of data.

3.9 Discussion and implications

The above discussion makes it clear that blockchain is likely to have a much wider and revolutionary impact on SCs if this technology is combined with other technologies, especially those related to the 4R. Machine vision can be used to supply information related to basic visual attributes and physical object features, such as shape, size, color, text, image, brightness, and

In Focus 3.3 Danone's farm-to-fork dual QR tracking utilizes blockchain, serialization, and data aggregation technology

Danone's Track & Connect service for consumers and retailers combines blockchain with dual QR code packaging to improve traceability services. The solution has been launched in China for its Aptamil and Nutrilon brands. The plan is to roll out the service in Australia, New Zealand, and Germany for Aptamil and Karicare brands, and in France for its Laboratoire Gallia brand.[75]

Shoppers can use Track & Connect with their smartphones by scanning two QR codes on baby formula packages. By scanning the first, outer QR code, consumers find verified information about the package such as where and when the formula was manufactured and the package's SC journey. The second, inner QR code is printed behind a tamper-resistant seal. It provides the buyer a one-time message to verify the product's authenticity. The inner QR code also has a key that provides important data and information for Danone as well as other SC participants such as distributors and retailers. The information can be used to forecast consumer demand and consumer preferences fast and more easily.[76]

Danone's Track & Connect service is powered by blockchain, serialization, and data aggregation technology.[76] Data aggregation involves instantly aggregating data that arrive from numerous systems such as Warehouse Management System (WMS), Transportation Management System (TMS), enterprise resource planning (ERP), and POS. The goal is to eliminate data latency and ensure that users have the most recent and most detailed transactional data.[77]

Danone's future plans include leveraging the dual-QR code packaging innovation to introduce customized after-sale support and services. The plan is to provide health and nutrition apps and information to consumers which include "how to" parenting videos, and customer helplines, and online e-commerce services.

texture, which can be entered in the ledger. With IoT, environmental conditions such as temperature and humidity can be tracked. Information about geographic locations of various events can be recorded by attaching GPS tracking devices. For some products, consumers can also verify product origin, regulatory compliance, seed type for crops, proof of ownership, as well as cultivating and manufacturing processes.[78]

Solutions are being developed that evaluate farming systems' contribution to environmental sustainability by looking at indicators related to the diversity of harvests and makeup of farmlands. For instance, farmlands with

high percentage of flowering crops such as spices and oil seeds, medicinal plants (e.g., aloe, mint, basil, henbane, flax, poppy, herbal medicines), and forage plants (e.g., cowpeas, alfalfa, corn, and legumes) are able to increase crop yields by as much as 79% due to more efficient pollination from bees. Such indicators can be measured in a cost-effective way by taking aerial images of the farm with drones or using satellite imageries. Image recognition algorithms using AI can evaluate whether farmland is allocated in an optimal way to attract sufficient numbers of pollinators such as bees, wasps, and butterflies. Technology companies are exploring the possibility of monitoring the actual movement of the pollinators in their hives and across the surrounding areas with video footage. An ecolabel certification can be issued to farmers based on such indicators.[27] By providing rich and detailed information related to relevant indicators in a tamperproof manner, firms can strengthen consumer confidence in the products they are selling to reward good practices among SC members.

3.10 Chapter summary and conclusion

There are various complementary and synergistic mechanisms by which blockchain and other key technologies are likely to have powerful impacts on structures, conduct, and performance of SCs. Together, these technologies can enhance trust, transparency, efficiency, and accountability.

Regarding the AI-blockchain combination, for instance, blockchain can enhance access to data, algorithms, and applications to enhance the AI ecosystem. Blockchain can also help provide a level playing field in the AI world in many different ways. AI can provide fast and efficient processing of blockchain systems to enable transactions. AI is likely to emerge as the driving force behind smart contracts by automatically updating and modifying the relevant conditions in and validating data to implement such contracts.

Likewise, IoTs represent important sources of data that are useful in measuring, monitoring, and controlling relevant conditions and tracking various performance indicators. QR codes, on the other hand, provide consumers with relevant information about the products.

Blockchain is not an all-encompassing technology and is far from sufficient to produce SC trust by itself. Thus, real value can only be created by combining blockchain with other technologies, which can help getting closer to the truth.

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CHAPTER 4

Food and beverage industry supply chains

4.1 The current challenges in food and beverage supply chains

Among many challenges facing the food and beverage industry, improving products' sustainability and safety are of particular importance.[1] About 600 million people in the world become ill due to contaminated food every year. Of those, about 420,000 die, which include 125,000 children under the age of five.[2] Unsafe and contaminated food products affect poor countries disproportionately. For instance, while 41% of the world's population lives in developing economies of South Asia, Southeast Asia, and sub-Saharan Africa, these economies account for 53% of all foodborne illness and 75% of deaths.[3] According to the World Bank, unsafe food products annually cost the developing economies US$ 110 billion in lost productivity and medical expenses.[2]

A study conducted at the household level in the United States found that inadequate quality of food products is one of the key sources of food insecurity.[4] Food fraud and adulteration cost more than US$ 40 billion to the global economy annually. Estimates suggest that 30%–40% of the food consumers eat is either "adulterated or mislabeled" (http://www.connect.catalyst-inc.org/techwatch/arcnet). For instance, it is estimated that more than 50% of wines that cost more than US$35 per bottle are counterfeit in China. About 30,000 fake bottles of wines are sold every hour in the country.[5] In a survey, 39% of food manufacturers thought that their products can be easily counterfeited, and 40% viewed that food fraud is difficult to detect using the currently available methods.[6] According to a 2019 study conducted by Juniper Research, the global food industry could save about US$31 billion in food fraud costs by 2024 by adopting blockchain to monitor supply chains.[7]

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Many firms in the food and beverage supply chains (FBSCs) employ unsustainable practices. Only 17% of palm oil producers claim to be sustainable.[8] The palm oil SC is opaque, and regulators are unable to verify sustainability claims. There is no information available for consumers to know whether they are buying ethical products.[9]

Serious ethical questions have also been raised regarding whether smallholder farmers and farm workers are being paid fairly. For instance, in the US$ 200 billion global coffee industry, coffee producers are estimated to receive only 2% of the price of a cup of coffee.[10] Only 10% of this value is estimated to stay in producing countries.[11] It is argued that the world's 25 million coffee producers have faced difficulties in covering their production costs. Coffee farmers have complained that roasters sell processed coffee at high prices, and the payment to coffee producers reduces each year.[12] There are also issues of slavery and forced labors in this industry.

This chapter highlights blockchain's potential to address key challenges in FBSCs. It also discusses cases of blockchain deployment FBSCs.

4.2 Blockchain's potential to address various challenges in the food and beverage industry

The FBSC is one area where blockchain is taking off rapidly. A major goal is to track perishable items from the farm to the table. Mainly permissioned blockchains are being used. Food manufacturers or retailers can invite participants such as food aggregators, sustainable farmers, or even individual growers in the networks. Typically at harvest, a produce is assigned a QR code. The code contains information, such as its origin, the name of the grower, size, variety, and whether it is organic or whether or not it is grown by a fair-trade company. The data are recorded into the blockchain. The information is updated with new information as the item moves through the supply chain.[13]

By combining blockchain with other technologies, it is possible to discourage unsustainable practices such as those observed in the palm oil industry. For instance, blockchain can securely store satellite imagery data as a part of the traceability system. Using machine learning (ML) and image recognition algorithms, it is possible to trigger an alert system if a deforestation problem linked with an oil palm farming is identified.[9]

To move to a different issue, a major friction that exists in the food and beverage market concerns the disconnection between consumers and producers. Farmers and food manufacturers who engage in sustainable

and ethical production of their products are rarely rewarded for their efforts. End customers, on the other hand, face difficulties in identifying products that are sustainably and ethically sourced. While many companies claim that they sustainably source their products, consumers often have no basis for trusting such claims.[14] Blockchain can provide a means to address this disconnection.

Blockchain, thus, holds a tremendous potential in addressing issues related to environment and social systems' sustainability that arise from the actions of various participants in FBSCs. An encouraging trend is that a number of companies in FBSCs have started using blockchain systems to track products originated from and targeted at consumers in developed countries in order to promote food safety and improve social and environmental sustainability. Regarding the former, blockchain systems are expected to address social issues such as slavery and worker's rights. For instance, Coca-Cola announced a plan to fight the use of forced labor worldwide by using blockchain's validation and digital notary capabilities to create a secure registry for workers and their contracts. The US Department of State collaborated with Coca-Cola in the pilot project.[4]

Some blockchain systems utilized in the FBSCs facilitate the accessibility and completeness of relevant information, which makes it possible to assess the integrity of the actions of SC participants. Blockchain can provide access to rich and detailed information about products, which is likely to reduce uncertainty and increase consumers' confidence. One way to increase certainty about the outcome is to have information about the entire process and population of interest rather than only a sample. For instance, Bureau Veritas, which is a company specialized in testing, inspection, and certification, employs blockchain-based system that provides continual verification rather than samples and, thus, highly reliable information about a product's history. In this way, blockchain can resolve ethical dilemmas consumers face in their decision to buy sustainable products. In Bureau Veritas' system, relevant participants share records and validate transactions. This is likely to reduce opportunism, which is a major challenge that parties face in transactions.[15]

4.2.1 Tracking and tracing FBSC

Tracking and tracing FBSCs using blockchain systems would provide tremendous benefits. Storing FBSC information on a blockchain has the potential to improve the following: food safety, food and beverage supplier

reputation, fairness and visibility of small farmers, efficiency in the process of tracing food contamination sources, and transparency and accountability.

Examples of successful food traceability systems indicate that such systems pay handsomely. For instance, in 2014, Uruguay implemented a fully computerized traceability system to track beef products. The system allowed consumers to know the origination of their beef as well as how the cows were raised. The Uruguayan government spent US$ 70 million to set up the system. Thanks to the system, Uruguay gained a reputation as the world's foremost producer of quality beef. It exported beef products valued over US$ 1.6 billion in 2015.[16] Blockchain-based food traceability systems are likely to have even bigger positive effects. Unsurprisingly, blockchain-based food traceability has become a national priority in some countries (See In Focus 4.1: The Australian government's "National Blockchain Roadmap" and good traceability).

In Focus 4.1 The Australian government's "National Blockchain Roadmap" and good traceability

In February 2020, the Australian government announced the "National Blockchain Roadmap," which identified supply chain tracking as a key use case. As a part of this initiative, many companies have teamed up to develop blockchain-based solution for food supply chains in the Australian–Chinese trade, which amounted US$76 billion (A$117 billion) in 2019[17] or 38% of total Australian exports.[18]

The industry body APAC Provenance Council is a major player in this initiative, which is supported by companies such as VeChain, Mastercard, and Alipay. Products are tracked using VeChain or the permissioned ledger Mastercard Provenance.[19] Key founding members include marketing technology company for the food and agricultural sector Fresh Supply Co, Source Certain, which commercializes TSW Trace technology and capabilities for food and food products and third-party item tracking service provider Laava.[19] Australian food suppliers will implement the VeChain ToolChain. The entire activities related to product delivery will be recorded on the VeChainThor blockchain. Data related to shipping, vehicle, carrier license, and temperature and other logistical updates are recorded on the blockchain.

Unsurprisingly, a large set of players of diverse nature are driving blockchain-related innovations in FBSCs to track and trace products. Chinese e-commerce firms JD.com and Alibaba are among the most high-profile companies to embrace blockchain in FBSCs. Alibaba's international e-marketplace Tmall has partnered with the logistics company Cainiao to use blockchain to track cross-border supply chains. As of mid-2019, the platform was being used to track supply chain information in over 50 countries.[20] Global food retailers and producers such as Carrefour, Nestle, and Walmart have also led efforts to introduce blockchains in FBSCs.

Retailers that have employed blockchains in FBSCs to track and trace products have seen direct benefits such as increase in sales. For instance, Carrefour reported that blockchain's deployment to track meat, milk, and fruit from farms to stores led to increase in sales of these products.[21]

4.3 IBM's blockchain-based Food Trust: the widely used platform for food SCs

IBM Food Trust was launched in August 2017 to explore the use of blockchain in food traceability. The solution was started with 10 Foundation Program members that included Walmart, Dole, and Nestlé.[22]

Before launching the Food Trust, in October 2016, IBM, Walmart, and Tsinghua University announced a collaboration to improve the traceability of food products sold to Chinese consumers. The goal was to use blockchain to enhance SC transparency and efficiency and ensure food safety for Chinese consumers.

Among the first uses, in 2016, Walmart trial-tested a blockchain-based solution to monitor pork products in China and produce imported to the United States from Latin America using IBM's Food Trust. The information tracked included the farm where the vegetable or pig originated and their operating practices. Radio frequency identification (RFID) tags, sensors, barcodes, and other sources provided relevant data.[23]

IBM's Food Trust is based on open-standard and open-governance platform Linux Hyperledger Fabric.[24] It is a software as a service (SaaS) solution which provides immediate access to food SC data. Data provided include entire history and current location of individual food items. Other relevant information such as certifications, test data, humidity, and temperature data are also available when they are entered on the blockchain.[9]

In October 2018, IBM commercially launched its Food Trust, which creates permanent food system record data and share among FBSC participants.[25] Companies of all sizes can join the network for a subscription fee, which ranges from US$ 100 to US$ 10,000 a month.[26] Among major companies in the FBSC using IBM's Food Trust include the US multinational retail corporation Walmart, the French retailer Carrefour, and the world's largest food producer Nestlé. In 2018, Carrefour announced a plan to track its own branded products in France, Spain, and Brazil and expand to other countries by 2022.[27]

The number of transactions completed by IBM Food Trust has increased rapidly since its launch (Fig. 4.1). In June 2020, about 300 suppliers and buyers were using the system, which tracked six million packed food products being sold in stores.[31] As noted in Chapter 1, as of early 2018, Hyperledger Fabric deployed in a single cloud data center had a throughput of over 3500 transactions per second (TPS) with latency rate of less than one second.[32]

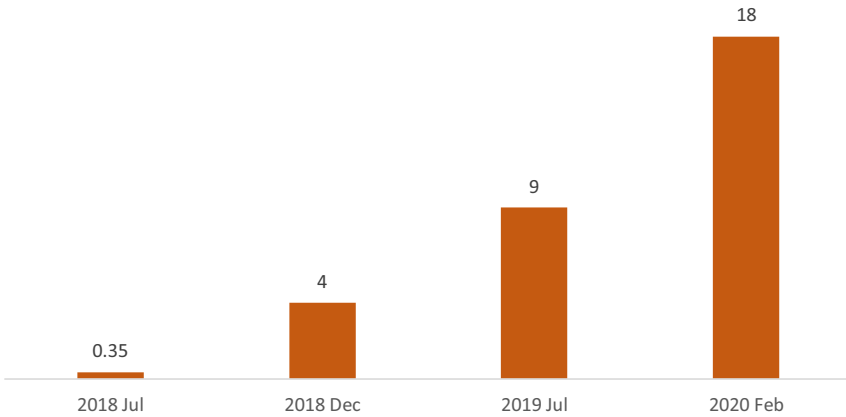

Figure 4.1 No. of transactions completed by IBM Food Trust (Million). *(Based on data from the following sources: July 20, 18 Wolfson R.* Understanding how IBM and others use blockchain technology to track global food supply chain*: Forbes; 2018. https://www.forbes.com/sites/rachelwolfson/2018/07/11/understanding-how-ibm-and-others-use-blockchain-technology-to-track-global-food-supply-chain/#127390ff2d1e; December 20, 18ibm.com.* IBM food trust – fact sheet*: IBM; December 2018. https://newsroom.ibm.com/download/IBM+Food+Trust+-+Ecosystem+Fact+Sheet+Dec+2018.pdf; July 20, 19 Organo.* ORGANO joins IBM food trust to enable increased traceability of ORGANO products worldwide*: PR Newswire; 2019. https://www.prnewswire.com/news-releases/organo-joins-ibm-food-trust-to-enable-increased-traceability-of-organo-products-worldwide-300881216.html; February 20, 20 Debter L, Dent M, Castillo M, Hansen S, Kauflin J, Sorvino C, Tucker H.* Blockchain 50*: Forbes; n.d. https://www.forbes.com/sites/michaeldelcastillo/2020/02/19/blockchain-50/#6dba6d567553.)*

In March 2019, Carrefour announced a plan to use blockchain for tracking its milk SC. The retailer announced that consumers can see global positioning system (GPS) coordinates of farms where milk was collected, as well as information about when the milk was collected and packaged. Details are also provided about various stakeholders involved in the SC.[33] It offered complete product traceability to its new blockchain-powered product, Carrefour Quality Line (CQL) microfiltered full-fat milk. In November 2018, Carrefour launched Hyperledger-based food tracking solution to track free-range chickens in Spain branded as "Calidad y Origen."[34]

In April 2020, Nestlé announced a plan to use IBM's Food Trust to track the company's luxury coffee brand Zoégas.[35] The blend brand consists of arabica coffee beans from Brazil, Rwanda, and Colombia. The coffee is roasted in Sweden. Consumers scan a QR code to access blockchain-recorded data which include information about the coffee's origins, farmer, harvest time, transaction certificate for the specific shipment, and the roasting period. The Rainforest Alliance certifies the coffee and the process behind its production.[9]

As of mid-2018, the system stored data related to one million items in about 50 food categories including Nestlé canned pumpkin, Driscoll's strawberries, and Tyson chicken thighs, and facilitated more than 350,000 data transactions.[28]

4.4 Cases of blockchain deployment in domestic FBSCs

Blockchain deployments have taken place within domestic FBSCs in a number of economies such as the United States, Brazil, and China. In this section, we discuss some such cases.

4.4.1 JD.com tracking products from Kerchin in China

A blockchain system developed by the Chinese e-commerce firm JD.com and inner Mongolia-based food supplier Kerchin connects these two firms. In 2017, the system went live.[36] Kerchin collects and stores data in its supply chain by scanning barcodes of its products. The information is then entered onto blockchain. After that any changes in data require a digital signature. Both parties are informed if there is any change and modification in the data.[37] JD periodically implements random spot checks at Kerchin's factories to examine the accuracy and validity of information.[37]

4.4.2 Alibaba tracking rice supply chain to stop counterfeit versions of the Wuchang rice

Alibaba has implemented blockchain in Chinese FBSCs. In August 2018, Alibaba's online payment affiliate Ant Financial signed a strategic cooperation with the Wuchang municipality in China's Heilongjiang province to track the rice supply chain.[38] Alibaba's Tmall and Rookie Logistics are other partners in the project.[39] A major goal is to stop counterfeit versions of the Wuchang rice, which is known for high quality but has limited production and supply. Wuchang is widely counterfeited.[40] Each bag of Wuchang rice sold on Tmall platform displays a QR code with a unique identification number. Consumers can scan this code using a smartphone app before paying for the rice. The details provided include the specific field the rice came from, seeds and fertilizers used to grow the rice, as well as information related to shipments.[41]

4.4.3 Walmart tracking food products in its Chinese stores

Walmart's Chinese trial took place in a farm operated by a company called Jinluo located in the northeastern city of Lingyi. Jinluo provided data about the pork products such as the farm inspection report and the livestock quarantine certificate.[42] These documents were digitized by an industrial personal digital assistant, which is a smartphone-like device in a rugged case. These data were uploaded to Walmart's blockchain in real time. Data related to products, farms, factories, batch number, storage temperature, and shipping as well as files related to farm inspection report and the livestock quarantine certificate were secured with blockchain. The blockchain with these proofs is stored by Walmart. It used Hyperledger platform to build the system.[24] This means that the copies of the records are also stored and validated by other peers. Walmart is responsible for setting up its peers to participate in the network. The peers may also include relevant government agencies.

Walmart China commercially launched its Blockchain Traceability Platform in June 2019. By that time, 23 product lines sold in China used the platform, which was expected to increase to 100 by the end of 2019. Walmart aims to have 50% of packaged fresh meats and vegetables and 12.5% of all seafood sales tracked on the platform by the end of 2020.[43] The company trained about 100,000 employees and suppliers to use the platform. The goal is to make sure that enterprises or consumers can use the system without additional costs.[44]

In June 2020, Walmart's membership-only retail warehouse Sam's Club China launched Sam's Club Blockchain Traceability Platform.[45] Sam's Club has positioned itself differently in China than in the United States. It is viewed as a high-end shopping club in China. Sam's Club Blockchain Traceability Platform uses VeChain ToolChain, which is Blockchain-as-a-Service (BaaS) platform. ToolChain offers services such as product lifecycle management, supply chain process control, data deposit, and certification of data and process.[46] ToolChain is combined with cold-chain Internet of things (IoT)[47] and different types of software and hardware sensors. All SC members upload logistics and manufacturing data in the VeChainThor blockchain. The products are tagged with secured QR codes. Customers can scan the QR code with their smartphones to see the product's full logistical history such as country of origin, packaging information, and storage temperature. Additional relevant information is included in pictures and videos.

4.4.4 BanQu systems in India, Uganda, and Zambia to track cassava and barley

In June 2018, BanQu, a BaaS company, teamed up with the multinational drink and brewing holdings company Anheuser-Busch to promote supply chain transparency and traceability in Zambia using blockchain. Using BanQu solutions, Anheuser-Busch's local business, Zambian Breweries can track its products throughout the supply chain: from the farmer to local businesses to aggregated buyers and retailers.[48] The program started with 2000 cassava farmers. The system is projected to track 1400 tons of cassava, used to produce a high-quality starch used in beer. Zambian Breweries was expected to add 2500 additional cassava farmers by the end of 2019.[17] In April 2019, BanQu announced a plan to start a new program with 1000 Indian barley farmers.

BanQu has deployed similar solutions in Uganda. As of June 2019, Nile Breweries, which operates as a subsidiary of Anheuser-Busch, implemented this system to track over 5000 barley farmers in Sebei region of Eastern Uganda. Farmers take their crops to a buying center. The goal was to reach 7000 Ugandan barley farmers by the end of 2019.[17] At the center, Nile Breweries officials check for quality and other details, which are recorded in BanQu's blockchain system.[49] After delivering crops in the buying center, a farmer receives a text message, which shows the quality, quantity, and price of the crop sold to Nile Breweries. This record is with the farmer and Nile breweries. The farmer receives a digital payment in the form of virtual

tokens, which can be accessed by presenting the code received in the text message to partner banks or mobile money providers.[18] The virtual tokens can be redeemed for cash or applied for payment to other transactions such as paying energy bills.[17]

4.5 Cases of blockchain deployment in cross-border FBSCs

Blockchain solutions have also been developed to track food and beverage products in cross-border SCs.

4.5.1 Walmart monitoring produce imported to the United States from Latin America

In 2016, in a well-publicized story, Walmart's then vice president of food safety picked up a package of sliced mangoes from one of the company's stores and asked his team to find where it originated from. It took the team 6 days, 18 h, and 26 min to find an answer.[50] Since then the company has started blockchain trials to address problems such as this.

An early trial of a blockchain system to track food from farm to consumer was in 2016, when Walmart collected information on mangoes imported to the United States from Latin America. Each pallet of mangoes is tagged with numeric identifiers when the journey at the farm. When the pallets of mangoes changed hands (e.g., from farm to broker to distributor to store), their status was signed by the relevant SC members and logged on the blockchain. In a trial, the company found that it took only 2.2 s for consumers to find out an individual fruit's weight, variety, growing location, time it was harvested, date it passed through US customs, when and where it was sliced, which cold-storage facility the sliced mango was held in, and for how long it waited before being delivered to a store. A sample of major events associated with the procedure is illustrated in Fig. 4.2 and Table 4.1 with in an example of a trial conducted in April—May 2017.

4.5.2 Bext360 tracking coffee exported from Uganda and Ethiopia to the United States and the Netherlands

Denver, Colorado-based startup Bext360's kiosks in Uganda evaluate coffee beans using its Bextmachines. A Bextmachine is a Coinstar-like device, which employs smart image recognition technology machine vision, artificial intelligence, IoT, and blockchain to grade and track coffee beans. It takes a three-dimensional scan of each bean's outer fruit.[52]

Figure 4.2 ***Walmart's monitoring of produce imported to the United States from Latin America.*** *(Reproduced from Kshetri N.* Blockchain systems are tracking food safety and origins*: Coinivore; 2018. https://coinivore.com/2018/11/21/blockchain-systems-are-tracking-food-safety-and-origins/.)*

Table 4.1 The use of blockchain to track the journey of mango spears (10 ounces) sold in a Walmart store (April–May 2017).

Date	SC event	Remarks
April 24	The fruit was harvested from orchards in a farm orchards in Oaxaca, Mexico.	The mangoes were "Tommy" variety, which was a cultivar optimized for transport.
April 25	Hot water treatment was carried out on the fruits.	Applied to exterminate potentially invasive insects' eggs.
April 27	The shipment was received by an importer.	The fruit passed through the US Customs and Border Protection. A safety inspection certificate can be seen on the system.
May 1	The fruits arrived at a processing plant, where they were sliced.	The mangoes were moved to a cold storage facility in Los Angeles and then to a Walmart store.[50]

Bextmachines analyze farmers' coffee cherries and coffee parchment deposited at collection stations and sort them to assess quality. Farmers that supply bigger and riper cherries are paid more. Bext360's systems store data related to time, date, and location of transactions and amount of payment. It also includes indicators related to sustainable sourcing and satellite images to show if producers are polluting water.[53]

The bextmachines link the output to cryptotokens, which represent the coffee's value. New tokens are automatically created when the product passes through the supply chain. The values of tokens increase at each successive stage of the supply chain.[54]

Using a mobile app, relevant parties can negotiate a fair price.[55] Farmers get paid immediately via the app. The app also determines the identity of the person selling the products. Using Bext360's API, intermediaries such as wholesalers and retailers embed the technology into their websites, marketing, and point of sales (PoS). This level of transparency may not be possible without blockchain. In April 2018, the world's first blockchain-traced coffee tracked by Bex360's solutions was sold.

The company started its pilot program in November 2017. In the same month, it teamed up with the Dutch startup Moyee Coffee and the Fair-Chain Foundation to produce blockchain-traced coffee called Token. By June 2018, 60,000 kg of coffee from Ethiopia was exported to Amsterdam. It provides a proof that living-wage payments were made to the farmers.[56] Moyee's plan is to launch Token in Kenya, Colombia, and Rwanda in 2019.[57]

4.5.3 Alibaba tracking food products imported to China from New Zealand and Australia

Alibaba teamed up with New Zealand dairy product maker Fonterra and New Zealand Post to track products imported to China from New Zealand. It also collaborated with Australian healthcare supply firm Blackmores and Australia Post to develop blockchain-based Food Trust Framework.[58] The goal is to develop a blockchain solution model that participants across the FBSCs can use.[12]

Tmall uses blockchain and product tagging with unique QR code assigned to each product. Imported food products are tracked and monitored this way, and relevant information is made available to consumers. Each step in the supply chain is authenticated and verified. Relevant data such as those related to production, transportation, customs, inspection, and transfer of ownership are secured with blockchain. The blockchain with these proofs is stored by the Alibaba. The copies of the records are also stored and validated by other participants.[59]

4.5.4 Nestle's pilot project to track milk from New Zealand to the Middle East

In July 2019, the Swiss multinational food and beverage company Nestle announced a pilot project to allow consumers to track food products from the farm using the open blockchain platform OpenSC (See In Focus 4.2: How OpenSC works). The OpenSC platform allows anyone to access to

In Focus 4.2 How OpenSC works

The nonprofit organization focused on wildlife conservation and endangered species. World Wildlife Fund (WWF) teamed up with the management consultancy Boston Consulting Group's (BCG) digital innovation, product development, and commercialization firm BCG Digital Ventures to create the open blockchain platform OpenSC. OpenSC can be used to track a wide range of materials such as food products and tissue paper. OpenSC combines blockchain with other technologies such as ML and IoT to track products from their sources to their end consumers.[64]

Data from vessel monitoring systems (VMS) are also used to gather data about maritime fishing activities. VMS is operated by national governments to monitor national fishing fleets and foreign vessels that fish in their waters. Vessels broadcast encrypted signals, which means that the data can be accessed by the government and those they share it with.[65]

A main use has been in cracking down on illegal and unsustainable fishing practices. OpenSC uses a four-step process for this purpose.

In the first step, "Tag," when a fish is caught, an RFID tag is attached to the fish at the location.[66] The next step, "Check," involves employing ML and GPS tracking tools to verify that does not belong to an illegal fishing zone. The third step, "Trace," is filleting the fish attaching a QR code. In this step, the RFID tag is converted into a unique QR code that is attached to each piece of the fillet. In the final step "Share," by scanning the QR code, anyone can verify that the piece of the fillet is from a certified sustainable fishery and it was not caught in a protected area.[64]

Deployment in the Pacific Islands tuna industry

WWF-New Zealand, WWF-Australia, and WWF-Fiji have collaborated with the blockchain company ConsenSys, information and communications technology (ICT) implementer focusing on traceability TraSeable, and tuna fishing and processing company Sea Quest Fiji Ltd to deploy a blockchain solution in the Pacific Islands tuna industry.[67] The goal is to track the journey of tuna from "bait to plate."[68] As of the end of 2019, about half a dozen companies were using the solutions, and about 50,000 fishes had been tracked.[69]

Continued

In Focus 4.2 How OpenSC works—cont'd

Illegal, unreported, and unregulated (IUU) fishing has been a major problem in the region. Currently buying and selling of Pacific tuna is mostly tracked by paper records. In many cases, they are not tracked at all.[67] Every year US$548 million worth of skipjack, yellowfin, albacore, and bigeye tunas are illegally caught and sold.[70]

Due to the high costs involved in ConsenSys' enterprise-level systems, a traceability system was built by integrating blockchain on top of the existing digital traceability system.[69] Using TraSeable's tablet-based application, fishermen on boats *in the sea* and regulators on shore enter data into the blockchain system. Other SC participants such as fishing companies and the processors are also connected to TraSeable's system. The system also allows regulatory authorities to provide third-party verification. The system is built on Ethereum, which allows customers to pay extra for TraSeable's blockchain feature.[69]

Scaling up the use rapidly

OpenSC platform has scaled quickly in terms of users and numbers of transactions. As of early 2020, it tracked and traced large amounts of Patagonian Toothfish (Chilean Sea Bass) and prawns. The platform is also expanding into other categories of food products such as dairy, palm oil, and coffee.[70]

Australia's integrated commercial fishing company Austral Fisheries is an example of a company that uses OpenSC. The company sells wild-caught fish to 13 countries.[71] A Patagonian toothfish caught in sub-Antarctic waters by Austral in January 2019 was one of the first products tracked by OpenSC. The fish was cooked and served to customers who scanned on the set menu to see the fish's complete SC journey.

As of December 2019, Austral Fisheries operated 10 of the 52 licensed vessels[72] fishing the northern prawn fishery (NPF), which covers about 880,000 square kilometers of Australia's northern waters.[73] Austral Fisheries tracks the catches from the fishery with OpenSC.

independently verifiable sustainability data on FBSCs. The project started with tracing milk products from New Zealand farms to warehouse and factories in the Middle East.[60] In 2019, Nestle also began a pilot involving OpenSC to increase palm oil traceability and provide proof of sustainability to consumers.[61]

Regarding Nestle's adoption of public blockchain OpenSC, which aims to promote greater transparency, the companies supply chain digital transformation manager Benjamin Dubois put the issue this way:

"Something that allows full disclosure, without any Nestle control, where the data is uploaded by every actor along the value chain and is available for anyone and anywhere to take on this data." He went on saying that this would allow people to "make their judgment on the sustainability factors of [Nestle's] supply chain."[62]

The OpenSC platform used by Nestle combines data from multiple sources such as GPS tracking and RFID tags. The company plans to further enrich the data. Nestle was exploring about the possibility of including data from other monitoring systems, such as farms' satellite images.[63]

The nature of food products also determines whether it can be traced with a high level of accuracy using blockchain. Nestle noted that tracking palm oil SC was difficult since the product is liquid, which adds more complexity.[63]

4.6 Key insights drawn from the cases

The above cases lead to a number of insights and implications for the use of blockchain in FBSCs.

4.6.1 Strengthening food safety programs

Blockchain systems have tremendous potential and provide a promising future to strengthen national food safety programs in developing countries. For instance, food items such as milk, meat, rice, and vegetables sold in China are heavily tainted and contaminated. Three hundred and thousand babies became ill in 2008 after drinking infant formula made from adulterated milk, which led to the death of six infants.[74] The Chinese government has, thus, made food safety a top priority. Chinese regulators were part of the pilot project run by IBM and Walmart to make the retailer's supply network more transparent by tracing products such as pork and organic food.[75]

4.6.2 Enhancing corporate reputation

Chinese consumers are skeptical about sellers' claims regarding what their food products are and where they are coming from. Such skepticism can be greatly alleviated by the application of blockchain to track FBSCs. With blockchain deployment in FBSCs, retailers can keep buyers' confidence in their products and avoid the danger of consumers getting ill. Their reputation is likely to increase with these activities.

Companies may be viewed as more credible and trustworthy if blockchain solutions are combined with other technologies such as QR codes. For instance, advancements in QR codes have made counterfeiting impossible or extremely expensive. Even before introducing blockchain, Alibaba launched its "Blue Stars" campaign in 2015 for high-end food and other products. The campaign used the next generation "dotless" QR codes. Participating merchants selling on Alibaba's online marketplace Taobao can attach a label containing a QR code with colorful image with each package to verify the authenticity. A secure scanner developed by software company Visualead is used to scan the QR codes. Each QR code is unique, cannot be duplicated, and brands can customize the code using different combinations of visually appealing images, logo, and different colors.[76]

Theoretically, it is possible for counterfeiters to sell fake goods with legitimate Blue Stars QR codes. To do so, they can buy legitimate products, get enough genuine QR codes, and put them on the packages of fakes. However, each item has a unique QR-code identifier. When a customer receives the product ordered online and scans the code, it will "burn," which means that each code can be used only one time.[77] This means that counterfeiters will have to buy large quantities of legitimate goods to get enough genuine codes. This makes fraudsters' business model less attractive.[78]

4.6.3 Distributive fairness and transparency

Blockchain deployment in FBSCs can lead to a higher degree of fairness in the distribution of profits. For instance, coffee is among the most important exports from the developing world. Moreover, since the 1960s, the exports of coffee from developing countries have increased by a factor of 5.5.[79] Coffee accounts for about half of total net exports of tropical agricultural products from developing countries. Blockchain solutions, such as those of Bext360, have a potential to enhance fairness in this industry.

Blockchain system's fairness can further be improved when smallholding farmers can take part in high-value activities. For instance, blockchain-based supply chains such as those of Bext360 are transparent due to the step-by-step and detailed process. It makes sharing the value added among various supply chain participants fairer and easier. Bext360's business model also required that kiosks that evaluate coffee beans be owned by local entrepreneurs and local cooperatives.[80]

Farmers can also learn specific ways in which they can play a more important role in the value creation process. For instance, in the Bext360's case, each coffee bean is provided a unique ID which can be used to track it throughout the life cycle.[81] Wholesalers and roasters can learn about attributes that may produce certain tastes.[19] They can make future sourcing decisions based on this. Farmers can focus their efforts to grow the types of coffee beans that are valued more by consumers.

4.6.4 Enhancing efficiency

Blockchain is likely to bring efficiency and will improve supply chain processes. In a crisis involving contaminated food products such as infant formula discussed above, for instance, retailers such as Walmart can easily identify the source and engage in strategic removals of affected products. They do not need to recall the entire product line. Blockchain also enables more effective response if tainted products are discovered. Blockchain has important cost-saving implications for retailers.

There have been some encouraging developments to address the above challenges. In Walmart's trial of a blockchain-based solution to monitor pork products in China mentioned above, blockchain enabled to digitally track individual pork products in a few minutes compared to many days taken in the past. Details about the farm, factory, batch number, storage temperature, and shipping can be viewed on blockchain. These details help assess the authenticity of products. If an item is spoiled or the source of a product is compromised, the system acts proactively. In the case of food contamination, it is possible to pinpoint the products to recall.[82]

4.6.5 Supply chain transparency

Blockchain can provide a complete transparency and accountability regime in the FBSCs. Firms in FBSCs have implemented blockchain for different supply chain links for different business processes. For instance, Anheuser-Busch and JD.com have implemented blockchain mainly involving B2B e-commerce.

In SCA's blockchain system, data generated by sensors related to the activities of farmers, roasters, product developers, manufacturers, and retailers are put into blockchain. The SCA aims to fight exploitation of farmers by powerful retailers with the help of immutable records of transactions in the food industry. These examples are excellent demonstrations that blockchain could address various sustainability-related

challenges in inter-organizational relationships. Moreover, regulators have been involved in the some blockchain systems such as those of Walmart and Coca-Cola.

As noted earlier, consumers are also increasingly becoming concerned about the source of food and beverages.[21] Consumers value information transparency and ethical behavior. Blockchain can give them a high level of confidence about the origination of food products they eat and the way they were produced. The solutions implemented by food manufacturers such as Nestle, retailers such as Walmart and Carrefour, and Chinese e-commerce companies such as Alibaba and JD.com are aimed at providing consumers with information about food and beverage products that they are consuming. For instance, by flashing a QR code before buying products in a store, shoppers can see a product's history in order to make informed purchase decisions.

4.6.6 Lack of skill and absorptive capacity in developing countries

Developing countries lack adequate absorptive capacity to benefit from blockchain applications due to the lack of competences, skills, infrastructures, and institutions. As mentioned, Walmart needed to train employees and suppliers to use its blockchain platform in China.

Smaller and poorer countries lack attractiveness for multinationals such as Walmart to develop blockchain systems and train employees and suppliers. Moreover, it is unreasonable to expect that organizations in FBSCs in developing countries can set up their own systems such as IoT devices, and they will fix their systems when they do not work.

Most blockchain systems in the FBSCs have been designed keeping in mind that big companies can benefit from these systems. For instance, BanQu system is attractive for buyers such as Zambian Breweries and Nile Breweries, who can track all details related to produce from suppliers and achieve various supply chain goals. The benefits are minimal to farmers because they lack skills and opportunities to benefit from the information put on the blockchain systems.

4.6.7 Infrastructure, market, and technical challenges

Low levels of economic activities in developing countries are associated with thin markets, in which there are few buyers and sellers and few

transactions in which blockchain-based applications can be used. Additional challenges include high transaction costs/and risks and high unit costs in the development of technological and physical infrastructures.[83]

Due to these factors, being a part of blockchain systems set up by large organizations would involve significant costs and efforts for smallholder farmers. These farmers often need to travel long distances to take advantage of blockchain systems such as Bext360's kiosks and Nile Breweries' buying centers. For instance, farmers in Eastern Uganda are required to transport their crops to Nile Breweries' buying centers, which are located 10 kms or farther from their towns.

Moreover, some such systems use less sophisticated and less accurate systems to measure the quality of crops. At the center, Nile Breweries officials check for quality and other details, which are recorded in the system.[18] Whereas Bext360's kiosks can assure a reasonable accuracy in the measurement of the quality of coffee thanks to the use of sophisticated technologies, this cannot be said of the systems used by Nile Breweries. One stated benefit of blockchain systems is that aggregators no longer can manipulate the farmers.[18] However, in solutions such as those developed by BanQu, the possibility of manipulation by buyers such as Nile Breweries cannot be ruled out. Quality related decisions are likely to be more trustworthy and credible if such decisions are made by technologies rather than by human minds. However, the low levels of economic activities and thin markets make investments in blockchain and supporting technologies unattractive. For these reasons, even if blockchain solutions are deployed in FBSCs in developing countries, such solutions are far from full-fledged.

4.6.8 Small businesses in food SCs often lack capabilities and resources to implement blockchain

Like other technologies, blockchain deployment tends to diffuse from larger to smaller organizations. This is commonly known as the rank effect.[84] Due to cost and complexity, blockchain systems are expensive to implement and manage. For this reason, blockchain is out of reach for many organizations. For instance, JD's supply chain partner Kerchin that has adopted blockchain had US$ 300 million in revenue in 2017.[9] Most of the food products in developing economies like Africa[85] and China are produced on very small farms that lack access to technology or internet connectivity. This is a main reason why food safety has been difficult to achieve

in China[86] and other developing countries. Most of these small farms do not possess the capability to adopt a blockchain-based system and provide relevant information.

4.6.9 Not practical to use the solution for low-value food products

Due to cost and complexity, it is not currently practical to implement blockchain systems for low-cost retail food products that poor people consume. Most firms have limited blockchain deployment to high-value food products. For instance, the Chinese e-commerce company JD.com's implementation of blockchain to allow customers to track meat products in 2018 was on high-end beef.[87] Likewise, the French retailer Carrefour's traceability project focused on its premium farm products.[88]

4.7 Chapter summary and conclusion

The adoption of blockchain in FBSCs is being shaped by a number of forces and factors, including political, legal and trade related as well as consumer preferences. In today's world, environmental sustainability, ethics, and knowledge about food products are becoming increasingly important for consumers. Policymakers are motivated in improving food safety. For developing countries that export food and beverage products, blockchain deployment in FBSCs can enhance the "reputation" of their exports.

Unsurprisingly in order to ensure the full traceability of FBSCs, greater efforts and resources are being devoted to track all supply chain data using blockchain. In this regard, blockchain will benefit from an enriching IoT ecosystem, which is likely to make tracking possible and more accurate. Many blockchain systems designed to track physical assets such as fine wine currently do not track some factors related to the physical state such as bottle temperature. With the further development in IoT technologies, temperature and other indicators can be tracked in a cost-effective manner.

There are differential benefits of blockchain-led transformation in FBSCs to different segments of the population. Wealthy consumers will have access to safe and sustainable food and beverage products. Such benefits are mostly irrelevant to less wealthy consumers. Blockchain solutions have not yet been deployed in food products that are affordable for

the poor. There is, however, a hope that blockchain will ensure a fair and living wage for smallholder farmers and farm workers. Because of the lack of check and balance of power and the lack of transparency in much of the activities in FBSCs, it is difficult for powerful companies to set examples. This is particularly true when the large companies are benefiting from the status quo. Blockchain's transparency may force big food manufacturers, retailers, and middlemen to improve their practices to the potential benefits of small farmers.

Many barriers and challenges exist in the adoption of blockchain in FBSCs in developing countries. Blockchain deployments in FBSCs in these countries are likely to be hindered by the complexity/understanding of blockchain, lack of skills as well as infrastructural and technical challenges (e.g., poor network connectivity)—and the high cost (e.g., this may not be practical for a low-value food). Some categories of barriers also negatively affect smallholder farmers' and farm workers' capabilities to take advantage of this technology. In the long run, however, this technology is expected to assist the empowerment of smallholder farmers and their organizations.

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CHAPTER 5

Healthcare and pharmaceutical industry supply chains

5.1 Introduction

The healthcare and pharmaceutical industry has a number of idiosyncratic features that make this industry attractive and interesting for blockchain applications. Companies' concerns about sharing private data with others have been a major obstacle that stands in the way of blockchain's takeoff. Wireless asset management systems producer PowerFleet's senior vice president of global branding and marketing Craig Montgomery argued that the technology holds a promise for the healthcare and pharmaceutical industry because transparency is valued highly in this industry.[1] Data in this industry are characterized by high value and risk, and third-party companies are willing to pay for useful data. Since the pharmaceutical industry is heavily regulated and its products are environmentally sensitive, they need to be monitored.

While some types of data in this industry need to be shared with other SC participants, other types of data such as sensitive data related to patient records need to be protected. Blockchain has a considerable potential to strengthen security of such data.[2] Blockchain's value in the healthcare and pharmaceutical industry also stems from the industry's tremendous size and significant wastage of resource. For instance, according to marketresearch.com, the size of the global pharmaceuticals market was US$934.8 billion in 2017.[3] The industry is estimated to reach US$1.3 trillion in 2020.[1] Cold chain cargo or environmentally sensitive products account for about 28% of the sales or US$370 billion.[1] Losses related to temperature deviations in the industry alone amount to US$35 billion each year.[4] Estimates suggest that about 20% of temperature-sensitive products are damaged due to temperature excursions during shipment.[1] Note that temperature excursion is "an excursion event in which a Time Temperature Sensitive Pharmaceutical Product (TTSPP) is exposed to temperatures outside the range(s)

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prescribed for storage and/or transport. Temperature ranges for storage and transport may be the same or different; they are determined by the product manufacturer, based on stability data."[5] This wastage can be reduced significantly if indicators related to ambient condition such as temperature are recorded throughout a drug's journey along the SC, and data related to these conditions are using blockchain among all relevant participants.

Another problem that blockchain can address involves fake and counterfeit medical equipment and drugs.[6] Especially illegitimate and substandard version of sensitive products such as medical equipment and drugs can have life or death consequences for patients.

Two main problems can be addressed if a medical device's chain of custody (CoC) can be tracked. First, it is possible to ensure that it came from the correct source. Second, if something goes wrong with the device, its origin can be easily traced. The best way to do so would be to digitize the CoC records and store transactions on blockchain. If all SC participants register the transfers of custody, counterfeits' costs to enter the SC increases. Counterfeiters will not have a valid identifier. Even if they had one, the record on blockchain will show that they did not originate from the authentic supplier or manufacturer. Concerned SC participants can work backward through the registered CoC and find out the point the counterfeiter entered the SC.[7] Another challenge with the present CoC process is that if an organization responsible for tracking goes out of business, the data may not be accessible to other parties.

Unsurprisingly, healthcare has been selected as among the highest priority industry sectors to apply blockchain in major economies across the world. Measures are being taken to enrich the supply chains of healthcare data and information. In South Korea, healthcare is among the first industries to benefit from the country's focus on the use of blockchains for data management and storage.[8] In mid-2020, South Korea's Gangwan-do province announced a plan to use blockchain and artificial intelligence (AI) to manage chronic cardiovascular disease data without the requirement of a hospital visit. The province records patients' health data on blockchain and uses AI to predict and analyze chronic health events. It plans to start with a small number and expand the service over time to 450,000 people in the province that have chronic diseases.[9]

5.2 Fighting counterfeit and substandard products in a drug supply chain

According to the World Health Organization (WHO), in low- and middle-income countries, one in 10 medical products such as pills, vaccines, and diagnostic kits are substandard, fake, or falsified.[10] Counterfeit drugs or substandard medicines in Africa are estimated to account for up to 30% of the continent's total pharmaceutical supply.[11] The WHO's estimates suggest that counterfeit medicines worth US$79.26 billion are sold every year.[12] Blockchain solutions are addressing such challenges (See: In Focus 5.1: Uthabiti's blockchain solutions to enhance traceability and trackability of pharmaceutical supply chain in Kenya).

In Focus 5.1 Uthabiti's blockchain solutions to enhance traceability and trackability of pharmaceutical supply chain in Kenya

According to the WHO, 42% of all fake medicines reported to the organization between 2013 and 2017 were from Africa.[13] About 250,000 children in Africa die every year due to the use of fake drugs to treat diseases such as malaria or pneumonia.[14] Medicines in Africa change hands as many as 30 times before reaching to a pharmacy retail point.[15] The manufacturers of legitimate products, thus, find it difficult to track their products, and it is not possible to trace a medicine back to the origin.

Kenya's web and mobile platform Uthabiti, which is used to consult doctors and other health auxiliaries online order prescribed or nonprescribed medicines from pharmacies, has launched a blockchain solution to address this challenge.[16] After procuring medicines from manufacturers, Uthabiti performs a quality test in its internal laboratory. The medicines are them labeled with the product's safety lab report. Each medicine also has its unique blockchain ID. The medicines are then sent to the partnering retailers. Patients buying the medicines at the retail outlet can verify the authenticity through a mobile app or via SMS service before consumption.[15] Uthabiti's system checks against the database provided by the manufacturers to verify the product's legitimacy and replies to the query automatically.

As of August 2020, Uthabiti had partnered with four manufacturers and distributors of sexual health products. It had completed 2300 deliveries and verified 5000 scans.[17]

This also allows Uthabiti Health to know the location of its products on the SC.[18]

According to the WHO, India accounts for 35% of counterfeit drugs being distributed worldwide.[19] The Indian government aims to fight the counterfeiting problem with blockchain.[20] In 2018, Indian policy think tank NITI Aayog and Oracle signed an agreement to use blockchain and Internet of things (IoT) to conduct a pilot project to track India's domestic pharmaceutical SCs.[21] Among participants in the pilot involving real drug SC included India's hospital chain Apollo Hospitals and drug manufacturer Strides Pharma Science Ltd. Oracle reported that the pilot was successful. Oracle's blockchain registers a drug's record such as serial number and labeling in the manufacturer's drug SC. Drugs were tracked during the SC journey from manufacturer to logistics to distributors to hospital/pharmacy to consumers. If a fake drug enters the system, the software detects irregularity and notifies the nodes. The IoT tracked information such as the drug's chemical ingredients and the maintenance of acceptable temperature for some drugs or vaccines.[22]

The importance of fighting counterfeit and fake drugs and other types of frauds has been especially highlighted during the COVID-19 pandemic. In its annual Operation Pangea, which took place from March 3 to 10, 2020, Interpol found an 18% increase in the seizures of unauthorized antiviral medication compared to the same period in 2018. Seizures of unauthorized chloroquine increase over 100% during the period. It seized more than 34,000 counterfeit and substandard masks, as well as medicinal products that were advertised as "corona sprays," "coronavirus packages," and "coronavirus medicines."[23] The operation also found 2000 online links that advertised COVID-19 related items.[24]

The use of blockchain to track the entire SC from the raw materials used in pharmaceutical production to finished products sold by drug manufacturers to hospital and to end users could be the most effective way to fight counterfeit and substandard drugs. Afghanistan's Ministry of Health teamed up with smart contract platform *Fantom* to fight against substandard or falsified medicines in the county. In July 2020, the Ministry announced a plan to start a trial of a blockchain-based smart medicine pilot program on Fantom's Opera mainnet, which is permissionless and open source.

According to the plan, pharmaceutical products of two Indian companies—Bliss GVS and Nabros Pharma—would be attached with labels provided by Fantom. Fantom's plan was to work with Nigerian health startup Chekkit, which uses ID labels—secured on the Ethereum blockchain and USSD or QR scanning to verify product's authenticity.[25] The pharmaceutical distributor Royal Star Pharma would scan labels at each step

of the distribution process. The scanned data are recorded in the Fantom blockchain using cryptographic encryption. The Royal Star and the Ministry of Public Health can verify the products' authenticity by comparing the hash of the data stored in the blockchain to the hash printed in the label. The plan was to use blockchain to track SCs of 80,000 products that include hand sanitizers, joint cream items to relieve joint pain, Kofol chewable tablets for coughs, colds, and sore throats and diacare foot cream for diabetics and skin infections.[26]

Fantom's directed acyclic graph (DAG)-based smart contract platform has a high transactional throughput, which provides fast confirmation times to the required scale to power a country's entire healthcare system.[25] Fantom claims that its Lachesis algorithm confirms transactions in 1–2 s.[27]

The use of substandard ingredients has also become a key challenge in medicinal Cannabis products such as cannabidiol (CBD) oil, which is an essential ingredient of medical marijuana. A study published in the *Journal of the American Medical Association* reported that about 40% of CBD products that were purchased online do not contain the ingredients that are printed on the labels.[28] Some of them were reported to test positive for enough Tetrahydrocannabinol (THC), which would cause an individual to fail a drug test. For instance, many CBD users have tested positive for marijuana due to manufacturing defects in such products.[29] The US Food and Drug Administration (FDA) has urged consumers to "beware purchasing and using any such products."[30]

Integrated CBD, which is a large-scale supplier of organically grown hemp and hemp-derived CBD, has implemented blockchain in its CDB SC (In Focus 5.2: Integrated CBD trials Treum blockchain). Likewise, Rymedi's CBD oil tracking allows users to scan a barcode with a cell phone to receive data about a product's origin and journey in the SC.[32] Blockchain is expected to ensure safety and increase consumer confidence.in CBD products.

5.3 Optimizing operational efficiency and reducing costs

Healthcare IT systems perform poorly in interoperability and standardization, which has led to data silos. The use of healthcare blockchain can

In Focus 5.2 Integrated CBD trials Treum blockchain

In mid-2019, Integrated CBD trialed an Ethereum-based blockchain solution developed by ConsenSys-backed SC product Treum and Verified Organic, which allows farmers to log their crop yield's metadata. The information entered included the type and variety of fertilizer and seed used, and the irrigation techniques. Inputs are also validated by third-party laboratories and certification bodies, who independently assess the product, soil samples, and plant tissue samples.[31]

To enter the data about the planting process into the blockchain, Treum has developed the Verified Organic Web platform for managers. They can use the platform to register organic certificates and manage assets such as seeds, crops, pesticide, fields, fertilizer, and equipment. Farmers enter the relevant data using a mobile application which also works offline. The system, thus, allows farmers to capture data, even when there is no Internet. The steps performed in the mobile application can tag additional documentation such as paid invoices, third-party lab tests, Certificate of Analysis (CoA) from an accredited laboratory showing the quantity of various cannabinoids in a product and other certifications.[29]

This means that auditors can verify that the crop actually originated where the farmers claim that it has originated.

In the first 3 weeks of the trial, 100 fields in Arizona hemp farm that produced CBD oil had been registered on the app. Integrated CBD's farm manager commented that the Treum-based solution is no more difficult or time-consuming than the excel used by the farm before.

Farmers can use the geolocation function to tag fields with various properties. For instance, one type of hemp may be cultivated in one specific field. The farmer enters the data into the app. The data are then transferred to the Ethereum network.

While there is always the possibility that the data entered in the blockchain ledger could be false, a key advantage of this system is that anyone can match the data in the immutable ledger against what is in the field. For instance, external auditors and certifiers can use the ledger to match with the field in order to perform inspection. It also increases the efficiency of the jobs of certifiers and external auditors.[33]

Each step in the crop production and distribution process—planting, fertilizing, natural pesticide application, harvesting, packaging, and distributing in the supply chain—is tracked by the platform. Each step in the process is recorded and verified with time, date, and geolocation as well as a secondary means of verification. Consumers can scan QR code on the product packaging to know the details about the product they buy such as the production process, freshness, and farming practices (https://www.integrated-cbd.com/verified-organic).

facilitate data exchange and address many sources of inefficiency (see: In Focus 5.3: Ant Financial's blockchain-based healthcare solutions). A study conducted by global market intelligence, research, and advisory company BIS Research found that the healthcare industry could save up to US$100 billion per year by 2025 by utilizing blockchain.[47] Businesses in healthcare SCs can cut various costs related to IT, operations, support functions, personnel, and health data breaches. Health insurance companies can cut operational costs and fight health insurance frauds.[47]

In Focus 5.3 Ant Group's blockchain-based healthcare solutions

The Chinese payment processor and financial services company Ant Group (previously Ant Financial), which is an affiliate company of the Alibaba Group, has developed a number of blockchain solutions for the healthcare sector. In April 2017, Alipay launched a blockchain-based free health insurance product as part of its rewards system. The company teamed up with the Chinese life insurer Taikang Insurance. Alipay account holders who use their account to pay offline with Alipay earn bonus points, which allows them to join the health insurance plan.[34]

How the free health insurance product works?

As an example of how the health insurance plan works, a patient at Taizhou Central Hospital in Zhejiang province used Alipay to pay the bills. The patient's identity is linked to Alipay. The electronic invoices issued by the hospital was entered on the blockchain. The fact that the invoice is in the blockchain means that there is no need for Alipay to check their authenticity. After using the prescription once, it cannot be reused. The blockchain-based system, thus, addresses issues such as false reporting and fraudulent invoices.

When the Taizhou Central Hospital enters the invoices in blockchain, it is coded in such as a way that allows Alipay to identify the type of illness. This is important since the insurance covers treatment to only specific illnesses.

The patient saved the invoices in their Alipay invoice manager and submitted a claim with other relevant materials. It was reported that they received a reimbursement of 97 yuan (about US$14) in their Alipay account in 5 s. In this way, a low-cost claim processing benefitted Alipay and Taikang.

Continued

In Focus 5.3 Ant Group's blockchain-based healthcare solutions—cont'd

Blockchain-based collective claims-sharing platform Xiang Hu Bao

In October 2018, Ant worked with the mutual life insurance organization Xinmei to launch a blockchain-based collective claims-sharing platform Xiang Hu Bao (which means "mutual protection" or "lend a helping hand"). The service uses crowdfunding and pooled insurance products to cover costs for larger illnesses that are not covered by traditional insurance programs.[35] Xinmei, which guarantees the payouts, was established by Ant with other external partners.

Xiang Hu Bao is built on Alipay's proprietary blockchain technology.[36] Ant Group charges 8% of all claims paid as management fee.[37]

As of early 2020, Xiang Hu Bao had over 100 million participants.[38] Xiang Hu Bao provides money to cover medical needs of the participants. Blockchain's decentralized, trust-free, and tamper-proof features allow faster claim process and payments. Policyholders submit supporting documents, which can be immediately accessed by firms that investigate the claim.[39]

Xiang Hu Bao has been targeted at lower-income patients that are not currently served by insurance companies. For instance, in rural areas, official data from 2015 showed that 44% of households below the poverty line found difficulties to cover healthcare costs.[40] Over two-thirds of Xiang Hu Bao participants were reported to earn less than RMB 100,000 (US$ 14,000) annually and a third of them lived in the country's rural areas.[41] Likewise, as of April 2019%, 47% of Xiang Hu Bao users were migrant workers.[40]

Xiang Hu Bao has been tied to its Sesame Credit system.[42] As of July 2019, users needed a Sesame Credit score of at least 600 to participate. This score depends on various factors related to financial health as well as those related to social data and consumption behaviors.[40] The highest possible Sesame Credit score is 950, and a 600 credit score is considered to be in the "Fair" range.[43]

Insurance was among 20 blockchain projects China launched to fight against COVID-19.[44] In February 2020, Xiang Hu Bao introduced a one-time COVID-19 protection scheme free of charge for all participants. The scheme offered a payment of up to RMB 100,000 (USD 14,000) if a participant dies from COVID-19. Ant Group covered the payment.[45]

Blockchain-based drug prescription system

In 2018, Alipay also collaborated with Shanghai-based Huashan Hospital to launch a blockchain-based drug prescription system.[46] A prescription drug is marked with QR code (or a stamp). When a prescription drug is dispensed, the QR code is scanned. The information about the drug goes to the blockchain.

Using blockchain in drugs SCs, operational efficiency can be improved. For each damaged product, the average labor cost to analyze causes is in the US$3,000 to US$10,000 range.[1] Currently when a pharmaceutical product is damaged, the pharmaceutical company needs to complete a corrective and preventive action (CAPA) report. It also needs to run diagnostics to understand the cause of the problem and prepare a report to make sure that such problems will not occur in the future. Some supply chain partners such as the trucking company are free from such responsibilities.[1] Blockchain makes it possible to have access to all relevant SC data, which would make it easy to identify the root cause of problems such as a temperature variance.[1]

Pharmaceutical companies can also reduce losses associated with counterfeit drugs by about US$200 billion. SAP's blockchain-powered drug distribution tracking system, which was launched in January 2019, allows SC participants to authenticate medical packages returned by pharmacies and eliminate counterfeit drugs from the market.[49] SAP's partners participating in development of the software included AmerisourceBergen, Boehringer Ingelheim, GlaxoSmithKline, and Merck Sharp & Dohme. Using the system, it is possible to verify the product code, lot, expiration date, and a unique serial number embedded in the barcode against manufacturers' data stored in the blockchain.[50]

A drug is registered before distributing to the suppliers, then distributors, and to the customers. If the drug is returned, the pharmacy can use the Drug Verify app to check its authenticity. They can do so by scanning the barcode.[51] If the drug passes the verification process, the app displays all the relevant information. The pharmacy warehouse then can accept the drug. Irrespective of whether verification passes or fails, the app logs each verification request along with relevant information such as requested timestamp and location from which the verification is requested. These data are stored in the SAP Cloud Platform HANA instance, which is the set of SAP HANA system components installed on one host.[51] SAP Analytics Cloud can analyze the data to generate useful insights such as locations where suspicious activities are taking place and the pharmacy warehouse that is dealing with more counterfeit drug problems.[51]

5.4 Promoting transparency

Blockchain has the potential to address some of the major flaws in the present system for postmarketing surveillance. The goal of this system is to

identify possible adverse effects once new drugs are used widely. A major drawback of the current system is that mostly drug manufacturers collect, evaluate, and report postmarketing studies' data of their own products. According to a 2004 report of the Department of Health and Human Services, of the postmarketing studies that manufacturers had made commitments to conduct as a condition of drug approval, fewer than half were actually completed. Many of the studies had not been initiated.[52]

Equally or even more serious is the fact that while the FDA requires companies selected for postmarketing safety reporting to report adverse events, it is suspected that drug manufacturers may conceal available data that are associated with possible risks. It is also likely that the FDA and drug manufacturers may decide not to act on adverse events-related information. For instance, they may not conduct further studies immediately to rigorously examine a potential risk.[53]

The above observation makes it clear that the lack of transparency is one of the factors that prevent quick response to unsafe and ineffective drugs. By facilitating secured and traceable access and management of data, blockchain can help obtain real-world evidence on medical product development.[54]

5.5 Complying with regulatory requirements

Regulatory pressures have played a critical role in blockchain's adoption in the pharmaceutical industry. Blockchain makes it possible to handle regulated drugs in a manner consistent with existing rules (See: In Focus 5.4: Blockchain in controlled drugs).

The US Drug Supply Chain Security Act (DSCSA) requires firms in the pharmaceutical industry to be able to track and trace drugs throughout the SCs electronically. That includes the raw materials to manufacturing and the end consumer. The DSCSA also requires wholesalers to verify returned prescription drugs that are intended for resale.[58] Enterprise blockchain solutions are the most effective tools to accomplish that.[59]

In June 2019, IBM, Merck, Walmart, and KPMG were selected by the US FDA to be included in a blockchain pilot project program to track pharmaceutical products. The pilot project was carried out to meet the requirements of the DSCSA to identify, track, and trace prescription drugs and vaccines distributed in the United States.[60] The DSCSA was signed into law in 2013. The law requires for an "electronic, interoperable system" to "verify, track, and trace prescription drugs" by 2023.

In Focus 5.4 Blockchain in controlled drugs

Controlled drugs such as opioid, β-blockers, and digoxin are susceptible for abuse, misuse, and illegal activity. In 2017 alone, prescription opioid drugs killed 116 people daily and resulted in an economic cost of US$115 billion.[55] They are, thus, heavily regulated.[56]

Standards and procedures for such drugs are monitored by regulators. While there are registers that log the movements of controlled drugs, theft, and misuse, and inventory discrepancies caused by human errors are common.[56] Many pharmacies rely on manual paper documents to record supply, delivery, and destruction of such drugs. Manual processes also lead to delays in the dispensing of such drugs.

Blockchain has the potential to address these challenges. By tracking with controlled drugs with blockchain, authorized parties get real-time access for information related to drugs-related transactions and interventions.

Some blockchain startups are attempting to fill the gap. Tennessee, the US-based blockchain platform EIRSystems tracks a prescription **from the doctor to the** patient through a ledger that complies with the Health Insurance Portability and Accountability Act (HIPPA). Doctors can monitor the patient's history of opioid use over time. When the pharmacist fills the prescription, the platform checks that it is within the legal limits of that state and federal law.[55] The system can also send alert notifications when a doctor prescribes opioids with higher than usual frequency.[57]

Regulators and enforcement agencies can view all transactions and initiate an investigation in cases of suspected abuse or misuse. They can also track specific geographic entities, such as countries and states in order to assess the situation of controlled substances.[57]

By utilizing IoT, recording of the register can be automated. For instance, with IoT implementation, when a drug is put into the safe, the transaction could be automatically recorded onto the ledger.[56]

In May 2020, the four companies completed the pilot program.[61] KPMG was responsible for the functional design part of the pilot. That included designing the process workflow and user interface and defining configuration requirements. IBM provided the blockchain platform.

Walmart is the third largest retail pharmacy, which has a deep knowledge and experience of pharmaceutical SCs.[62] The biopharmaceutical company Merck has developed a blockchain solution to secure its own SC and detect counterfeit drugs. Merck's contribution in the project was in its industry-standard system for serialization. Product serialization involves

assigning and marking each product with a unique identifier. It is a key process for fighting product falsification or counterfeiting. Many governments worldwide rely on some form of product serialization for securing the pharmaceutical SCs.[63]

The pilot project demonstrated that blockchain can be incorporated to determine product quality and track a product's origin. Additionally, the pilot plant was used to test the performance of blockchain in improving patient safety in case of defective medicines. It demonstrated that blockchain can reduce the time taken to alert the SC of a product recall from a few days to a few seconds.[64]

5.6 Some representative cases

5.6.1 Kadena and Rymedi team up to track drug supply chains

The first blockchain technology company launched by JP Morgan's Blockchain Center for Excellence Kadena has partnered with healthcare data platform Rymedi. Rymedi has integrated Kadena's blockchain into its existing platform in order to provide consumers and other SC members with important data.[65]

Blockchain is touted as a technology that eliminates unnecessary intermediaries in business processes. Such intermediaries in card payments include the acquiring bank, issuing bank, and payment networks. Friction can be minimized by using a public blockchain (e.g., Bitcoin). It is argued that by running on a private blockchain, enterprises just substitute one intermediary (e.g., financial institutions) by another (e.g., software companies and hosting organizations).[66] A key challenge of public blockchain, however, is related to privacy concerns. Such concerns may make it difficult for companies to comply with regulations. In other cases, public blockchain may require companies to publicly share sensitive information.[67]

Using the Kadena network, enterprises can build applications on the private chain. This means they do not need to build things from scratch. They can create smart contracts on its public chain, which allows users to interact with those applications.[67]

Kadena uses parallelized proof of work (PoW) consensus mechanism and relies on sharding to increase the transactional throughput.[68] "Sharding" involves splitting up the network into distinct partitions also known as shards. Each shard has its own consensus region and ledger. It, thus, creates multiple PoW-based partitions through which multiple parallel chains operate.[68] Nodes and validators only process transactions that are local to their shards.[69]

Medicinal products being tracked by Rymedi and Kadena include antibiotics, Hepatitis C cures, CBD products, kidney dialysis, and treatments for cancer, HIV, and neonatal pulmonary. The companies have deployed their solutions in Kenya, Mongolia, and the United States. As of 2019, they were planning to expand the services to the Caribbean and Central American countries.[70]

The WHO has been monitoring vaccination records, treatments, and prevention methods in Mongolia with Rymedi's system.[26] Rymedi's focus has been on deploying hepatitis C vaccines in Mongolia.[71] About 8.5% of the population in Mongolia or 255,000 people have hepatitis C.[72] The process includes screening the population for hepatitis C, rapid diagnostics in the field, viral load testing, e-prescription, treatment delivery, and monitoring patient outcomes. With Kadena's blockchain technology, Rymedi can capture, track, and share data related to these processes faster and more securely. The data are linked to electronic medical records. These processes have been reported to strengthen the mechanisms for quality assurance of healthcare and improve the coordination of SCs.[72]

5.6.2 Chronicled's MediLedger

Blockchain-based system allows companies to collaborate on a shared platform without sharing sensitive data and information. Chronicled's MediLedger Network provides such solutions for the pharma supply chains. The MediLedger project was created in response to the FDA's call for pilot projects testing an electronic interoperable system under the DSCSA.[12]

Using MediLedger's product verification solution, pharmacies and hospitals can authenticate products that are high risk or suspicious. MediLedger's system utilizes a barcode scan to validate product data against the original drug manufacturer's data. In July 2020, Chronicled and Deloitte announced an alliance to help life sciences and healthcare industries to adopt MediLedger solutions.[72]

As of mid-2020, MediLedger worked with "big three" wholesalers in the United States: AmerisourceBergen, McKesson, and Cardinal Health. It enabled verification by pharmaceutical wholesalers for over 95% of drugs being resold in the country.[73] The MediLedger solutions are also being used by Gilead, Pfizer, Amgen, Genentech, and others.[74]

The Healthcare Distribution Alliance estimated that about 60 million units of salable drugs are returned annually.[75] It is the wholesalers' job to verify these drugs' authenticity before they are resold. The process in the

nonblockchain world is extremely time-consuming and tedious. Wholesalers need to contact manufacturers to track down the serial numbers. The process takes up to 48 h.[76] Using blockchain and a barcode scanner, the verification can be performed with much simpler and faster technique in less than a second. MediLedger solution's response times are reported to be less than 400 ms.[77]

This means that medical products can be put back into commercial distribution more rapidly. Moreover, drug manufacturers can maintain complete control over their data. Other drug SC participants such as hospitals and pharmacies can also benefit. Just using a web browser and a barcode scanner, it is possible to verify a drug's authenticity. If counterfeiters copy barcodes in an attempt to sell fake drugs, the system will flag them. The system also permanently records suspicious activity.

As of early 2020, MediLedger was working to apply the technology to "track and trace." It allows drug manufacturers and other SC partners to know the current status and SC history of a specific box of drugs. This can be accomplished without revealing sensitive information of SC partners.

As of early 2020, MediLedger had completed a blockchain-based "track and trace" pilot project. It was conducted in response to the FDA's request in 2019 to conduct pilot projects to address issues that may arise in the execution of electronic interoperable systems that are outlined in the DSCSA[78] Twenty-five participants in drug supply chains such as retailers (e.g., Walgreens and Walmart), logistics, and transportation provider FedEx, standards organization GS1, wholesale distributors (AmerisourceBergen and Cardinal Health), and manufacturers (Pfizer, Novartis, Gilead) participated in the pilot.[79]

It is crucial to define appropriate rules in the smart contract for healthcare. When the system fully develops, MediLedger Network participants are expected to be in a position to enforce business rules on a real-time basis as drugs travel in an SC. By doing so, disagreements can be more readily handled.

5.6.2.1 Contracts & Chargebacks solution

Blockchain solutions can also eliminate potential sources of losses related to chargeback, a protective payment reversal process in which consumers of pharmaceutical products contact their financial institutions to dispute a transaction and ask for a forced refund. Estimates suggest that more than 5% of chargeback processes in the US pharmaceutical industry are disputed due to differences in business rules and misalignments of data between SC

participants.[73] Most pharmaceutical companies have pricing agreements with wholesalers as well as with group purchasing organizations (GPOs) that operate on behalf of hospitals. The wholesalers and GPOs are eligible for discounts. The various sources of disagreements are related to the discounts, chargebacks, price changes, and the membership of a hospital of a GPO when the purchase took place.[73]

MediLedger's Contracts & Chargebacks solution aims to eliminate disputes among pharmaceutical SC partners. It provides shared, immutable sources of information and contracts to parties. They use the platform's blockchain identities to communicate sensitive pricing information on a P2P basis to a contract. Such information is stored in the blockchain. Wholesalers can check the blockchain to ensure that they are using the correct version of the contract and pricing terms. The main benefit of the system is to enhance efficiency and value rather than legal compliance.[77] As of mid-2019, pharma company Pfizer and wholesalers McKesson and AmerisourceBergen had signed up to use MediLedger's contracting solution.[77]

Auditing is embedded in the system and is automated. The system flags problems and tells which SC participant had custody of the products when the violation took place. In this way, when drugs reach their destination, they are accompanied with data that assure the authenticity and have complied with all the relevant rules during their SC journey.[76]

5.6.3 Swiss Post's blockchain-based solutions for the pharmaceutical and medical industry

Switzerland's national postal service Swiss Post started collaborating with the digital supply chain monitoring and optimization solutions provider Modum since summer 2017 (Table 5.1). In April 2018, Swiss Post announced a plan to integrate a blockchain-based solution developed by Modum to deliver pharma shipments and other temperature-sensitive products.[81]

In 2018, blockchain from the German multinational software corporation SAP was used for a PoC to implement the solution.[82] In December 2018, Swiss Post announced the launch of 100% Swiss blockchain infrastructure with Switzerland's telecommunications provider Swisscom, which allows to store all data within Switzerland.[83]

Swiss Post's entire supply chains have incorporated temperature monitoring with blockchain in order to meet the needs of hospitals and medical practices. Swiss Post needs to comply with regulatory requirements

Table 5.1 Swiss Post's blockchain journey: a timeline.

Time	Activity/event
June 2017	The joint project between Swiss Post and Modum began.[80]
2017 end	Modum approached SAP for incorporating blockchain.[80]
Early 2018	SAP teamed up with Modum, and Swiss Post.[80]
June 5–7, 2018	Early feedback on the solution was collected from partners and customers at 2018 SAPPHIRE NOW, which is an annual conference for users and partners of SAP.[80]
November 15, 2018	Modum presented MODSense at the enterprise blockchain summit "outside the block" in berlin, which was organized to present use cases and discuss what the future of blockchain.[80] MODSense was commercially available by then.
November end 2018	A pilot project was started.[80]
2019	Swiss Post teamed up with a hospital group to explore the optimization of transports within hospitals with new technologies such as autonomous indoor delivery robots.

such as Good Distribution Practice (GDP) and ship parcels in an efficient manner. These two goals are often competing.

Its storage system is pharma-qualified, and the picking system is fully automated. Swiss Post was needed to design shipping solutions to transport medicines and healthcare products that comply with EU guidelines on the GDP. The company, however, did not want to invest in a fleet of refrigerated vehicles. It decided to develop boxes that are able to maintain a certain temperature.[80]

In order to achieve GDP-compliant, temperature-controlled delivery, Swiss Post has developed a new generation of ThermoCare boxes. The systems for return delivery and disposal of pharmaceutical products also fulfill legal requirements.[84] Modum has developed a solution MODSense to monitor temperature for sensitive shipments, which is placed inside a package. Depending on the content of that package, MODSense is programmed with the permitted temperature range. The sensors transmit data to a blockchain database.[85] The MODsense web application is a solution for deviation management, which provides instant notifications in case of deviation from a regular pattern of temperature.[86]

These boxes have adaptable insulating properties and can be shipped in the vehicles' regular parcel channel. The ThermoCare boxes are configured based on the transit routes' predicted weather conditions. In most cases, only a few shipments may need the full thermic capacity of the boxes.

ThermoCare passive temperature-controlled boxes[87] are cheap, secure, reusable, and easy to handle. A challenge Swiss Post faces with a passive solution is to know whether the medication has been maintained within the required temperature range throughout the journey. To ensure this, Swiss Post uses blockchain and IoT to monitor the temperature and share with relevant participants. A sensor is inserted into the ThermoCare box to monitor the temperature of the medicine in transit. Temperature-related data are stored in blockchain. All interested participants such as quality managers, insurers, and customers have access to the data.[88] When the postman scans the shipment at delivery, the measurement data are read automatically. The data are then transmitted to the sender, who will immediately know if there are any temperature deviations.[89]

Due to the continual and complete nature of measurement, the system can be helpful in the assessment and management of quality. If a deviation in temperature has occurred, it is possible to pinpoint the exact location and cause of such deviation. For instance, by knowing where the violation occurred (e.g., when the dispatcher delivered the goods, the post office vehicle, etc.), Swiss Post can identify the causes, so that such deviations can be corrected in the future.[84]

As of 2019, Swiss Post had teamed with a hospital group to explore the optimization of transports within hospitals with new technologies such as autonomous indoor delivery robots. The robots transport laboratory samples through hospital corridors. They learn their routes independently. They use radios to communicate with elevators and doors.[84]

5.7 Discussion and implications

Like in any other industry, blockchain solutions in the healthcare and pharmaceutical industries may face resistance and opposition from some key stakeholders. In 2015, the China Food and Drug Administration (CFDA) announced a plan to establish an electronic drug tracing system. The plan faced a strong opposition from pharmacists. They argued that scanning drugs and uploading relevant information on the system would involve high financial costs and time requirements for pharmacists. They also questioned the appropriateness of the tracing systems proposed by the CFDA because hospitals that sell about 80% of medicines in the country were not required to comply with the tracing requirement. Consequently, the CFDA's plan to implement drug track and trace system in China could not takeoff.[90]

Blockchain-led transparency can also create a level playing field for developing world-based pharmaceutical companies. Indian drug companies have complained that in its efforts to protect US consumers and increase the validity of its regulatory processes, the FDA took actions that led to a decline in trust in Indian drug companies at home and in overseas markets. The Indian regulatory body Central Drugs Standard Control Organization (CDSCO) has been portrayed as lacking effectiveness. Many Indian drug companies are confident that they can meet the international standards and increase profits by exporting their products to foreign markets. But they are concerned that their foreign competitors allegedly engaged in lobbying with regulatory bodies to prevent Indian companies from accessing overseas markets.[91]

5.8 Chapter summary and conclusion

Due to high value of data and heavily regulations, transparency is important in the healthcare and pharmaceutical industries. Blockchain is, thus, especially suited to these industries.

Established companies such as IBM, as well as startups such as Chronicled have developed innovative blockchain-based solutions to address diverse challenges facing this industry.

Blockchain solutions in the healthcare and pharmaceutical industries have greatly enhanced efficiency, security, and traceability. For instance, MediLedger's product verification system makes it easier to verify the authenticity of a returned drug. This process is common, but difficult and time-consuming. Blockchain system can also lower chargeback rates by addressing the potential sources of errors and discrepancies.

Blockchain, especially in combination with other technologies such as the IoT, can increase verifiability, safety, and efficiency when medicines are transported. Blockchain also helps firms in these industries to comply with various regulatory requirements and increase consumer confidence. Blockchain has helped Swiss Post comply with all legal requirements in the transportation and storage of medical goods.

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CHAPTER 6

Supply chain finance and trade finance

6.1 Introduction

Trade receivables owed between firms that are yet to be paid are equivalent to about 20% of the global gross domestic product (GDP) or around US$16 trillion.[1] Many firms experience difficulties in meeting working capital requirements due to the delay in the payment of trade receivables. Especially small businesses are often short of cash and find it expensive—if not impossible—to borrow money. For instance, after delivering medicine to hospitals, small drug retailers in China often wait up to 90 days to get paid.[2] But to stay afloat, these companies need cash.

Supply chain finance (SCF) solutions have emerged to address such challenges. In order to cover their working capital needs, suppliers borrow money at a higher cost than paid by the buyer.[3] For instance, manufacturers rely on intermediaries that pay immediately, but do not pay in full. In the above example, for instance, a US$100 invoice to a hospital might be worth US$90 right away—and the intermediary would collect the US$100 when it is finally paid.[2]

A current challenge is that there is a big gap between the demand and supply of SCF. According to the Asian Development Bank (ADB), the global trade finance (TF) gap was US$1.5 trillion, or 10% of merchandise trade volume in 2018. This gap is expected to increase to US$2.4 trillion by 2025.[4]

Banks are not willing to lend money in places where fraudulent invoices are common, or where manufacturers and their customers might have inconsistent and error-ridden records. A blockchain system reduces those concerns because these records must be authenticated before being added to the ledger, and due to the distributed nature, they cannot be manipulated and changed. Some studies have suggested that the global TF gap can be reduced by US$1 trillion if blockchain is more widely used.[4]

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Blockchain-based smart contracts and single digital records for customs clearance are among the important mechanisms that enable small and medium-sized enterprises (SMEs)' access to TF by reducing credit risks, lowering fees, and removing barriers to trade. Indeed, it is argued that SMEs in emerging markets can benefit more from the implementation of blockchain-based solutions than from the removal of tariffs or negotiation of trade deals.[4]

In this chapter, we discuss the current challenges facing the global SCF and TF markets and blockchain's potential to address them. We also focus on several SCF- and TF-related blockchain- and DLT (distributed ledger technology)-based platforms and interoperability and standardization initiatives on this front.

6.2 Supply chain finance and trade finance

It is also important to distinguish between SCF and TF. SCF involves financial tools that are used to improve payments between companies and their suppliers. As noted above, upstream supply chain members such as manufacturers and raw material suppliers are not paid immediately after shipping products. In international trades, there is a time lag between an exporter's shipping of goods and an importer paying for them. SCF bridges this gap. SCF solutions represent technology solutions and financial services to connect various SC partners. The goal is to improve the effectiveness of financial supply chains by decreasing or even preventing the cost-shifting practices, which entail shifting inventory or other operating costs to SC partners. Such tactics can reduce a company's internal costs in the short term but not the total SC costs in the long run.[5] In order to improve the effectiveness of financial supply chains, downstream SC partners need to improve the visibility, availability, as well as costs of cash for upstream participants.[6]

TF is a broader term that encompasses financing to suppliers in order to help them manufacture goods and as well as to buyers to help them buy those goods. Trade-related supplier financing is made available through bank loans, which are backed by insured foreign accounts receivable by selling accounts receivable to a factoring company.[6] Trade credit insurers provide protection to banks. However, they cover 50%–90% of loan amount.[9]

6.2.1 Current challenges facing the SCF and TF markets

Currently high costs of financing prohibit the participation of many developing world-based small firms in international trade activities. These can be often attributed to high costs of due diligence. For instance, due primarily to frauds, bad loans account for about 20% of bank loans in India.[7] Loan frauds in the country amounts to about US$2 billion annually, which results in high interest rates due to low trust.[8]

Part of the problem also lies in the fact that many developing economies are characterized by the lack, or poor performance, of credit rating agencies to provide information about the creditworthiness of SMEs.[9] A national credit bureau would collect and distribute reliable credit information and hence increase transparency and minimize the banks' lending risks. Many emerging economies lack such an agency, and some have a poorly functioning one. This situation puts SMEs in a disadvantaged position in the credit market. This is because SMEs tend to be more informationally opaque than large corporations because the former often lack certified audited financial statements, and, thus, it is difficult for banks to assess or monitor the financial conditions.[10]

In SC relationships, it is a common practice for buyers to evaluate the operational performance of suppliers. The process is referred to as vendor rating.[11] Information required to perform vendor rating is, thus, unavailable for small vendors from developing countries.

The above gap between the demand and supply of SCF can be partly attributed to the complexity of the traditional SCF models. For instance, the first-level suppliers (the suppliers to the buyer) need to contact lenders for a loan. They use the loan money to make payment to second level suppliers (suppliers to the first-level suppliers) or to third-level suppliers. In some cases, the number of suppliers in an advanced global supply chains can be as deep as 13 layers. The funds, thus, may take many days or weeks to reach actual manufacturer, which needs the money.[12]

Especially due to the ease with which trade transactions can be falsified in the nonblockchain world, the use of fake export invoices to disguise cross-border capital flows has been pervasive in many developing economies. For instance, since China has maintained strict capital controls regimes, some importers and exporters falsify trade transactions in order to move capital in and out of the country. Many banks do not check the authenticity of trade documents.[13] During April to September of 2014, China found US$10 billion worth of fake trade transactions.[13] Some major

fraud cases were in the Port of Qingdao on the Yellow Sea in the Shandong Province. Some firms had used fake receipts to secure multiple loans against a single cargo of metal.[14] The Qingdao frauds involved 300,000 tons of alumina, 20,000 tons of copper, and 80,000 tons of aluminum ingots.[13] Due to the scandals, Chinese banks charge higher interest rates and have a lower tendency for collateral financing.[14] Since there is no single view of TF across banks, there is a challenge where one company can approach multiple banks with a Letter of Credit (LC) and fraudulently receive funds from multiple banks using the same letter of credit.[15]

According to Global Financial Integrity's (GFI) 2015 report, fraudulent misinvoicing of trade transactions accounted 83.4% of all illicit financial flows (IFFs) from developing countries.[16] An estimate suggested that during 1988–2012, US$186 billion worth of IFF went out from India through trade misinvoicing.[17] Ethiopian importers are reported to use fake invoices in order to pay lower taxes on imported goods. In 2017, the Ethiopian Revenue and Customs Authority (ERCA) collected US$1.6 billion in extra tax revenue by cracking down on fake invoices. Such invoices were mainly provided by companies in China and the United Arab Emirates.[18] About 80% of import invoices were estimated to be fake. Fake invoices mainly involve underinvoicing in order to reduce the amount of tax they pay on imported goods.

6.3 Blockchain's potential to address key challenges facing supply chain and trade finance

A typical cross-border transaction involves many parties. A letter of credit (LC), which is a promise to pay for the goods if certain conditions are fulfilled—is sent to the exporter by the bank of the importer. After receiving the LC, the exporter ships the goods. The risk that the bank faces is that the importer may be unable or unwilling to pay. The exporter then presents proof of shipping to get financing from its bank. The exporter's bank is paid directly by the importer's bank. Estimates suggest that, in the average, a single cross-border trade transaction involves the exchange of 36[19] to 40 different documents.[6] As many as 240 copies of such documents need to be exchanged among various parties such as financiers, logistics providers, customs officers, and warehouse managers.[19]

Blockchain offers tremendous potential to address various challenges noted above. A JP Morgan report published in early 2020 on enterprise blockchain and digital currencies identified TF, especially LC as the most

promising application.[26] In May 2020, China's National Internet Finance Association (NIFA) published a report about blockchain. Among all financial applications, SCF, TF, and insurance accounted for 32.6%, 11.2%, and 11.2% of all applications, respectively.[20]

The US computer technology corporation Oracle has claimed that in general, by automating TF processes such as LC issuance, processing times can be cut by 60%, and time required to enter and scrutinize data can be shortened by 70%.[21] With blockchain, it is also possible for all parties to see instantly all data related to transactions. Such data can have dramatic impact on the cost and availability of TF. Organizations using a common digital platform to track TF can also access data pool about potential clients as well as their transaction histories. New entrants such as institutional investors and technology firms that are interested in offering financing or refinancing also have access to such data. For these players, TF may yield higher returns than other options available to them such as public bond. An upshot of competition is that the cost of basic trade financing may fall close to zero. Banks may find more attractive to make money by selling data about exporters or importers.

Some solutions currently aim to increase the availability of TF for domestic trade transactions. The technology and experience gained from this situation can transfer to facilitate international trade in the future. Among the first such measures, in late 2016, India's Yes Bank teamed up with IBM for a blockchain project to digitize vendor financing for its client, India's consumer electrical equipment manufacturing company, Bajaj Electricals. India-based fintech startup Cateina Technologies developed a blockchain-based smart contract.[22]

As of mid-2018, 14 Indian banks had signed up to use the services of the blockchain platform India Trade Connect consortium, which was developed by the local software firm Infosys. The platform facilitates the issuance of loans that are backed by trade transactions.[23] The banks account for about half of India's internal trade. The solution is expected to speed up processes for approving new loans.

6.3.1 Access to high-quality and relevant data

With blockchain, SC participants can have access to detailed data on other participants about previous transactions, which can be used by the financier to assess risk. Using data from satellite, global positioning system (GPS), or radio-frequency identification technology, blockchain can make it possible

for interested parties to see the status of goods. Theoretically, the risk associated with TF reduces as the goods get closer to the importer, which can lower the interest rate. Also blockchain-based data can be more trustworthy due to the audit trail. All participants can see who made what changes to the documents (See: In Focus 6.1: Unilever and Sainsbury's "Trado Model").

In Focus 6.1 Unilever and Sainsbury's "Trado Model"

In 2017, British–Dutch multinational consumer goods company Unilever announced that it teamed up with the British supermarket chain Sainsbury, packaging company Sappi, and three global financial services companies—BNP Paribas; Barclays; and Standard Chartered—to develop a blockchain platform to track sustainability practices of its SCs. The initial yearlong project started with a US$700,000 in funding from the United Kingdom's Department for International Development and private sources to track two categories of products: tea supplies used by Unilever and Sainsbury's and wood fibers in certain Sappi packaging solutions. The plan was to start with a system to track and verify contracts for farmers in Malawi supplying tea to Unilever and Sainsbury. Financial incentives were offered to the tea farmers for feeding social or ecological data into the blockchain system.[26]

Tea is Malawi's second biggest agricultural export after tobacco. The initiative is expected to reach up to 10,000 farmers. The group announced that preferential pricing would be applied to farms that engage in sustainable farming methods, which increase harvests without using more land. The banks will finance farms that utilize sustainable farming methods.[27]

Provenance, blockchain-enabled fintech startup Halotrade, and real estate development company Meridia developed what they referred to as the "Trado Model," which facilitates data-sharing among producers, consumers, and SC players.[26] The Trado model was first piloted in the tea SC in collaboration with the Lujeri Tea Estate in Malawi. It made farming data from smallholder farmers directly accessible to Unilever. Data related to tea leaf production, social impact, and sustainability credentials were recorded in the Provenance platform. Using data related to the availability of goods, Unilever supported the release of payment earlier. The 18-month pilot found that Unilever and Sansibury's could increase SC transparency with the data.[3] It reduced the period of expensive financing for upstream partners. The transactions take place using a bank's regular SCF process. Thus, it results in a minimal disturbance of the banks' businesses.[28]

The resulted saving was invested to fund projects such as local farmer field school that trained farmers in sustainable practices. Local nongovernmental organizations (NGOs) confirmed payment distributions to the school and recorded the impact progress on the blockchain.[29]

In the Australian government's "National blockchain Roadmap," announced in February 2020, which identified SC tracking as a key use case, there have been some innovative uses of data to facilitate SCF. Alipay Australia will be responsible for payment for products exported to China. Alipay Australia uses logistics-related data generated by Internet of things (IoT) devices, which are on the VeChainThor blockchain to provide loans to suppliers to meet their working capital needed.[24] Mastercard will handle payments for products for other countries.

Retailers and other downstream players in SCs are considering what they refer to as "milestone" payments to various parties with the movement of shipments along the SC. Credits are used to make instant payments to a digital wallet. Manufacturers do not need to wait for a month for the accounts to settle. It could be argued that the benefits are especially pronounced in situations such as those created by COVID-19—led lockdowns, which has severely affected companies' cash flows. For example, under the "milestone" payments model, 30% can be paid to the manufacturers or other upstream suppliers, when the shipment clears customs in Australia and the information is recorded in blockchain. Additional 30% can be paid, when it clears customs in China. Rest of the payment will be transferred when the product is delivered.[25] In this way, blockchain-based models provide high-quality data about SC activities, which is a competitive factor for manufacturers, which is also an enabler for collaboration among SC participants.

6.3.2 Fighting fraudulent practices

Blockchain is an effective tool to fight fraudulent practices. As an example of an initiative that attempts to address fraudulent practices using blockchain, India's central bank, the Reserve Bank of India (RBI), licensed three entities RXIL, A.TReDS, and M1xhange to provide receivable financing to micro and small businesses. These three platforms wanted to share information in order to prevent fraud but keep the data private. Blockchain is a tool that can help achieve this goal. Using blockchain, it is possible to create a cryptographic representation of the invoice, known as a hash. A hash provides an indecipherable text and does not tell anything about the invoice. It is nearly impossible to convert a hash back to the original data. If a trader submits the same invoice to more than one trade finance platform (TFP), the hash will match, which raises a red flag. New York—based MonetaGo also hashes some of the elements of the invoice in order to

prevent the trader from making some modification in the invoice. An invoice that has a high degree of similarity with another invoice already submitted to a different platform will not be rejected, but it will produce an amber flag. The TFP may then ask the trader to explain.[30]

The risks associated with securitization, which involves taking illiquid assets (e.g., debts) and selling to investors, can be more effectively eliminated with blockchain. By digitizing and standardizing the data, tools such as big data analytics can be applied. Such a transparency would allow TFPs to undertake prudent financing decision based on more than just trust in the issuer of securitization, which was a main part of the problem in the 2008 global financial crisis.[30]

6.3.3 Meeting regulatory standards

The International Chamber of Commerce (ICC) survey found that banks encounter a number of barriers to meet the SCF needs of their customers. Some of the barriers can be addressed with blockchain-based solutions. For instance, 84% of the respondents reported that compliance issues such as those related to anti-money laundering (AML) and know your customer (KYC) requirements are a key obstacle to providing TF.

Blockchain can make it easier to satisfy regulatory standards such as KYC. Currently, there is a lack of standardization in identifying information that customers are required to submit to banks and financial institutions to perform KYC checks. Blockchain-based standards can reduce duplicate efforts and transaction costs for banks and customers. For instance, a blockchain transaction has a so-called transaction ledger, which holds encryption key access to the document folders related to identity, health, academic qualifications, and other individual attributes on a series of what is referred to as "key rings."[31] Digitally certified and professionally validated documents related to KYC and other attributes can be put on the subject's key rings by the certifier. After putting on, the blockchain certifiers do not have access to the data.[31] Using blockchain, it is possible to do a rigorous professional validation and use such identity document for all subsequent transactions.[32] Third parties such as banks and financial institutions, insurance providers, and government agencies may get permission to access documents based on a smart contract.[33]

6.4 Some representative cases of blockchain solutions to address the supply chain and trade finance gaps

In 2019, Euromoney reported that there were about 30 consortia that focused on using DLT in TF.[34] Some DLT- and blockchain-based TF solutions are presented in Table 6.1. These solutions have been initiated and supported by various actors such as national governments and industry consortia. They have targeted diverse application areas and markets.

6.4.1 Easy Trading Connect/komgo

In February 2017, the multinational bank ING and French multinational investment bank and financial services company Societe Generale successfully tested a blockchain-based TF prototype solution, which was called Easy Trading Connect (ETC). The trial took place on a transaction between the two banks and Mercuria, a Switzerland-based global commodities trading corporation. An oil cargo shipment containing African crude sold to the Chinese petrochemical company, ChemChina was processed. According to the two banks, the solution performed well in terms of assessment criteria such as elimination of documentary fraud, reduction of costs, and improvement in efficiency. The trade involved the banks, traders, an agent, and an inspector.[37] The prototype allowed all these parties to execute their roles directly on the platform. The prototype reduced the time taken by a bank to execute its role in such a transaction to 25 min from an average of 3 h.[37] While this test was for an oil transaction, the steps involved in trades of other commodities are same. This would allow the platform to easily scale.[38] It also reportedly led to a cost saving of up to 30%.[39]

ING and Societe Generale were negotiating with traders in liquefied natural gas (LNG) industry to test the solution.[39] Other economies in Africa and other parts of the world as well as other commodities sectors are, thus, likely to benefit from solutions such as like this.

An enhanced version of the ETC was used to conduct a live agricultural commodity trading transaction in January 2018. It involved 60,000 tons of soybeans sold by the global merchant firm Louis Dreyfus Company to China's Shandong Bohi Industry. All relevant documents such as sales contract, LC, and certificates were digitized. The US department of agriculture provided data on phytosanitary certificates. Russell Marine Group and Blue Water Shipping issued other required certificates. ING, Société

Table 6.1 Some blockchain-based trade finance solutions.

Platform	Targeted users	Key players involved	Products offered/ platform used/ benefits
Easy Trading Connect/ komgo	Energy and soft commodities.	ING, Societe Generale.	LC, standby LC,[a] and receivables discounting.
Chained Finance	Electronics, auto manufacturing, and clothing companies.	Dianrong and FnConn.	Suppliers are paid in cryptocurrencies based on Ethereum.
We.trade	SMEs in Europe.	12 major banks/ financial institutions (e.g., Deutsche Bank, HSBC, Rabobank, Santander, and Société Générale), and IBM.	Tools based on Hyperledger Fabric to manage, track, and secure open account trade transactions.
eTradeConnect	A general focus on settlement and financing of trades.	Supported by the HKMA and funded by a consortium of 12 major banks including HSBC and Standard Chartered Bank, Bank of East Asia, Australia and New Zealand Banking Group Limited, Hang Seng Bank, and DBS Bank. PwC is project manager.	Aims to reduce the time needed to approve trade loan applications from 36 to 4 h.[35]
Contour	A general focus on trade and TF.	Established by eight banks, including ING, BNP Paribas, and HSBC. It is built on R3's Corda.	Reduces the time taken to execute the LC from 5 to 10 days to less than 24 h.

Table 6.1 Some blockchain-based trade finance solutions.—cont'd

Platform	Targeted users	Key players involved	Products offered/ platform used/ benefits
Bay Area Trade Finance Blockchain Platform	Targeted jurisdictions include Guangdong, Hong Kong, and Macau.	Initiated by the PBoC. Participating banks: Bank of China, China Construction Bank, China Merchants Bank, Ping An Bank.	Loan approval time is expected to reduce to 20 min. Corporate financing charges dropped to less than 6%.[36]

[a]*A standby letter of credit guarantees that a bank will pay to a seller in the event that the buyer defaults for any reason*; n.d.

Générale, and ABN AMRO had issued and confirmed the LC.[40] It led to a shorter cash cycle.

The three banks—ING, Société Générale, and ABN AMRO—which started ETC were among the 15 shareholders of independent venture komgo, which was started in August 2018 to digitize and streamline commodity TF.[41] Among major clients, Sberbank Switzerland AG, which is subsidiary of Russia's largest bank Sberbank, signed an agreement with komgo to apply its blockchain-powered TF service.[42]

6.4.2 Chained Finance

In March 2017, China's Internet financial services company Dianrong and FnConn, the Chinese subsidiary of the Taiwanese electronics manufacturer Foxconn launched Chained Finance, which was China's first blockchain platform for SCF.[43] Electronics, auto manufacturing, and clothing companies facing difficulties to get SCF are the test markets for Chained Finance.[2] Instead of charging to the suppliers, Chained Finance charges peer-to-peer (P2P) lenders a fee to access to the system. Using the platform, nonbank lenders can make direct loans in SCs worldwide.[44] Before launching it, the two companies had successfully completed a pilot project and proof of concept (PoC) which secured US$6.5 million funding for Chinese SMEs. Different levels of suppliers are expected to be connected to the system of Chained Finance. The company aims to expand to other developing economies such as India and those in Africa.[12]

As of early 2020, more than 20 electronics suppliers were being paid on cryptocurrencies based on Ethereum. The company reported that financing costs reduced from 24% per year to 10%, and the time needed to get funding reduced from 7 days to 1 day.[45]

6.4.3 We.trade

We.trade was started in 2017 by 12 major banks and financial institutions such as Deutsche Bank, HSBC, Rabobank, Santander, and Société Générale.[46] In May 2020, IBM acquired a 7% stake in the company.

It aims to increases transparency by providing real-time monitoring of transactions. The platform can only be accessed by customers that are verified and authenticated by the member banks. The transactions, thus, have a high degree of security and trust.[47]

We.trade's target market is SMEs in Europe. It provides tools based on Hyperledger Fabric to manage, track, and secure open account trade transactions. It facilitates three key steps in SME trade: (a) access to counterparties to engage in direct online transactions, (b) bank payment undertaking,[48] and (c) financing requesting.[b]

The first transaction on the We.trade platform was conducted in August 2019 by HSBC. The transaction involved HSBC's client Beeswift, which is the UK-based manufacturer and wholesaler of personal protective clothing and equipment, as the seller. The buyer was a Dutch firm, which was a client of Rabobank.[b] Likewise, in early 2020, the Spanish bank CaixaBank started providing We.trade to its 15.8 million customers.[49]

6.4.4 eTradeConnect

In November 2017, Hong Kong's currency board and de facto central bank Hong Kong Monetary Authority (HKMA) teamed up with the professional services group Deloitte and some banks to develop a PoC for blockchain-based TFP.[50] Participating banks include HSBC, Standard Chartered, Bank of East Asia, Australia and New Zealand Banking Group Limited, Hang Seng Bank, and DBS Bank.[51]

The platform aims to reduce risks and increase efficiency by digitizing trade documents and automating TF processes.[51] Among the key benefits of the platform are lower risks related to fraudulent activities and higher level of business transparency. The risks of duplicate financing can be

[b] Partz 2019.

reduced for the participating banks. The HKMA worked with Ping An to cut paperwork and reduce frauds.[52] OneConnect, Ping An Group's financial technology company, designed the platform, which is based on Hyperledger Fabric.[53]

OneConnect has developed blockchain-based platforms that provide financial technology solutions for small and medium-sized banks. The technologies had already been deployed in China.[54] OneConnect can evaluate potential customers' creditworthiness by extracting a wide range of company data. It can also evaluate potential customers' creditworthiness at a low cost.

Such benefits are especially pronounced if cross-border trade can be facilitated by integrating such platforms with similar trade platforms in other jurisdictions.[51] eTradeConnect has teamed up with several other major platforms to facilitate interplatform data exchange and communications. In November 2017, the HKMA and the Monetary Authority of Singapore (MAS) signed a Memorandum of Understanding (MoU) to develop the Global Trade Connectivity Network (GTCN). The GTCN is a DLT-based cross-border TF network between eTradeConnect and the Singapore Networked Trade Platform. The goal is to facilitate cross-border trade and trade financing by enhancing safety, efficiency, and cost-effectiveness. The GTCN uses an open architecture, which makes it easier for other jurisdictions to join. Likewise, in October 2018, another MoU was signed between eTradeConnect and We.trade to connect the two platforms.[55] In the same vein, in November 2019, the People's Bank of China (PBoC) and eTradeConnect signed a deal to integrate their TF platforms.[36]

6.4.5 Contour

Contour was established in 2018 by eight banks, including ING, BNP Paribas, and HSBC. The goal is to eliminate LC-related paper work.[56] Contour has claimed that it reduces the time taken to execute the LC from 5 to 10 days to less than 24 h. It is built on R3's Corda. In May 2018, HSBC issued an LC for US food and agriculture firm Cargill using this platform. The transaction involved a bulk shipment of soybeans from Argentina to Malaysia.[57] It was arguably the world's first blockchain-based TF transaction. According to HSBC and ING, the exchange was performed in 24 h, which used to take five to 10 days through a paper-based system.[57]

After conducting live pilots in 14 countries and a global trial that involved more than 50 banks and corporations, it was launched commercially in January 2020.[58] By March 2020, it had processed more than

US$3.3 billion of deals. Just one company the Singapore-based Agrocorp had processed more than US$100 million in transactions by then.[59]

In September 2020, Standard Chartered announced that it completed the first cross-bank LC transaction between Vietnam and Thailand using Contour's blockchain. The trade involved the shipment of plastics worth US$50,000 from Thailand's SCG Plastics to Vietnam's Opec Plastics Joint Stock Company. The participating banks included Bank for Investment and Development of Vietnam and Thailand's Standard Chartered Bank. The ADB had provided a credit guarantee. It was the first credit guarantee that the ADB completed via the DLT. The time taken to complete the deal was reported to reduce from 5 days to about 7 h.[60]

6.4.6 Bay Area Trade Finance Blockchain Platform

In September 2018, China's central bank, the PBoC started to pilot TF project referred to as the Bay Area Trade Finance Blockchain Platform (BATFB). The solution targets SMEs. The BATFB was launched in Shenzhen. Targeted jurisdictions included Guangdong, Hong Kong, and Macau. The banks participating in the project include Bank of China, China Construction Bank, China Merchants Bank, Ping An Bank, and Standard Chartered Bank.[36]

In May 2020, the BATFB received US$4.7 million in "special funding" from the government over a 3-year period for R&D. In addition to lower interest rates, loan approval time is expected to be as short as 20 min.[61]

As of December 2019, 38 banks participated in the platform,[62] which reached 48 by September 2020.[63] During this period, the business volume processed by the platform increased from US$12.4 billion[62] to US$29 billion.[63] By August 2020, it had processed more than 50,000 transactions.[63]

The BATFB's jurisdiction of operation is no longer restricted to the Bay Area. New regions are being added regularly. In addition to TF, it covers SC accounts receivables and rediscounting[c] by the central bank. Additional services include automated tax filing and supervision of international trades.

[c] Rediscounting is a way of providing financing by a central bank to banks or other financial institutions. If a customer wants to borrow $100, the bank may ask them to sign a paper document (also referred to as a note) promising to repay $120 in one year. In this example, the bank is "discounting" the note because it is paying less than $120. The central bank could provide financing to the bank by "rediscounting" the note (e.g., by paying $110 for the note) n.d

The Institute is finding ways to expand the ecosystem. Especially, it is interested in third parties that can build applications to integrate with the platform.[63]

The auto manufacturer BYD is one of the participants. Majority of BYD's suppliers are SMEs, which include 10,000–20,000 tier one suppliers and even higher numbers of tier two and three suppliers. Especially, the latter group is reported to have a more significant funding gap. By sharing data between the banks, a firm cannot submit the same invoice to two banks for funding. If an invoice is authenticated by companies such as BYD, it provides credibility for the bank.

6.5 Standardization initiatives in trade finance

As discussed above, DLTs and blockchain have significantly improved TF. Many consortia have emerged in the past few years to address the TF gaps. However, they use different blockchains. In general, the blockchain industry has become highly fragmented, which has made it difficult for companies to use this technology in real-world applications and maximize economic benefits.[64] For instance, Chained Finance connects Foxconn, its small suppliers, and the suppliers' suppliers on an Ethereum-based blockchain.[65] Contour, on the other hand, is built on R3's Corda. Ethereum and an R3 Corda blockchains have different hashing algorithms (pointer to previous blocks) and different consensus protocols.[66]

Different consortia consist of different banks that use different platforms with slightly different offerings (See Table 6.1). True scalability in TF cannot, thus, be achieved with the current arrangement. Prior research in economics suggests that in situations such as this, after an organization joins a consortium, it is difficult to break the self-reinforcing mechanism associated with the consortium.[67] For instance, it is not possible for a manufacturer to get a low-cost loan from a bank, which is a member of a different consortium. In a 2019 survey of the TFP, Trade Finance Global (TFG), 91% of respondents noted that DLT faces an interoperability challenge.[68] Corporations and banks have complained that they find after investing in certain platforms and technologies that they are not the industry standard.[69]

Industry bodies have started taking some measures aimed at establishing blockchain standards.[32] As a major attempt to realize interoperability, the global trade association for transaction banking, the Bankers Association for Finance and Trade (BAFT) released technical and business best practices

specifications for a distributed ledger payment commitment (DLPC).[70] The DLPC aims to offer a standardized solution for companies to register commitment of payment digitally on a distributed ledger. Specifications have been proposed for various instruments such as LC, bills of exchange, bank payment obligations, and banker's acceptances. In order to facilitate interoperability between multiple trade solutions involving DLTs, the BATF has encouraged various parties to incorporate these specifications.[71] The DLPC was guided by the US blockchain company Skuchain.

The DLPC aims to offer scalability of TF by including suppliers and banks from different blockchain networks. For instance, a buyer can originate a DLPC on Skuchain's Hyperledger-based Empowered Collaborative Commerce Cloud (EC3) platform.[72] The DLPC can be sent to another network, such as Corda. A bank or counterparty from a different network can finance.[73]

The payment commitment is arguably the most important part of a TF transaction. The BAFT DLPC aims to overcome the interoperability challenge by standardizing payment commitment. Multiple solutions can compete in the marketplace, and scalability can be achieved through the network effect.[67]

Legally speaking, the DLPC is a promise to pay. All the involved parties sign and validate, and, thus, its authenticity can be trusted. Its goal is to act as a standard across blockchain networks. Counterparties that are not a part of the same network can engage in transactions involving the same payment commitment. They do not have to engage in costly infrastructure integration with other networks.[67]

Some efforts have yielded encouraging progress. Skuchain was reported to establish cross-blockchain interoperability in TF by linking together its Hyperledger-based EC3 platform with Corda. This is the first real-world example of the BAFT's DLPC.[73] Prior research suggests that solutions such as this can help overcome various self-reinforcing mechanisms[74] associated with lock-in to existing blockchain systems and take advantage of emerging, more resource efficient standards.

6.6 Discussion and implications

Blockchain has the potential to significantly transform the SCF and TF landscapes. The key mechanisms that underlie this transformation include reduction in the costs of international trade and increase in speed and efficiency. For instance, it was reported that the traditional TF process

within India involves processing a large number of documents, which can take up to 22 days. Blockchain platforms such as India Trade Connect consortium are expected to reduce the time to less than a day.[23] Other benefits include high level of trust and security and reduction in bureaucratic red tapes and corruption. Blockchain deployment in SCF streamlines the paper trail and improves transparency between parties. The benefits of easier access to low-cost finance are especially strong for SMEs.

Some go as far as to suggest that by 2050, blockchain could provide a digital record of transactions, and it will be unusual to rely on documentary contracts.[6] A programmable smart contract can be written, which can be tied to existing deposits of a digital currency or digital wallet. Payments will be made automatically when goods are successfully received. Independent oracles verify such receipts and enable the transaction to pass.[1] It is also envisioned that practices such as "dynamic factoring" can be introduced, which involves changing interest rates as goods approach final destinations.[6]

In the ICC survey noted above, high transaction costs or low fee income are among the major challenges faced by banks in satisfying their clients' SCF needs.[75] This can be attributed to high costs of due diligence and frauds.[7] The various mechanisms and examples noted above make it clear that blockchain-based solutions can reduce costs.[39] Financial institutions may pass the cost-saving efficiencies on their clients, which is likely to lead to lower TF costs. Blockchain-based solutions can also reduce or eliminate fraudulent transactions. Developments of blockchain standardization will have even more far-reaching impacts and consequences for the global SCF market.

Major global banks and financial intermediaries are working closely with blockchain companies to develop blockchain-based TF solutions. Manufacturers can help suppliers access low cost financing by making a payment commitment on the blockchain, which is linked to a purchase order or approved invoice.[73] In the ETC example, the African crude oil producer, the Chinese petrochemical company, ChemChina, as well as other players in the entire value chain of oil can benefit. The solution was also reported to perform well in terms of replicability.

Banks can also benefit greatly from the deployment of blockchain in SCF and TF. Indeed, SCF and TF are a highly attractive market for financial institutions. In general, TF has lower risks than instruments such as corporate loans.[35] TF is a significant source of revenue for some banks. In 2017, the British multinational investment bank and financial services holding company HSBC was reported to earn US$2.52 billion from

TF-related transactions.[35] According to a survey conducted by the ICC, which was released in July 2020, SCF was an immediate or near-term priority for 86% of respondents. 346 banks from 85 countries had participated in the 2020 ICC Global Survey on Trade Finance.[76] Blockchain has the potential to improve the already attractive TF market for banks.

More importantly, and a point sometime overlooked, is that some high-profile frauds have increased blockchain's attractiveness for many financial institutions. The British multinational banking and financial services company, Standard Chartered, lost about US$200 million from Qingdao frauds. As early as in 2016, Standard Chartered teamed up with DBS Group and Singapore's Infocomm Development Authority to develop blockchain-based platform.[77] Other players such as Bank of America and HSBC also started exploring blockchain for TF and other applications.[77]

Regulatory pressures have also prompted actions on this front. The Chinese government has asked its banks to take measure to increase transparency and combat fraud in its financial sector by adopting blockchain. Chinese banks are hiring blockchain experts and incorporating blockchain in their operations.[78]

Prior researchers have noted that standards that are motivated by business goals may face resistance.[79] It is important that an impartial player leads the blockchain efforts.[80] Thus, in the TF market, it is in the interest of banks to connect to a neutral entity rather than joining another bank's platform.[69] This is because there is "asymmetrical data problem" if a bank joins another bank's platform. The idea is that the bank which owns the platform is perceived to derive more value from data exchange. Some TF-related blockchain platforms such as komgo, We.trade, and Contour started as consortia. Subsequently, they moved away from their initial model and became separate legal entities. For instance, in 2018, We.trade and komgo created independent companies and appointed CEOs to run them. The founding members became shareholders. Contour took a similar measure.[69]

6.7 Concluding comments

A key challenge in the nonblockchain world is incomplete and slow flow of financial and other information in SCs. Several efforts involving blockchain have been made to address these challenges. Blockchain solutions can greatly enhance speed and efficiency.

Self-executing blockchain-based smart contracts are likely to replace the documentary contracts currently used in TF. This will dramatically increase

the speed with which contracts could be executed. For instance, when a shipment is confirmed on the phone, contract could be automatically executed. A further benefit is that blockchain-based systems can reduce fraudulent activities because records must be authenticated before being added to the books and because they cannot be changed. With further development in technologies, smart contracts are also likely to open up markets to more people. For instance, pictures can help suppliers that are illiterate and cannot understand the terms.

SC participants from different parts of the world may have little credit history. Creditors, thus, find it difficult to assess their risk to make lending decisions. Blockchain-based solutions also make it possible for financial institutions to have access to meaningful, high-quality, and relevant data in a timely fashion. Blockchain, thus, has the potential to help reduce the TF gap. Easier access to TF would give importers more choice of goods. It can also contribute to the economic development of developing countries. Some government led initiatives such as the BATFB and the HKMA-supported eTradeConnect are highly encouraging in this respect.

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CHAPTER 7

Opportunities, barriers, and enablers of blockchain in supply chains

7.1 Introduction

One way to view blockchain would be to consider this technology as an institutional governance mechanism for creating and maintaining distributed ledgers of information.[1] That is, blockchain can act as a governance structure that enables the flow of secure and trusted information about products for consumers, firms, and governments as they move along SCs.[2] Thus, blockchain's governance mechanisms can improve SC performance by forcing the participants to engage in responsible and ethical behaviors.

The international independent standards organization Global Reporting Initiative (GRI), whose goal is to help businesses and governments understand and communicate issues related to social and environmental sustainability, aims to standardize in corporate social responsibility (CSR) reporting and enhance the credibility and adoption of its standards worldwide.[3] It is argued that one way to achieve this is to use blockchain to record financial and nonfinancial data, which can be digitally validated and instantly made available to regulators, investors, and other stakeholders.[4]

One industry that has been at the center of the evolving blockchain application and governance mechanisms in supply chain management (SCM) is the mineral and mining industry. According to Marketline's Global Metals & Mining Industry Profile & Value Chain Analysis, the global mining and metals market was US$1.8 trillion in 2018.[5] Especially SCs involving cobalt stand out as a key area to benefit from blockchain. Lithium ion batteries used in diverse applications such as electric vehicles and phones at least partly run on cobalt. There has been a rapid growth in

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the demands of these products. Governments, non-governmental organizations (NGOs), and consumers have been intensifying efforts to combat the problems of human rights abuses in cobalt SCs. Due to such issues, cobalt is also referred to as "blood cobalt"[6] and is also known as the "Blood Diamond of Batteries."[7] The proponents of blockchain believe that these issues are likely to be tackled with blockchain.[8]

Likewise, blockchain is expected to address two major challenges that the diamond industry is facing. First, the extractions of diamonds and minerals are allegedly associated with child labor, human rights violations, and other occupational and environmental health hazards, such as toxic chemicals. Second, proceeds from diamonds may facilitate money laundering and smuggling, which may lead to violence and criminal activity.[4] Blockchain is likely to force supply chains to become more traceable and transparent and, thus, has a potential to address these problems.

Whether and to what extent SCs can benefit from blockchain-based governance structure would depend on this technology's potential to reduce transaction costs. Put simply transaction costs consist of two things: "(1) the costs of measuring the dimensions of whatever it is that is being produced or exchanged and (2) the costs of enforcement".[9] As to (1), many mineral-rich developing countries in Africa lack mobile network coverage and Internet access. These factors increase the costs of establishing and operating traceability systems. These problems are further compounded by the weak rules of law. Corruption hinders efforts to accurately assess SC sustainability-related indicators.

As to (2), formal contracts cannot be easily enforced in these countries. This means that even if individuals who are responsible for entering data into blockchain ledgers intentionally enters wrong information, such offenders are less likely to face criminal punishment. These factors increase the transaction costs.[10]

In this chapter, we focus on key enablers of blockchain in SCs. We also offer an overview of opportunities and barriers in implementing blockchain in SCs and for this technology to act as an effective governance mechanism, so that it can contribute in producing SC trust.

7.2 Key enablers

There are a number of factors and actors that have enabled and encouraged the adoption of blockchain in SCs.

7.2.1 Availability of quick and easy options to use blockchain

An increasing competition in the area of enterprise blockchain has facilitated the adoption of this technology in SCM. There are several quick and easy options for enterprises to build a blockchain project for SCM. For instance, Hyperledger Fabric has become a popular enterprise blockchain platform for SCM. Several technology companies such as IBM, AWS, SAP, Oracle, and Microsoft offer enterprise blockchain solutions based on Hyperledger Fabric. For instance, SAP provides Hyperledger Fabric on its cloud platform. Likewise, Microsoft offers Hyperledger Fabric on Azure.[11]

In order to set up a blockchain based on Hyperledger Fabric, two components of costs are involved: infrastructure-related costs and the development cost. Most companies provide Hyperledger Fabric infrastructure. This means that companies do not need to worry about infrastructure, storage, and networking costs. A ready-made blockchain platform also has sharing, encryption, consensus algorithm, and peer-to-peer (P2P) network.[11]

Some recent developments in this technology have enabled smaller companies' access to blockchain-based solutions. To take one example that fits well with this observation, we consider Coke One North America (CONA). In 2019, CONA started using Hyperledger Fabric on SAP Cloud Platform. In the initial phase, the solution was implemented by big 12 franchised bottling companies.

Seeing the benefits of blockchain, CONA decided to expand the technology to large numbers of suppliers of bottles and raw material.[12] In March 2020, CONA teamed up with Microsoft, professional services firm Ernst & Young and Ethereum venture studio ConsenSys to launch the "Coca-Cola Bottling Harbor" project. The project runs on the Baseline Protocol, which is a middleware solution for large companies. It enables confidential and complex collaboration between enterprises. Using the app, CONA's SC members can communicate and transact privately on the Ethereum public blockchain. They can also access decentralized finance (DeFi) applications and tokenize assets[13] (See In Focus 7.1: How DeFi works).

Ethereum's mainnet enables CONA's network of suppliers to apply for supply chain finance (SCFs) via DeFi applications. For instance, a supplier can use a digital token representing a purchase order as security to obtain working capital. Initial results are expected to be announced in 2020 Q4.[13]

In Focus 7.1 How decentralized finance (DeFi) works

DeFi relies on decentralized networks such as blockchain to create financial products utilizing trustless and transparent protocols, which run without intermediaries (https://defiprime.com/). In December 2019, the DeFi ecosystem was valued at US$700 million.[14] It increased to more than US$7.8 billion by August 30, 2020 (https://defipulse.com/).

Most of the DeFi protocols run on Ethereum.[15] DeFi aims to replace the legacy financial system with smart contracts, which removes the need for trusted third parties.

To be effective, most smart contracts require the use of a trusted third party, referred to as an oracle. Oracles need to be free from censorship and corruption and resistant to government regulation and cyberattacks.[16] In most cases, no satisfactory solution for an oracle currently exists. DeFi, thus, currently lacks a solid foundation. With the availability oracles in the future, DeFi has a potential to transform the financial landscape in SCs.

Some blockchain platform requires only minimal IT skills. Toronto, Canada-based digital company Convergence.tech launched a blockchain pilot to trace the Mongolian Cashmere supply chains. The solution tracks the journey of these bales from the herders to a processing factory in Ulaanbaatar. The firm's two executives went to Mongolia to train the herders to use the blockchain. An Android app enables farmers to register their Cashmere bales with location tagging. These bales, along with the packing slips, are attached with high-frequency radio-frequency identification (RFID) tags.[17]

7.2.2 Affordability and ease of use of blockchain compared to alternative solutions

In some areas, the affordability and increasing ease of use of blockchain compared to alternative solutions are likely to lead to their widespread adoption. For instance, compared to established traceability programs such as ITRI (International Tin Research Institute) Tin Supply Chain Initiative's (ITSCI's): "bagging and tagging" system, blockchain solutions launched by some start-ups to trace minerals are more cost-effective (See In Focus 7.2 for ITSCI's "bagging and tagging" system).

Depending on the type of mineral produced, miners in Rwanda pay between US$130 per ton and US$180 per ton to use ITSCI traceability system.[18] Artisanal mines in Rwanda are estimated to produce 0.5–3 tons per month (TPM).[19] Taking the minimum level of production, an artisanal mining company producing 0.5 ton per month (6 tons per year) is required

In Focus 7.2 The ITRI (Industrial Technology Research Institute) Tin Supply Chain Initiative's (ITSCI) bagging and tagging system

The ITSCI was established in response to the *Dodd–Frank Wall Street Reform and Consumer Protection Act*, which requires US companies to vet their SCs. The ITSCI's "bagging and tagging" system is an example a traceability scheme in the nonblockchain world. It involves a five-step due diligence framework.[23]

The first step involves establishing company procedures and policies. This includes developing due diligence skills, assigning due diligence responsibility to a manager, and providing them with the required resources and informing customers, suppliers, and other contractors the expectation to carry out due diligence.

In Step 2, the SC is identified. Independent evaluators assess the company's trade history, links to conflict, policies, and plans for company approval. For mine approval, field teams visit mine sites to assess whether they are conflict-free. They also evaluate transport routes. Local authorities are trained to implement a tagging and record-keeping system. The goal is to ensure traceability from the mine sites to processors and exporters, which also includes transport routes. Transaction information is provided to the central data center. The information is evaluated for errors and anomalies. Traceability information is made available to smelters that purchase the minerals.

In Step 3, risks are identified and managed. ITSCI's incident management teams help to collect local information on SC risks. The information is used to discuss with relevant stakeholders and provide input related to the risk mitigation process. Stakeholder committees are formed that consist of government agencies, civil society, and industry members.

Step 4 involves independent audit. Smelters are provided information to use in their Conflict-Free Smelter Program (CFSP) audit. The information includes ITSCI audit reports on upstream companies that supply to smelters.

In Step 5, Annual Reporting, companies need to prepare a report annually to show how they carried out due diligence. The report, which should be publicly available at the offices and on website, outlines the due diligence steps taken.[24]

to pay between US$780 and US$1080 per ton to use ITSCI traceability. These charges are prohibitively expensive for subsistence miners such as artisanal and small-scale miners (ASMs). At a 2019 mining forum in Kigali, the Chief Executive Officer of Rwanda Mines, Petroleum and Gas Board (RMB) demanded that "the cost of traceability and due diligence must be reduced to make it affordable and fair."[18]

The Traceability-as-a-Service (TaaS) provided Circulor has said that its system will change the business models of ASMs by shifting traceability costs from miners to end users.[20] Using Circulor's system, small mining companies do not see an increase in their workload. They may not know they are using blockchain. They use a mobile app, which is free for small companies and is easy to use.[8] Once the miners open the app, there are three buttons on the front page. A step-by-step process is presented by clicking "Start." The process begins with facial recognition. The next process involves the scanning of a tag. Then, the details of the material are entered.[8] Companies further up the supply chain need to pay and use more complicated interfaces. They register on the system. The final step of that registration is that the regulators approve it.

Some big exploration and mining companies are also switching to blockchain-based traceability solutions. For instance, Societe Miniere de Bisunzu (SMB) switched from ITSCI's system to Responsible Sourcing Group (RCS)'s Better Sourcing.[21] SMB complained that ITSCI's "higher and higher costs" as the main reason for switching. Another criticism that has been raised concerning ITSCi is that regional governments and officials were excluded from its data and operations.[22]

7.2.3 Efforts of civil society actors, development and multilateral organizations, and other powerful actors

Various civil society actors, development and multilateral organizations, and other powerful actors are taking a number of initiatives that are likely to intensify pressures on multinational companies (MNCs) to demonstrate transparency in their SCs using blockchain. NGOs are trying to promote CSR by naming and shaming companies knowingly and unknowingly responsible for human rights abuse and child abuse in the Democratic Republic of the Congo (DRC). In a 2016 article "Is my phone powered by child labour?"[25] Amnesty International forcefully argued that global cell-phone brands such as Apple and Samsung "won't tell us if their cobalt supply chains are tainted by child labor. They have a responsibility to do so—to check for and address child labor in their supply chains, setting an example for the rest of the industry to follow."

In October 2018, Amnesty International wrote to major carmakers—Daimler, Renault, Volkswagen, General Motors, Tesla, BMW, and Fiat Chrysler—that their supply chains potentially violate human rights. While all except Tesla were reported to respond, only three of them took essential first steps to address human rights abuse in their SCs. Renault identified its

cobalt suppliers. BMW and Daimler published details of smelters and refiners.[26]

Blockchain in mineral supply chains also have support of a powerful global actor such as the World Economic Forum. In October 2019, seven big mining companies—Antofagasta Minerals, Eurasian Resources Group Sàrl, Glencore, Klöckner & Co, Minsur SA, Tata Steel Limited, Anglo American/De Beers—joined the World Economic Forum's Mining and Metals Blockchain Initiative.[27] The companies plan to create a blockchain platform to store information such as the tracing of materials and carbon emissions. They also want to address issues related to the lack of standardization. The intention is to send out a signal of inclusivity and collaboration across the industry. The initiative is expected to expand to small operations.[28]

7.2.4 Increasing collaboration and coordination among key supply chain participants to develop blockchain solutions

Increasing collaboration and coordination among key SC participants have accelerated the adoption of blockchain. One prominent example is the Responsible Minerals Initiative (RMI), which was founded in 2008 by members of the Responsible Business Alliance and the Global e-Sustainability Initiative.[29] As of September 2020, RMI had more than 380 member companies from 10 industries (http://www.responsiblemineralsinitiative.org/).

In March 2020, the RMI released its Second Edition of the Blockchain Guidelines.[30] One of the goals of the RMI is to promote blockchain-enabled solutions' interoperability in mineral SCs. Among major initiatives in the push to increase interoperability have been the common adoption of definitions and concepts related to blockchain-enabled solutions, and consensus regarding the fundamental data attributes and an industry identification (ID) system for each stage of the SC. The RMI also aims to increase awareness of blockchain's applicability, its limitations, and impact on SC actors and local communities.[30]

In 2018, Google, which is a member of the RMI, teamed up with Cisco, SGS, Volkswagen, and Peruvian mining company Minsur to launch an end-to-end mineral traceability.[31] Phase one of the pilot focuses on tin from Minsur's San Rafael mine. The project formally started in 2019 and successfully tracked tin's end-to-end SC. The plan is to add new members.[32]

7.3 Major opportunities

Blockchain provides tremendous opportunities for companies, countries, communities, and consumers. In this section, we provide a brief overview of such opportunities offered by this technology.

7.3.1 Means to improve the welfare of disadvantaged groups

Disadvantaged groups are being exploited by dominant and powerful groups in global SCs. In order to illustrate this point, we consider the mineral and metal industry in some African countries such as the DRC and Sierra Leone. For instance, the value of the DRC's untapped mineral reserves is estimated at US$24 trillion. However, about three-quarters of the country's population live below the poverty line.[33]

DRC also has the world's largest artisanal mining workforce, which is estimated at about two million.[34] Of those, about 200,000 miners work in the DRC's copper and cobalt mining operations, who dig by hand.[35] About 150,000 of these workers are in Kolwezi, the capital city of Lualaba Province in the south. According to the UNICEF, about 40,000 boys and girls work in southern DRC's ASM industry, mostly in cobalt mines.[25] About 30% the DRC's cobalt in 2018 came from ASMs.

Likewise, the diamond industry still continues to be the lifeline for a large part of the population in some African countries. In Sierra Leone, the number of jobs generated by the diamond sector is estimated to be around one million, which is about 50% of the country's labor force.[36] The informal sector accounts for most of the jobs. In 2018, Sierra Leone's official poverty rate was 56.8%.[37]

Blockchain can be used to ensure better treatment to disadvantaged groups such as ensuring fair value of their work and reducing health hazards. When blockchain-led transparency forces downstream participants in mineral SCs to be more responsible, people working in the ASM sector may be entitled to the fair value of their work rather than the amount that exploitative multinational corporations offer. Blockchain, thus, provides an important opportunity for unlocking this potential and changes its abundance of minerals from curse to blessing (In Focus 7.3: Tracking diamonds and other precious metals using blockchain).

7.3.2 Enhancing efficiency and responsiveness of SCs

As discussed in previous chapters, blockchain, in combination with other technologies, has the potential to improve responsiveness and efficiency of SCs.

In Focus 7.3 Tracking diamonds and other precious metals using blockchain

The diamond industry and artisanal miners

The global diamond industry is about US$15—US$16 billion. 133 million carats (about 27 tonnes) of rough diamonds are sold every year. About half of this value originates in Africa.[38] ASMs accounts for 20% of global diamond production[39] and even higher proportions in some other jewelry industry products such as colored gemstones. Globally between 80% and 90% of colored gemstones are mined by ASMs.[40]

Since many of the ASM players are informal and unregulated, they lack access to established international markets and do not get fair value for their products.[39] The ASM sector has earned a bad reputation for producing the so-called "blood diamond." An increasing number of buyers are looking for evidence that production activities of their gems did not use child labor or did not finance civil wars or terrorist activity.[41] Consumer confidence for diamonds and other precious metals sold by ASMs has been low.

The Kimberley Process and its drawbacks

The Kimberley Process was launched in 2000 in a meeting of Southern African diamond-producing States, which took place in Kimberley, South Africa. The goal of the Process is to prevent the illicit diamond trade and to ensure that the diamond industry does not finance violence and weaken legitimate governments. In December 2000, the UN Assembly adopted a landmark resolution supporting the creation of an international certification scheme for rough diamonds.[42]

The Kimberley Process Certification Scheme (KPCS) has not been able to address concerns for producers, sellers, and buyers.[43] For instance, Sierra Leone is a signatory to the KPCS, which aims to prevent the use of diamonds funds to support conflicts.[36] However, the scheme has failed to stop diamond smuggling. One estimate suggested that the proportion of illegal diamonds was at least 50%.[44] In March 2020, the UN General Assembly emphasized the importance of strengthening the KPCS in order to make it more effective and to ensure its relevance in the future.

Blockchain platforms to track diamond and other precious metals

Blockchain can address some of the drawbacks and play a key role to increase consumer confidence in diamonds and other precious metals produced and manufactured by ASMs. Several blockchain systems have been launched to track diamonds and other precious metals. The blockchain platform Tracr was launched by De Beers in early 2018 to establish provenance, authenticity, and traceability in the diamond supply chain.[43] The platform was developed with Boston Consulting Group's Digital Ventures using the Ethereum blockchain.

Continued

In Focus 7.3 Tracking diamonds and other precious metals using blockchain—cont'd

As of early 2020, more than 30 participants including Signet Jewelers, which owns Kay, Zales, and Jared, Chow Tai Fook Jewelry Group, and diamond mining company Alrosa had started using Tracr.[43] Tens of thousands of precious stones are registered per month on the Tracr platform.[45]

Tracr started with tracking bigger diamonds. The initial test was conducted with 100 large diamonds. In mid-2018, the platform was used to track a rough stone of 2 carat and above.[46]

The plan was to track diamonds up to 1 carat in rough by the end 2019 and up to a half carat in rough by the first half of 2020.[47] In the early test, most of its SC activities were owned or controlled by De Beers, which made compliance relatively easy to achieve.[48]

Tracr aims to develop a "Global Diamond ID." Diamonds undergo 3D scans when they are mined, cut, polished, and sold.[45] Tracr assigns each diamond a unique ID. It uses scientific data involving 200 different characteristics such as weight, color, clarity, and photos to uniquely identify each diamond.[46]

De Beers has also launched a GemFair program to log diamonds produced by small-scale African miners. The program started with artisanal and small-scale diamond miners in Sierra Leone. In the first phase, De Beers trained ASMs in 16 mine sites in Sierra Leone. The training program focuses on digitally tracking diamonds throughout the supply chain. By April 2019, De Beers extended the pilot to 38 additional sites.[49] The goal is to make sure that diamonds tracked by the platform do not originate in conflict zones.

ASMs are required to identify and manage key risks defined in "OECD Due Diligence Guidance for Responsible Supply Chains from Conflict and High-Risk Areas" in order to participate in the GemFair program.[50] Among the major requirements is that ASMs need to "identify and address the worst forms of child labor in mineral supply chains." Compliance with the requirements is ensured through first-party (e.g., a member completes a Self-Assessment workbook provided by GemFair), second-party (GemFair's monitoring of mine sites biannually), and third-party (commissioning a third-party assessment of a sample of mine sites twice a year) verification.

Everledger and Richline Group have launched similar projects. Both use IBM's TrustChain platform built on the Hyperledger Fabric.[49] Everledger stores diamonds' unique identities that are derived from more than 40 attributes. They include the so-called 4Cs—carat, cut, clarity, and color—as well as information about provenance and price. All permissioned parties in the SC have access to data. It can help prevent double financing. Another benefit of blockchain-registered diamonds is that it is possible to recover if they are stolen goods by tracing their movement. An insurer could register a change in ownership if a diamond is reported stolen. Jewelers have access to that record if someone tries to resell it.[51] As of April 2019, the company recorded the origins of about 2.2 million diamonds on its blockchain[51] as a part of its operations tracking

In Focus 7.3 Tracking diamonds and other precious metals using blockchain—cont'd

high-value assets on a global digital ledger.[43] TrustChain has included Underwriter Labs (UL), as an independent third-party verifier. The idea is to increase the confidence of the TrustChain platform.[48]

How the systems work?

Tracr identified three major challenges that must be addressed for tracking diamonds in SCs: (a) determining the features to uniquely identify a piece of rough diamond; (b) determining the features to uniquely identify a piece of polished diamond; and (c) matching a polished piece with the rough piece it comes from. The last step is arguably the most challenging one. It was reported that Tracr successfully tracked 200 different diamonds in its pilot phase.[46] The company claims that it uses state-of-the-art artificial intelligence (AI) tools to observe a diamond to determine its SC journey (https://www.tracr.com/).

Each organization involved in the traceability can use a smartphone or other devices to sign into a blockchain platform. De Beers' program records global positioning system (GPS) locations for each diamond found. The diamond is then placed in a tamperproof bag, which is QR-coded.[38] GemFair provides a tablet for a participating mine site to log in the GemFair app. The app can function offline. However, the tablet must be connected to the internet for production records to be stored in the GemFair system.

After this step, the raw diamond or other precious metals move on to the supply chain's next stage.[48] For instance, De Beers tracks diamonds as they move from the mine to cutter and polisher, and then to jewelers.

Everledger also utilizes advanced technologies such as AI. Everledger gives unique cryptographic ID to each piece of diamond. The cognitive analytics systems utilize AI to cross-check data related to regulations, relevant records, supply chain, and Internet of things (IoT) to ensure that the gems from conflict regions do not enter the global supply chain.[52]

Everledger launched its Diamond Time-Lapse Protocol in 2017, which provides real-time data related to origin, cutting and polishing, artisans' work, and certification. The protocol has two user interfaces: Manufacturer & Retailer User Interface and Consumer User Interface. The Manufacturer & Retailer User Interface allows manufacturers to capture data as a piece of diamond moves through the manufacturing processes. Retailers can record relevant retail information, when the diamond reaches point of sale. The Consumer User Interface is a mobile application for iOS and Android operating systems. Customers can log in the system to view the complete provenance report of their purchased diamonds.[53]

Blockchain-based solutions can help provide instant answers to questions such as: Where is the current location of the shipment? When will it arrive to a destination? Were there any issues in the journey such as excess temperature, inappropriate humidity levels, custom delays, physical tampering, etc.? Which SC participant is responsible for the issue involved?.[54] For instance, stores know the details of arrival of a shipment, so they can be prepared to receive it.[55] In Food and Beverage Supply Chains (FBSCs), for instance, when it is confirmed that a load of apples would arrive at a juice factory, a code is generated and stored remotely. The code is available for verification at any time. Information about the apples and the factory that receive them is "chained" together by this code. Theoretically, the data can be portrayed as color-coded maps of inputs, conversion steps, and outputs from "farm to fork."[56]

7.3.3 Powerful marketing, branding, and communications tool

Blockchain is also emerging as a powerful marketing, branding, and communications tool. First, blockchain-based databases would make it possible for firms to communicate with authenticity and credibility. For instance, Provenance blockchain platform, which provides SC details through in-store QR codes or e-commerce product pages, is being utilized by many companies to connect with customers.[57] Seattle, the US-based start-up Fuchsia Shoes uses Provenance blockchain platform to share details about the workers in Pakistan who handmake its shoes. The information provided includes craftsmanship and working conditions in their workshops. Fuchsia's shoppers can learn about the tradition, people, and quality behind the product.[58] Six months after adding such information on its e-commerce website, its online conversions and engagement increased by 31% and 45%, respectively.

Provenance's clients also includes knitwear designer Martine Jarlgaard and London-based high-end vegan accessories brand Mashu. Martine Jarlgaard's smart labels provide all details about SCs back to the British Alpaca Fashion farm. Each step of the process—shearing at the Alpaca farm, spinning at Two Rivers Mill, knitting at Knitster LDN, and finally to the designer's studio in London—is tracked via the Provenance app.[59]

Martine Jarlgaard's blockchain pilot project was presented at the Copenhagen Fashion Summit held in May 2017. The featured item for the pilot project was Martine Jarlgaard Alpaca Mirror Jumper. When users scan the QR code or near field communication (NFC) label, they are

taken to the Provenance website (https://www.provenance.org/assets/0x7abc1d84e96aa8f5b50f5d86c6f73e95888db06c) where all relevant details are shown. A map shows the locations of all collaborators involved in making the piece. At the bottom of the website, under the question: "how can I verify this information?" it assures consumers by stating that "Provenance stores data on the blockchain." The website also gives the corresponding Ethereum address (ETH address). By clicking the address, users can visit the Etherscan[60] Website to find the relevant details. For the Alpaca Mirror Jumper, the address with all the details given on the Provenance website is: https://kovan.etherscan.io/address/0x7abc1d84e96aa8f5b50f5d86c6f73e95888db06c#internaltx.

The sustainable and vegan accessories label Mashu uses in-store QR tags to share details about its bags' Greek origins.[57] When shoppers scan a QR code, they are taken to provenance website (https://www.provenance.org/journeys/j5fUragZ?utm_source=blog), which explains the details about materials used in the bags and how they are handcrafted. The project was first implemented in the Spring of 2019 at luxury department store Harvey Nichols in London. The founder of Mashu, Ioanna Topouzoglou, reported that there was a positive response from both shoppers and the retailer. Mashu implemented the Provenance powered story on the company's online stores and also integrated it new campaign content.[61]

De Beers Group, which specializes in exploitation, mining, retail, and trading of diamond has claimed that it tracks a piece of diamond "each time they change hands starting from the moment they are dug from the ground."[62] It is argued that blockchain use gives De Beers a reputation advantage.[4]

Blockchain presents an opportunity for firms such as De Beers to demonstrate that their products are sustainable. In the food industry, blockchain is being used by some firms to enhance reputational value by demonstrating their ability to innovate and increasing consumers' perception of food safety.[63] For instance, Carrefour reported that blockchain's deployment to track meat, milk, and fruit from farms to stores led to increase in sales of these products.[64]

7.3.4 Consumer empowerment, confidence, and satisfaction with services

Consumers are increasingly concerned about the sources of their food, beverages, and other products.[65] There has also been an increasing consumer awareness and desire for products meeting sustainability standards.[66]

In a survey, 66% of respondents were willing to pay more for sustainably and ethically sourced products. The proportion was 73% for millennials.[67] Likewise, according to a survey conducted by Accenture among 6000 consumers in 11 countries in North America, Europe, and Asia, more than half of the respondents reported that they would pay more for sustainable products that are designed to be reused or recycled.[68]

There is a related trend that may have important implications for firms' sustainability-related practices. Consumers have become increasingly skeptical and critical of firms' sustainability practices. In a survey of 2264 UK internet users by market research Software-as-a-Service (SaaS) company GlobalWebIndex, 49% of the respondents believed that big brands' commitments on sustainability are false or insincere. A manager at GlobalWebIndex noted that while brands have made social and environmental pledges, these efforts have failed to translate into real consumer sentiment and increased loyalty. A possible explanation offered by GlobalWebIndex is that firms may not clearly communicate their CSR efforts. Consequently, 70% of online consumers surveyed by GlobalWebIndex reported that they "would or might stop" using a brand due to poor social or environmental performance.[69]

A related point is that consumption of such products is at a low level. In 2014, the UK retailer, Tesco, stocked only three Fairtrade wines. It suggested that the demand was not significant. This situation is somewhat paradoxical and counterintuitive. An explanation for such an anomalous behavior might be the lack of mechanisms to ensure sustainability-related performance of products.

There is, thus, a weak relationship between what consumers say and what they actually do in regard to the consumption of sustainable products. These can be attributed to consumers' lack of trust in value chain actors such as manufacturers of sustainable products and certifiers. There are problems related to the lack of effective communications between manufacturers and consumers. For instance, messages to consumers regarding the achievements of sustainability programs are unclear. Some of the major obstacles encompass the difficulties associated with measurement and documentation. Such problems are especially apparent in some eco-friendly aspects such as biodiversity benefits and improvement in soil tilth.[66]

Blockchain is being seen as a fundamental tool to empower consumers and enhance their confidence and satisfaction. Blockchain-based traceability systems allow consumers to verify product information themselves.[70] For instance, Everledger's Diamond Time-Lapse Protocol's Consumer User

Interface allows customers to log in the system to view the complete provenance report of the diamonds they purchase.[53]

As another example, Bureau Veritas, which provides testing, inspection, and certification services, has developed blockchain-based consumer facing food traceability system (http://www.origin.bureauveritas.com//). Relevant participants share records and validate transactions. Data are confidential. Different participants have different data access levels (https://www.foodqualitynews.com/Article/2018/03/12/Blockchain-news-from-Bureau-Veritas-DNV-GL-and-Ambrosus). By flashing a QR code in stores, shoppers can see a product's history in order to make informed purchase decisions.

Blockchain-based systems can provide access to rich and detailed information about products, which is likely to increase consumers' confidence. For instance, Bureau Veritas system's continual verification rather than samples provides highly reliable information about product's history. In this way, blockchain can also resolve ethical dilemmas consumers face in their decision to buy sustainable products.

7.4 Salient barriers

Despite the potentials noted above, however, blockchain has a number of major challenges to overcome. In this section, we explore some of the most salient barriers that deter firms from adopting blockchain or joining and engaging with blockchain-based SC systems initiated by other organizations.

7.4.1 The lack of institutional capacities

As mentioned above, blockchains can be viewed as a technology that governs information and exchange.[73] Note that a governance system is the "totality of institutional arrangements—including rules and rule-making agents—that regulate transactions inside and across the boundaries of an economic system".[74] A key point that needs to be emphasized is that blockchain systems are embedded in the broader political and economic systems, and they should not be viewed as a self-contained phenomenon with self-contained solutions. Blockchain's effectiveness in achieving effective SC governance, thus, depends on the nature of the power struggle between actors in the broader context of the political economy.

Global SCs operate in a complex environment that requires various parties to comply with diverse laws, regulations, and institutions. They include

maritime laws and regulations, commercial codes, laws pertaining *to* ownership and possession of multiple jurisdictions in the shipping routes. Since international businesses operate against the backdrop of these established old laws, customs, and institutions that are managed by human beings, implementing blockchain-based solutions can be an extremely complex task.[75] Addressing this challenge may be no small feat.

Especially political and institutional arrangements in many developing economies such as those in Africa are among the most salient barriers that prevent the deployment of blockchain in SCs. As Fig. 7.1 has shown, countries associated with conflict minerals are experiencing a high degree of corruption. In most parts of the DRC, for instance, the central government authority is virtually nonexistent.[76] The DRC's social hierarchy system is described as neopatrimonialism in which state resources are used by patrons to ensure the loyalty of clients in the general population.[77] The patron–client relationship, which is often informal, reaches from the state structures

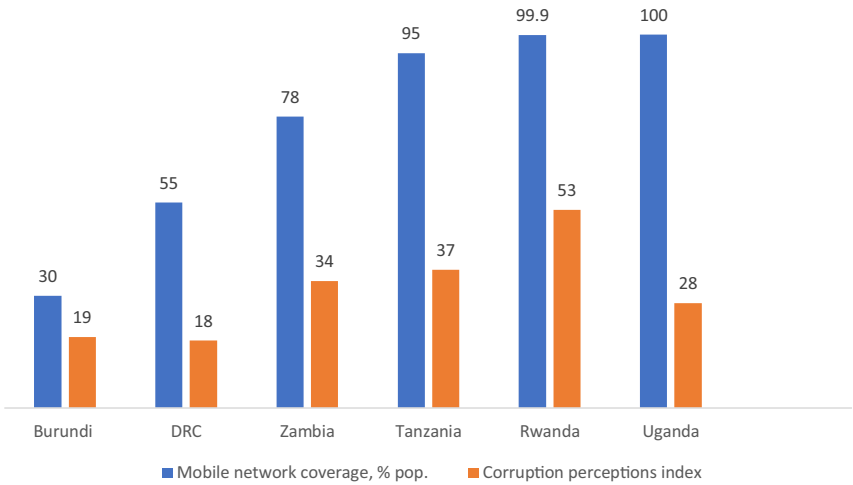

Figure 7.1 Mobile network coverage and corruption perceptions index in selected countries included in the Dodd–Frank Act. *(Data source: For Mobile network coverage, % of population (pop), DRC Siedek H.* Thoughts on DFS in "Europe minus infrastructure" – DRC*: MicroSave consulting; 2015. https://www.microsave.net/2015/07/29/thoughts-on-dfs-in-europe-minus-infrastructure-drc/. For other countries* Mobile network coverage, % pop*: World Bank Group; 2016. https://tcdata360.worldbank.org/indicators/entrp.mob.cov?country=BRA&indicator=3403&viz=line_chart&years=2012. Data are for 2015 for the DRC and 2016 for other countries. For Corruption Perceptions Index, Transparency International. Data are for 2019.)*

to small villages. The DRC is one of the most corrupt countries in Africa due to its economic resources, the lack of good governance and history of repression, and corruption during as well as after colonialism.[76] In 2019, the DRC ranked 168 out of the 180 countries in terms of the Corruption Perceptions Index. In the previous 12 months survey period, 85% of the country's people thought corruption increased and 80% public service users needed to pay a bribe (https://www.transparency.org/en/countries/democratic-republic-of-the-congo).

Since no one party has all data related to ownership and flow of products in an SC, blockchain systems provide incentives for SC participants to provide information, so that the provenance and state of products can be evaluated.[78] However, some parties may have incentives to provide false information related to product provenance. In some institutional settings, there is no or insufficient penalty for providing false and incorrect information.

7.4.2 Low degree of digitization

Most serious environmental, social, and governance (ESG) risks reside deeper down in the supply chain.[79] These include vulnerable smallholder farmers in developing economies that grow subsistence and cash crops and ASMs in Africa.

Due to the requirement of high degree of computerization, not all countries are ready to participate in blockchain-based solutions. Many supply chain partners located in developing and least developed countries (LDCs) often are far from ready to adopt blockchain because they face a significant challenge to digitize their SCs (Figs. 7.1 and 7.2). Without their participation, it is difficult to realize the full potential of blockchain in supply chain. For instance, as of 2015, mobile network coverage was estimated to reach 50%–60% of the DRC population.[71] Likewise, significant proportions of the population in other mineral-rich African countries such as Burundi and Zambia lack mobile network coverage. In general, as of 2019, more than 21% of the population in LDCs, which are low-income countries (Fig. 7.2) that perform poorly in human assets and face high economic vulnerability,[80] lacked mobile network coverage. Likewise, more than 25% of the population did not have a cellphone, and more than 80% lacked Internet access in 2019 in these economies (Fig. 7.2).

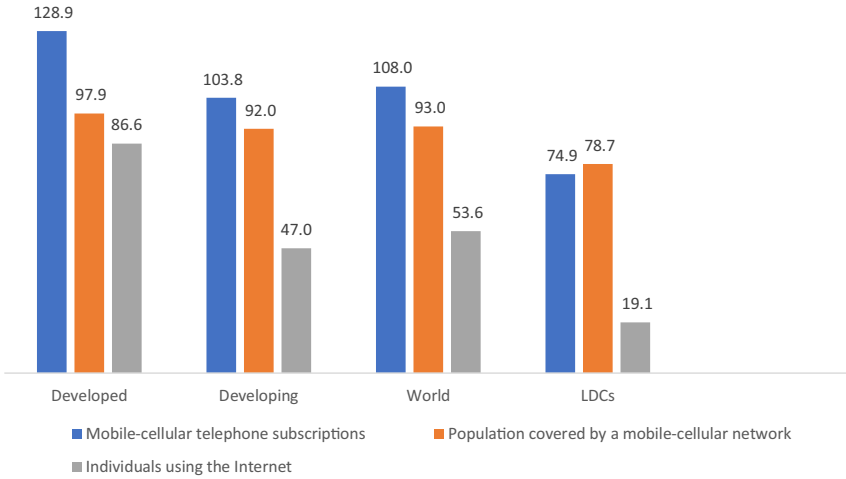

Figure 7.2 Digitization in economies with various levels of economic development. *(Source: International Telecommunications Union.)*

7.4.3 Lack of technological expertise and absorptive capacity

Although many companies describe themselves as "blockchain companies," few real use cases have emerged. For instance, among China's 262 public companies that self-categorized themselves as "blockchain companies," as of September 2020, only 23 had mentioned blockchain use cases that had gone live.[81]

The lack of capabilities such as technical knowledge and skills also affect the deployment of blockchain. For instance, as of 2018, there were about 20 million software developers in the world, but only 0.1% of them knew about blockchain codes. No more than 6000 coders were estimated to have the levels of skill and experience needed to develop high-quality blockchain solutions.[82] Out of India's 2 million software developers, only 5000 were estimated to have blockchain skills. Some speculate that about 80% of these developers may pursue job opportunities outside the country.[83] Other developing countries are in an even more unfavorable situation.

It is unreasonable to expect that blockchain solutions can be sent into rural Africa for ASMs to use them.[84] Even if such systems are set up with outside helps, small farmers and miners cannot perform technical tasks such as troubleshooting and maintenance.

7.4.4 The rank effect and barriers faced by small companies

Like other technologies, blockchain deployment tends to diffuse from larger to smaller organizations. This is commonly known as the rank effect.[85] Blockchain systems are expensive to implement and manage. Despite some smaller companies' access to blockchain-based solutions as noted above, due to cost and complexity, this technology is out of reach for many organizations. For instance, as of August 2020, the costs per month of using IBM enterprise blockchain platform, which is based on Hyperledger Fabric,[11] included membership fee of US$1000 and per peer fee of US$1,000.[86] This translates to an annual peer fee of US$12,000 for each additional member added to IBM enterprise blockchain platform.

7.4.5 Regulatory incompatibility and the lack of standardization

Past paperless trade processes mostly entailed digitizing existing forms and processes. Blockchain-led digitization is different in the sense that it enables new data structures. Blockchain data structures may also lead to regulatory incompatibility. That is, new forms of data in blockchains and DLTs may not satisfy regulatory requirements of some jurisdictions. The creation of standards for data structures is necessary for at least two reasons. First, from a technical perspective, different blockchain platforms may carry SC information, and, thus, interaction of data between different blockchains is critical. Second, looking from an information perspective, standards of data structure are needed to comply with different regulatory requirements.[87]

Standardization and interoperability have been a concern for the use of enterprise permissioned blockchains.[88] For instance, in supply chains, different suppliers use different blockchains that lack interoperability.[89] Likewise, in 2019, Euromoney reported that there were about 30 consortia that focused on using DLT in trade finance.[90] Each consortium consists of many different banks that use different platforms with slightly different offerings. After an organization joins a consortium, it is difficult to break the self-reinforcing mechanism associated with the consortium.[91]

7.4.6 Bringing all the relevant parties together

Another key challenge that arises in the implementation of blockchain consists of bringing all the relevant parties together, which can be a difficult undertaking in many cases. Everledger Founder and CEO Leanne Kemp

noted that it took about 18 months to negotiate the relationships needed to make the Everledger service possible.[92]

Especially downstream firms' lack of willingness to pay for SC visibility has been a concern in the mineral sector. For instance, most ASMs in the DRC sell to the SMB which is authorized to buy minerals found in Rubaya, which is the capital of the North Kivu province and has the largest coltan mining site in DRC. SMB then sells the minerals to the international market. In an April 2019 report, the consulting group focusing on African markets Sofala Partners estimated that SMB buys between US$3 million and US$5 million worth of coltan each month from about 3500 ASMs in Rubaya.[93] Citing data from the DRC's Ministry of Mines, news website Reuters reported that in 2018, SMB had supplied ore to two smelting Asian companies, which "are, or may be" in the SCs of Tesla, GM, Ford, and Apple according to their public filings.[93] US carmakers and technology companies have mostly exhibited indifferent attitude toward conflict minerals. Reuters reported that Tesla did not respond to requests for comment, and Apple declined to comment. GM and Ford referred to their filings with the US Securities and Exchange Commission (SEC).[93]

7.4.7 Stockholder centric bias in the actions of blockchain start-ups

There has been an increased pressure to meet stockholder expectations.[94] An upshot of this tendency is that philanthropic activities are declining. A technology start-up writer noted that "many of the highly publicized ICOs have yet to carry out much beyond upgrading the lifestyles of their founders and promoters".[95]

Many blockchain-based systems are designed to benefit big companies rather than disadvantaged groups. For instance, in the BanQu systems in India, Uganda, and Zambia to track cassava and barley discussed in Chapter 4, Anheuser-Busch can benefit tremendously from blockchain's use to promote SC transparency and traceability. Blockchain can help to guarantee the quality of products with relevant data. Making digital payments to farmers may lower the costs associated with payments. However, these big firms have done very little to ensure that farmers can genuinely benefit from the integration of blockchain in SCs.

For instance, smallholder farmers that supply crops to Anheuser-Busch may theoretically enjoy additional benefits (e.g., getting low-cost loans from financial institutions) using their identity and transaction information put on BanQu's blockchain. However, constraints related to information

flows, transaction costs, and market access would prevent them from realizing such benefits. For instance, the farmers may not be able to present the information in a way that meets the requirement of banks. They may also lack persons in their social network who possess capability to understand the various available loan services. Due to the lack of education, many potential borrowers cannot fill out loan applications.[96] Poor people often need loans in small amounts. It is costly for financial institutions to deal with small transactions. In some cases, poor people may face prejudice and stereotypes. Some banks refuse their admission to bank branch offices.[97]

7.5 Limitations of the technology

Various limitations of the technology need to be considered. In the case of mineral and mining industry, one broad observation shapes everything that follows: "Mining, at its most simple, is a process of digging up dirt, filtering it for minerals or ore, smelting and then refining to a product."[98] There are unique problems at every stage when minerals move along an SC. As noted in Chapter 3, it is pointed out that in some key applications, blockchain cannot address the "first mile" problem, which is arguably the most crucial step in assuring the ore's quality.[99] Some have raised the question of trust at this point because blockchain systems can be corrupted if the actors involved do not engage in trustworthy behaviors. For instance, the government agents who tag bags can collude with smugglers and enter incorrect data.[100] In the tantalum blockchain system used in Rwanda, participants that have been identified and trusted perform their allocated roles when the mineral passes through various stages of SCs. A key weakness of the system lies in the "the gate" when the ore is first registered to enter the ledger's "safe space." Facial recognition system provides a guarantee that the participants entering the data at this initial point are known and verified. However, this system by itself is far from enough to guarantee that the ore registered by the verified persons originated from legitimate sources. For instance, individuals from a mine controlled by armed groups may use illegal kickbacks and bribes to influence the persons registering the ore into colluding and entering false data. In this way, mutual illegal gains occur to both parties, and a batch of tantalum produced by an armed group could be tagged as a legitimate ore by the verified participants. Thus, the recording of facial scanning or GPS cannot guarantee the source from which the authenticated seller got the tantalum.[99]

Different types of problems are faced when the minerals move along the SC.

A main challenge is that during smelting and refining ores from multiple sources are often mixed and amalgamated into single batches of metal. This cannot be addressed by current blockchain-based solutions.[98] Global risk analysis firm Verisk Maplecroft's vice president Gus MacFarlane put the issue this way: "The fact that a whole batch of metal could be made up of multiple ore sources (some traceable and some not) and could be 'contaminated' by ore from any single source linked to human rights abuses, potentially presents its own challenges in terms of maintaining the unbroken integrity of the blockchain process."

Another key challenge lies in mapping minerals and metals in one state of an SC to the successive stages. For instance, Tracr reported that matching a polished piece with the rough piece it comes from is among the most challenging tasks.[46] The efforts of mapping and matching materials in successive stages face a challenge of another magnitude for metals and minerals such as cobalt, zinc, gold, copper, and silver which need to undergo physical and chemical transformations by utilizing thermal treatment in the pyrometallurgy process and applying aqueous solutions in the hydrometallurgy process.

Another limitation is that blockchain solutions often cannot protect an SC against attacks such as physical tampering and modification. For this reason, some critics say that blockchain can be easily gamed. Manual entries may lead to human error or intentional manipulation. For instance, products in the FBSCs can be easily adulterated, and it may not be possible to know who did, when, and how.[101] Bloomberg columnist Matt Levine notes: "… if you then drill a hole in the container, take out all the teddy bears, and replace them with cocaine, the blockchain won't catch that. The blockchain is about taming all of the virtual attributes of the container, all of the paperwork that accompanies it. But the boundary between the physical and virtual worlds will always be a bit more lawless."[102]

Finally, some technologists who like completely decentralized networks such as Bitcoin think that the newer, corporate-designed blockchains lack one of the main elements that made bitcoin a success: the decentralized structure. For instance, anyone in the world is able to join bitcoin and study the ledgers. On the other hand, only a limited set of participants can have access to a blockchain system like that of IBM. This feature can make such system more vulnerable to attack. For instance, a hacker can target a few of

the participants. Despite a higher degree of decentralization of IBM's blockchain-based technology for tracking shipments compared to previous methods, it arguably "concentrates power in a handful of entities."[103]

7.6 Chapter summary and conclusion

The above discussion suggests that, while far from perfect, blockchain systems allow for the development of traceability systems that provides fairly accurate information regarding the production process and activities of SC participants. In the past, the lack of the availability of quick and easy-to-develop, easy-to-use, and specific solutions hindered the use of blockchain in SCM. To some extent, such barriers can be addressed by deploying blockchain solutions in SCM.

Blockchain traceability systems have many benefits vis-a`-vis established nonblockchain systems. For instance, some critics of blockchain solutions go as far as to say that blockchain systems have made no progress over existing bag-and-tag traceability systems. Despite the blockchain system's failure to address trust-related issues at the "first mile," blockchain's features such as decentralization and transparency would provide obvious benefits to various actors involved in the mineral SCs compared to ITSCI's cloud-based system. Compared to established traceability programs such as ITSCI's: "bagging and tagging" system, new blockchain-based business models also favor ASMs, which can join the network for free.

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CHAPTER 8

Policy, legal, and ethical implications

8.1 Introduction

The use of blockchain in supply chain management (SCM) has broad policy, legal, and ethical implications. Legislative and regulatory considerations affect whether, to what extent, and how blockchain solutions are used in SCs. For instance, China's "Regulations on the Management of Blockchain Information Services," which became effective on February 15, 2019,[1] requires blockchain users to provide real names as well as national ID card numbers, mobile phones, or company registration to use blockchain services. User anonymity is, thus, not allowed, which may discourage some individuals to use blockchain solutions in SCs.[2]

Due to the global nature of modern SCs, poor law enforcement and lawlessness in some jurisdictions can make the implementation process of blockchain projects more difficult. In such cases, ensuring the accuracy and reliability of data entered in a blockchain ledger is a challenging task. For instance, there are several blockchain systems to track mineral SCs in the Democratic Republic of the Congo (DRC). An April 2019 report by the Belgium-based International Peace Information Service (IPIS) and the Danish Institute for International Studies documented that of the 711 mine sites they visited during 2016–18, the DRC's military or armed militias had interfered at 28% of the sites. Among the mines that faced interference, 20 were being monitored by the ITSCI.[3] As noted in Chapter 7, a key weakness of the blockchain system in mineral SCs lies in the "first mile" or "the gate," where there is the possibility of accepting bribes and entering false information by the verified persons.[4] The possibility of engaging in such behavior is high in economies that are characterized by a weak law enforcement record.

Various legislative developments have occurred in industrialized countries to tackle ethical trade issues such as modern slavery and child labor

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practices, which are likely to increase the attractiveness of blockchain. Some entities of governance such as the European Union (EU) have recommended that the use of technology such as blockchain be explored to enhance SC visibility in these countries.[5]

Other considerations that are particularly relevant include how existing laws, such as the General Data Protection Regulation (GDPR) affect the implementation of blockchain in SCs. For instance, due to privacy concerns of personal data, the recommendation of the French data protection watchdog commission nationale de l'informatique et des libertés (CNIL) has been against the use of permissionless blockchain.

Modern slavery's challenges to SCM have been widely acknowledged and recognized.[6] Many international SCs are knowingly and unknowingly connected to the global slave labor market. Various sections of the civil society such as nongovernmental organizations (NGOs) and regulators are taking important initiatives to change this situation in international supply chains with new legislations and enforcement and other measures to increase reputational risks of companies.[7] Blockchain is probably the technology with the most potential to stop such products from entering into the SCs.

Disagreements have also been expressed concerning the roles of blockchain in promoting ethical behaviors in SCs. The proponents of this technology have claimed that blockchain helps firms comply with ethical and regulatory requirements and that blockchain-based traceability initiatives are more effective than other major nonblockchain traceability programs such as ITSCI and Better Sourcing Program.[8] In this way, this technology arguably can address various Environmental, Social, and Governance (ESG) concerns. Note that ESG issues deal with standards related to a company's operations that are being increasingly used by investors to screen their potential investments. Its three components include: Environmental (a company's performance in protecting natural environment), Social (relationships with diverse stakeholders such as employees, suppliers, customers, and the communities), and Governance (leadership, audits, executive pay, internal controls, and rights of shareholders).

The critics on the other hand argue that many firms have become a part of blockchain traceability initiatives to give the false impression that they are genuinely interested in addressing issues such as child labor.[9] The idea here is that the envisioned impacts of blockchain are based on the assumption that the original record is reliable.[10] However, when some SC actors find incentives to behave in unethical and illegal ways, records entered in blockchain ledgers are not necessarily correct.

In light of the above, this chapter provides an account of legal, regulatory, governance, and law enforcement issues associated with blockchain deployment in SCs. It highlights international heterogeneity in regulatory regimes that might pose challenges in the implementation of blockchain in global SC networks. It also provides a critical evaluation of various ethical issues associated with blockchain deployment in global SCs.

8.2 Regulatory and law enforcement issues

Blockchain use in SC should be viewed in the backdrop of the regulatory and law enforcement systems. As noted in Chapter 7, most serious ESG risks can be found deeper down in the supply chains involving agriculture, mineral, and metal industries in developing economies. Regulatory and law enforcement issues in these economies, thus, deserve special attention.

A 2015 study of experts in the United Nations (UN) found that 20%–40% of all minerals extracted in Rubaya are smuggled to Rwanda. Buyers in Rwanda are reported to pay about 20% more than what SMB pays. Counterfeit paper tags with bar codes are then attached to the smuggled minerals which resemble the tags required to track them from the mine to the smelter. DRC miners also smuggled to other bordering countries such as Uganda and Burundi.[11] The UN experts found smuggling of minerals is facilitated by the army, the National Intelligence Agency, the Mining Police, the Mining Division, and the Service for Assistance and Support to Small-Scale Mining (or Service d'Assistance et d'Encadrement d'Artisanal et Small-Scale Mining (SAESSCAM)).[11]

There are allegations that personnel of the SAESSCAM, which was created to issue and maintain a registry and provide technical services to the artisanal and small-scale mining (ASM) sector, demand extralegal payments from the artisanal miners.[12] The NGO Global Witness, which focuses on natural resource exploitation, conflict, poverty, corruption, and human rights abuses, found that armed group in the DRC unlawfully tax workers in collaboration with the SAESSCAM officials.[13]

8.3 Legislative developments increasing the attractiveness of blockchain

For many decades, powerful multinationals committed serious human rights abuses such as child labor and forced labor with impunity because they can jurisdictionally shield due to cross-border nature of supply chains. Abuses mostly take place in jurisdictions that have weak legislation and even weaker enforcement.

From the 2010s, regulators in Western countries have started responding to serious human rights violations by their companies even if such violations take place in outside their jurisdictions. Most of these regulations are directed at the exploitation of labor for private profit and environmental pollution. Table 8.1 presents some examples of regulations put in place to enhance SC traceability and encourage better environmental and human rights practices.

Table 8.1 Some regulations aimed at improving supply chain (SC) traceability and encouraging better environmental and human rights practices.

Jurisdiction	Regulation	Explanation
The US	Dodd–Frank wall street reform and Consumer Protection Act	It requires US companies to vet their SCs. Countries that are covered under this legislation includeSouth Sudan, Uganda, Rwanda, Burundi, Tanzania, Malawi, Zambia, Angola, Congo, Central African Republic, and Democratic Republic of Congo.
The UK	The Modern Slavery Act 2015	It aims to fight modern slavery. Requires organizations conducting business in the United Kingdom with worldwide revenues of at least £36 million to publish a transparency statement explaining the steps taken in the previous financial year to ensure that their business and SCs are free from modern slavery and human trafficking.
The EU	Conflict Minerals regulation	From January 1, 2021, importers of tin, tantalum, tungsten, and gold will be required to carry out due diligence on their SCs.
The Netherlands	The 2019 Child Labor Due Diligence Law	It requires companies selling goods and services to Dutch end users to perform due diligence to determine whether child labor occurs in their SCs.[14]
France	The 2017 Duty of Vigilance law	It imposes a mandatory due diligence requirement for human rights and environmental impacts

Table 8.1 Some regulations aimed at improving supply chain (SC) traceability and encouraging better environmental and human rights practices.—cont'd

Jurisdiction	Regulation	Explanation
		on large French companies (with 5000 employees in France, or 10,000 worldwide). The law is also applicable to French companies' subsidiaries, subcontractors, and business enterprises in the SCs.
Australia	Modern Slavery Act 2018	It requires businesses with revenue of more than A$100 million to report on the risks of modern slavery in their SCs annually. The report should also include the action they have taken to assess the risks and address them as well as the effectiveness of their response.[15]

The Dodd–Frank Wall Street Reform and Consumer Protection Act requires US companies to vet their SCs. Countries that are covered under this legislation include South Sudan, Uganda, Rwanda, Burundi, Tanzania, Malawi, Zambia, Angola, Congo, Central African Republic, and DRC.[16] Section 1502 of the Act requires mining companies to disclose if they source conflict minerals: tin, tungsten, tantalum and gold—from DRC and nine neighboring countries.[17]

The EU Conflict Minerals Regulation (EU Regulation No. 2017/821) was adopted in May 2017 by the EU Parliament and EU Council.[18] The new law is expected to come into force in the EU in 2021. From January 1, 2021, importers of tin, tantalum, tungsten, and gold (3TG) in the EU will be required to carry out due diligence on their SCs. That is, they need to check the sources of the minerals and metals they import and ensure that they were processed responsibly.[19]

This import regulation covers the so-called 3TG minerals. Companies importing these minerals will be impacted by the regulation. The regulation is expected to affect the activities of more than 1000 importers directly and tens of thousands of economic actors indirectly.[20] For instance, smelters, refiners, original equipment manufacturers (OEMs), component manufacturers, and other businesses that use 3TG to manufacture products are required to source 3TG responsibly.[21]

In order to monitor firms' compliance with the EU Conflict Minerals Regulation, each member state will establish a supervising authority. The roles of the authorities will be to examine documents, audit reports, and perform inspections of premises. In case of noncompliance, the national level supervising authority will issue an order to take actions to comply with the regulation within a set time period.[22] The EU's 2020 report "Study on due diligence requirements through the supply chain" has recommended that the use of technology such as blockchain be explored to enhance SC visibility and reduction of SC complexity.[5]

As of early 2020, in the EU economies, the 2017 French Duty of Vigilance Law was the only legislation that imposed a mandatory due diligence requirement for human rights and negative environmental impacts. However, until that time, there were no court judgments that illustrated how this law would be interpreted and applied.[5]

The Modern Slavery Act 2015 in the United Kingdom aims to fight modern slavery in the United Kingdom.[21] This law requires organizations conducting business in the United Kingdom with worldwide revenues of at least £36 million (US$47.5 million) to publish a transparency statement explaining the steps taken in the previous financial year to ensure that their business and SCs are free from modern slavery and human trafficking. There is no need for organizations to take substantive measures to combat modern slavery. Nonetheless, regulators hope that the reporting obligation is used by businesses to introduce substantial measures because it is "the right thing to do."[23]

The nonprofit organization Business & Human Rights Resource Centre has created a register of published transparency statements (https://www.modernslaveryregistry.org/). This would allow consumers, investors, and campaigners to monitor and compare different businesses' measures.

Other new legislations are on the horizon which can increase the importance of blockchain-based traceability. For instance, in July 2020, the European Commission (EC) launched public consultations on taxation rules to meet the EU's climate goals.[24] The public consultation document intended to revise the internal Energy Tax Directive by introducing a carbon border adjustment mechanism. The idea is to reduce carbon leakage risks and discourage companies from shifting their production activities to countries that have less stringent green regulations and poor enforcement mechanisms.[25]

Likewise, starting 2025, the London Metal Exchange (LME) plans to ban metals from its lists of approved brands if the extraction involves child

labor and other abuses. In its initial plan announced in April 2019, the exchange had set 2022 as the deadline to comply with the guidelines. The deadline needed to be postponed because some major producers reportedly complained about the difficulties in meeting the requirements.[26]

8.4 International heterogeneity in regulatory regimes

On the regulatory front, a wave of new regulations in various jurisdictions has increased the importance of deploying blockchain in SCs. However, most of them such as the US and the EU regulations have no financial or criminal penalties for noncompliance. They are more likely to be seen as "name and shame schemes." Nonetheless by making disclosure mandatory, consumers may put pressure on companies. The idea is that these regulations are a "foot in the door" and likely to strengthen over time due to pressure from activist, civil society groups, and consumers.[27]

It is important to note that the EU Regulation fills some of the gaps that the Dodd–Frank Wall Street Reform and Consumer Protection Act did not cover. For instance, whereas the Dodd–Frank Act covers the DRC and some neighboring countries, the EU regulation covers imports and upstream actors and expands geographical scope to include any "high-risk, conflict-affected area" in the world.[27]

While many Western countries are enacting regulations that require their companies to disclose their efforts to fight these abuses, these laws lack "teeth," since there are no clear sanctions or penalties. It is argued that companies do not practice what they preach. Industry organizations have been lobbying to avoid hard laws. Some view that Western democracies are mostly to be blamed for this failure to address the governance gap in regulating cross-border supply chains.[28]

There is little reason to believe that these laws serve as a deterrent to unethical practices in SCs. Recently, however, a second wave of legislation has been pushed through to address unethical issues in SCs. By enacting the corporate duty of vigilance law in 2017, France became the first country that has made it mandatory for companies to go beyond identifying supply chain abuses. If companies fail to adequately address the issue, they can face sanctions (Table 8.1). Pressures for antislavery-related hard laws are building in other jurisdictions as well. As of August 2020, at least 13 other European countries including Germany, Netherlands, Switzerland, and Norway had pending proposals or campaigns to introduce hard laws to address human rights abuses in SCs.

Of special concern is China's lack of legislative commitment to responsible sourcing. Regarding the LME's plans to ban trading of metals involving child labor and other abuses, Chinese firms' support is especially important since China is the world's largest consumer of industrial metals (See In Focus 8.1: China's dominance in the global cobalt supply chain and indifferent attitude toward human rights abuses). However, what is referred to as the "China barrier" has been a major concern in the implementation of responsible sourcing initiatives in the global metal and mineral industry.[26] Whereas industrialized countries in North America, Western Europe, Oceania, and other parts are strengthening regulatory and enforcement mechanisms to address the issues related to conflict minerals, China lacks such measures. Citing industry sources, news website Reuters stated that absence of legislation and the lack of experience in sourcing conflict-free minerals have been major hindrances to China's engagement in the process.[26] For instance, in China, there are no regulations equivalent to the Dodd–Frank Wall Street Reform and Consumer Protection Act of the United States or the Modern Slavery Act 2015 of the United Kingdom.

8.5 Existing laws and implementation of blockchain

The implementation of blockchain in SCs needs to take into account various regulations. For instance, companies in the electronics supply chain share a significant amount of data. A distributor that sells components to a customer may share the customer's information with component suppliers. In many SCs, the customer could be a business. In the electronics design chain, however, it is a common practice for engineers to buy small volumes of components with a personal credit card. Some inventors also buy electronics components.[41] All these mean that personal data are involved in these transactions. However, different legislations may treat the issue of personal data differently.

8.5.1 The EU's general data protection regulation and blockchain

While the GDPR was enacted to apply to any technology, there has been quite a lot of confusion as to how solutions based on this technology can be designed to comply with the GDPR. Blockchain solutions' developers are currently operating in an uncertain regulatory environment.

The European Parliament's resolution on distributed ledger technologies and blockchain (the "Blockchain Resolution") passed in October 2018 affirmed that blockchain applications pseudonymize users but cannot

In Focus 8.1 China's dominance in the global cobalt supply chain and indifferent attitude toward human rights abuses

Currently, China dominates the world in the electric vehicles (EV) market as well as EV battery manufacturing. Around 73% of global EV batteries are supplied by China.[29] China is also the world's biggest EV market. In 2018, China accounted for 60% of the 2.1 million EVs sold worldwide. According to Paris-based autonomous intergovernmental organization International Energy Agency (IEA), by 2030, EV sales are expected to reach between 23 million and 43 million annually. The IEA's estimate also suggested that in 2030, EVs will account for as much as 57% of vehicle sales in China, 26% in Europe, and 8% in the United States.[30]

By 2028, Contemporary Amperex Technology Co. Limited (CATL) will have enough capacity to supply 4.2 million EVs annually, which is more than other major competitors such as South Korea's LG Chem Ltd. and Samsung SDI Co. and Japan's Panasonic.[30]

China's dominance in the global EV batteries market is associated with and facilitated by its control over the global cobalt supply chain. China's cobalt mining within the country accounted for 1% of the world's total output in 2017. However, of the 14 largest cobalt miners in the Democratic Republic of the Congo (DRC), eight are owned by Chinese companies, which account for about half of the country's output.[31] China's cobalt refineries, which receive cobalt mostly from Chinese owned mines, control the downstream cobalt SCs. China's share in the global production increases as cobalt materials move downstream along the SC. In 2016, China's share was 14% in mine, 33% in intermediate, and 55% in refined cobalt[32] (Fig. 8.1). Note that intermediate production involves the pyrometallurgical[33] or hydrometallurgical[34] processing of concentrates in order to produce cobalt mattes[35] from crude compounds that still need to be purified to obtain cobalt and cobalt-copper-iron alloys.[36] In the refining stage, cobalt is separated from other metals that are present. The end products of this stage could be cobalt metal, cobalt metal powders, oxides of cobalt, and other simple chemical compounds.[37]

Chinese firms' shares are even higher in more downstream activities. China's dominance is especially strongly pronounced in the production of cobalt chemicals needed to make batteries.[38] For instance, according to data from the UK-based cobalt trading firm Darton Commodities, Chinese firms supply 80% of the world's battery-ready high-grade cobalt chemicals needed to make batteries.[39]

The Chinese government is less concerned about human rights violation in cobalt mines in the DRC.[40] This factor, together with China's dominance in the cobalt SC, has made it difficult to implement blockchain-based traceability in an effective way.

Continued

In Focus 8.1 China's dominance in the global cobalt supply chain and indifferent attitude toward human rights abuses—cont'd

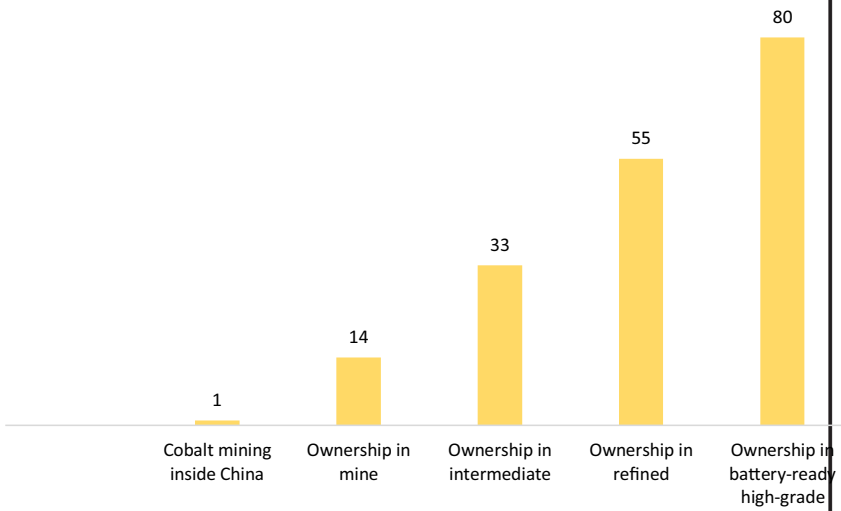

Figure 8.1 China's control in the cobalt value chain (% of the global total).

anonymize them. Note that anonymization makes it impossible to connect the data to a natural person. Pseudonymization, on the other hand, makes it possible to de-identify the data, and with additional information, the data can be connected to a natural person. The fact that data on blockchain are only pseudonymized, but not anonymized, makes data stored in blockchain's ledgers subject to the GDPR.

The GDPR assumes that there is a data controller. Data subjects enforce their data protection rights against the controller. Blockchain's decentralization feature means that there is no single center of control. There has been a lack of regulatory guidance as to how the data controller is determined in a blockchain network.[42] When personal data are abused, it is difficult to determine who should be legally accountable.[43]

Blockchain's immutability feature is also of concern. When a block is added, it is extremely difficult or even impossible to delete or modify data in the block. The difficulties of deleting blockchain data violates data minimization and purpose limitation provisions of the GDPR. The idea here is that personal data should not be held longer than needed to achieve the purpose for which the data are collected. This is clearly stated before the

data are collected. Furthermore, data must be collected for "specified, explicit, and legitimate purposes and not further processed in a manner that is incompatible with those purposes" (https://gdpr-info.eu/art-5-gdpr/).

Blockchain's functioning is also incompatible with the "right to be forgotten" provision. This provision allows data subject to request the deletion of personal data or limits the duration for which it can be stored.

The recommendation of the French data protection watchdog CNIL has been against the use of permissionless blockchain. Avoiding such blockchain networks, parties can come to a careful agreement regarding various members' data responsibilities. The CNIL has also suggested developers to look for "other solutions" if possible until the agency provides legal clarification.

8.6 New laws related to blockchain and cryptocurrencies

Policymakers also need to rethink regulatory frameworks and incentives in order to maximize the benefits of blockchain. For instance, executing a blockchain-based smart contract is extremely challenging and time-consuming without cryptocurrencies. While many private blockchain solutions have been designed for international SCs, their benefits are limited due to problems encountered in settling international transactions and challenges arising from foreign exchange rate considerations. Cryptocurrencies play a key role in such cases, which help to conduct cross-border transactions near real time.[44] However, cryptocurrencies have been banned in many countries. As of 2019, trading bitcoin and other cryptocurrencies was a jailable offense in at least three countries: Bangladesh, Nepal, and North Macedonia.[45]

8.6.1 China's "Regulations on the Management of Blockchain Information Services"

The "Regulations on the Management of Blockchain Information Services" became effective on February 15, 2019.[1] The regulation requires users to provide real names as well as national ID card numbers, mobile phones, or company registration to use blockchain services. User anonymity is, thus, not allowed. Blockchain services are required to remove "illegal information" quickly in order to stop it from spreading among users. Providers of blockchain services are also required to retain backups of user data for 6 months. Moreover, law enforcement must be able to get access to data whenever it is necessary.[2] Blockchain service providers are required to keep relevant records of transactions and report to authorities in case of illegal use. They are also obliged to prevent the production,

duplication, publication, and dissemination of contents that are banned by Chinese laws. In April 2019, the cyberspace administration of China (CAC) released the first list of 197 companies that were approved to conduct business with blockchain.[46]

8.7 ESG issues and blockchain implementation in supply chains

We start this section with some observations concerning how the Internet was viewed in terms of its effect on ethical issues versus how it actually performed. When the Internet was new, there was a big hope that it would promote corporate transparency. Some analysts predicted that the Internet would make it impossible for corporations to hide anything.[47] However, soon it turned out to be a naïve view. Prior researchers noted that business-to-business (B2B) online reverse auctions (ORAs) technologies, which were a popular tool for large buying firms in the early days of e-commerce, facilitated many unethical practices. Consequently, the e-commerce sector experienced more ethical concerns compared to most other economic activities.[48,49] analysis indicated that most unethical behaviors in ORAs were associated with the buyers. Some examples of unethical behaviors included ambiguous auction rules that change over time, changing terms between request for quote (RFQ), and actually awarding the contract, ghost bidding, and providing limited, false, or misrepresented information, to bidders[49,50].

It is fair to say that from ethical considerations in blockchain today is viewed in the same way as the Internet in its early days. Blockchain has been touted as a technology that can address various ethical issues. It is argued that this technology can force firms to innovate their business models to demonstrate that their actions have not harmed the environment and human dignity has not been compromised by their activities. Some critics, however, wonder whether blockchain is overrated as a means of resolving ethical problems in SCs.

8.7.1 Blockchain to fight modern slavery

8.7.1.1 The current situation

According to studies conducted by International Labor Organization (ILO), the Walk Free Foundation and the International Organization for Migration, in 2016, 40.3 million people were estimated to be living in modern slavery, and 70% of them were women and girls. This means that

they were forced to work under threat against their will or were living in a forced marriage.[51] A large number of products that the populations in this unfortunate situation were forced to produce are exported to rich countries. In 2018, G20 countries imported $354 billion worth of products that were at risk of being produced by forced labor (Fig. 8.2). This is an extremely sad situation because Western brands have made voluntary efforts for about 3 decades to address issues related to forced labor, bondage, sweatshops, and other abuses in their SCs.[28]

Some industries in developing countries exporting products to industrialized countries have also made widespread use of child labor. According to the ILO, in 2016, 152 million children in the world between the ages of 5 and 17 became victims of child labor.[52] Most of them work in farming. But, a large number of children are employed in the services and industrial sectors such as mines. The ILO and the United Nations Children's Fund (UNICEF) have warned that victims of child labor could increase due to the COVID-19 crisis-led surge in poverty.

The marine fishing industry exhibits a high propensity to use "slave" or underpaid labor due to its huge size and the lack of clear regulations and

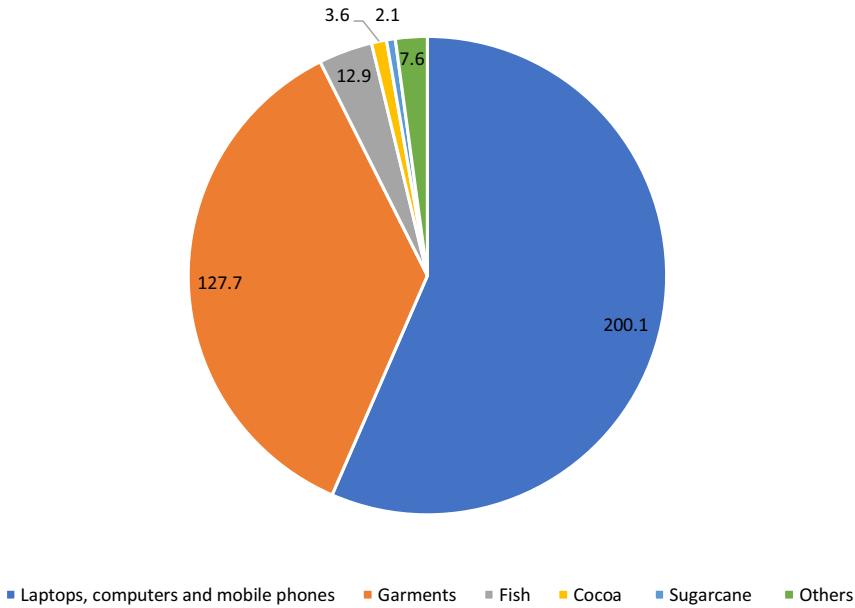

Figure 8.2 Products imported by G20 countries that were at risk of being produced by forced labor (US$ billion, 2018). *(Data Source: https://www.globalslaveryindex.org/2018/findings/highlights/.)*

enforcement mechanisms (Fig. 8.2). There is also the exploitation of migrant workers in this industry. For instance, in 2014, 82% of 172,430 fishermen employed by the Thai fishing industry were migrant workers, mainly from Cambodia and Myanmar. Most of the workers in seafood processing plants are also migrants. They often fall prey to recruiters promising well-paying jobs in Thailand. However, they are paid about 25% lower than the Thai minimum wage. The migrant workers, so the argument goes, often sign a contract in their home country, but their contracts change when they arrive in a foreign country to begin work.[53] Unlike Thai workers, they cannot join unions and do not have other protections that Thai workers are entitled to.[54]

In traditional mineral and commodities such as the gold industry, for instance, small operations, also referred to as artisanal miners, produce significant amounts of mineral and metals most of which are not officially recorded. For instance, ASMs produce about a quarter of the world's gold supply. The artisanal mining sector is characterized by spotty or nonexistent regulatory oversight. Working conditions in this sector are dangerous.[55]

Some nonprofit organizations are helping the victims of modern slavery (See In Focus 8.2: Apple, Alphabet, Dell, Microsoft, and Tesla face a class action lawsuit). These efforts are likely to spotlight the problem of this social evil and force companies to enhance their ESG practices to lessen the problem.

In Focus 8.2 Apple, Alphabet, Dell, Microsoft, and Tesla face a class action lawsuit

The lack of SC visibility can lead to legal liability. To take an example, in December 2019, the human rights firm International Rights Advocates filed a class action lawsuit in Washington DC on behalf of 14 parents and children from the DRC in which Apple, Alphabet, Dell, Microsoft, and Tesla have been named as defendants. Some of the plaintiffs were as young as six. They were trafficked to work in the mining sites. Ten of the plaintiffs had been severely wounded or maimed. "John Doe 3," who worked at a mine operated by a subsidiary of a Chinese mining company, had lost his leg.[56] The lawsuit accused that deaths and serious injuries of several children who claimed that they worked in cobalt mines were aided and abetted by the defendant companies, that are "knowingly benefiting from … brutal use of young children in Democratic Republic of Congo" (http://www.iradvocates.org/sites/iradvocates.org/files/stamped%20-Complaint.pdf). A by-product of copper and nickel mining, cobalt is used to power the rechargeable lithium batteries used in products of these companies such as smartphones, laptops, and electric vehicles. The

In Focus 8.2 Apple, Alphabet, Dell, Microsoft, and Tesla face a class action lawsuit—cont'd

plaintiffs contended that the cobalt mines that employed the children were at the bottom of the defendant companies' SCs, and, hence, it is their responsibility to pay the damages for forced labor.[57] The families and injured children were also seeking additional compensation for "unjust enrichment, negligent supervision, and intentional infliction of emotional distress."[57]

The SCs of the defendant companies lack visibility. The plaintiffs argued that their children illegally worked at mines that were owned by the Swiss mining and commodity trading company Glencore. The cobalt from the Glencore-owned mines was then sold to Belgian metal and mining trader Umicore. An economist, who investigated child labor practices in the DRC cobalt mining sites, argued that Glencore relies on "penny-wage artisanal cobalt mining to boost their production at minimal expense."[56] Umicore sold battery-grade cobalt to the defendant companies.[57]

Other families claimed that their children worked at mines owned by Chinese cobalt firm Zhejiang Huayou Cobalt. Zhejiang Huayou Cobalt allegedly supplies cobalt to Apple, Dell, and Microsoft and possibly to the other defendants as well. The court documents describe that the children were paid $2 a day for dangerous work that required using primitive tools to dig for cobalt rocks in dark, underground tunnels. None of the children that were plaintiffs in the complaint were able to attend schools.[56] The court documents described one child, referred to as John Doe 1, who started working in the mines at the age of nine. In early 2019, he fell into a tunnel when he was carrying heavy bags of cobalt rocks for Kamoto Copper Company. He was paid $0.75 a day. His fellow workers were able to drag him out of the tunnel, but he was left alone at the mining site until his parents arrived. The lawsuit claimed that John Doe 1 was paralyzed from the chest down and will not be able to walk again.

All the defendants in the lawsuit prohibit child labor use in their suppliers' codes of conduct. The plaintiffs' lawyer, however, claimed that Apple, Alphabet, Dell, Microsoft, and Tesla "knew or reasonably should have known that the cobalt supply chain ventures operated by Glencore/Umicore and Huayou Cobalt were using forced child labor."[56]

Some of the defendant companies have joined traceability initiatives. For instance, Google is a member of the Responsible Minerals Initiative. Apple provides funding to the Fund for Global Human Rights, which is a nonprofit that aims to advance human rights worldwide.[58] Glencore is a member of the Responsible Sourcing Blockchain Network (RSBN). In the 2019 Conflict Minerals Report filed to the SEC, Apple noted that the company participated in responsible minerals initiative (RMI's) blockchain working group. Specifically, Apple stated that it helped to standardize data interoperability across different blockchain solutions in mineral SCs and contributed to data privacy measures. Apple's position is that blockchain solutions should be used "as a tool to

Continued

In Focus 8.2 Apple, Alphabet, Dell, Microsoft, and Tesla face a class action lawsuit—cont'd

support—but not to replace—supply chain due diligence." Apple also noted that the interests of local communities and people working at mine sites should be taken into consideration.[59]

The plaintiffs noted that the social responsibility programs have done little or nothing to stop child abuse and exploitation practices in the mineral industry and argued that, "They do this to create the false impression that they have acted to prevent the known horrors of cobalt mining in Congo."[60]

8.7.2 Blockchain solutions to address the situation

Some recent initiatives are expected to improve this issue. The blockchain solutions provider Diginex has been working with the International Organization for Migration and the antislavery nongovernmental organization Mekong Club to ensure ethical recruitment of migrant workers by increasing the transparency of workers' contracts. British Embassy in Bangkok partly funded the pilot phase of the project.[21]

Blockchain-based mobile app eMin tool (https://www.eminproject.com/) is used to store copies of employment contracts for workers in the aquaculture sector.[53] Employment contracts and related data are stored on the Ethereum blockchain.

Workers can access their contracts, which allows them a basis for claiming the rights and benefits they were offered at the time of recruitment.[53]

The eMin tool's pilot started in February 2019 with data intelligence and analytics provider for agribusiness suppliers Verifik8 at a shrimp farm in Phuket, Thailand.[53] In October 2019, Diginex signed an agreement with Verifik8 to integrate eMin into the latter's existing farming monitoring tools. As of October 2019, Verifik8's farming monitoring tools called Blue 8/Green 8 were being used by 5,000 workers in Thailand.[21] Diginex's plan is to expand into different sectors in other Southeast Asian nations, Bangladesh and Bahrain.[53]

To take another example, in April 2019, Levi Strauss & Co. started using a blockchain platform to test workers' well-being through anonymous surveys. It started with a Mexico vendor that employs 4,000 people. The anonymity overcomes challenges associated with employees' reluctance to share personal health details and speak negative things about their

direct managers based on company organization chart. A key benefit is that it can quickly collect feedback and share results. The results are shown on screens on the factory floor. In one survey, the results were processed within 48 h of its completion.[61] The goal of the system is to develop a self-reporting infrastructure by the workers to replace external factory health and safety auditors. The blockchain system used in the project is provided by ConsenSys. The development of the system is funded through a grant from the United States State Department.[62]

Some consumers, investors, and employees genuinely care about the origins of products as well as health and environmental impacts of the products and services of firms with which they are associated with and involved.[10] Consumers are applying pressure for ethical practices. Such pressures especially affect companies, whose target customers are millennials. According to National Coffee Association, two-thirds of consumers in the age group 19–24 years prefer to purchase products that are sustainably grown and responsibly sourced.[63] These symbolize hope for a positive change on this front.

Blockchain is shown to have technical and economic feasibility to implement sustainable practices and demonstrate such practices to various stakeholders.

One of the best ways to validate the claims that firms are sourcing ethically would, thus, be to use blockchain systems in which workers can enter data themselves to attest to and report on their working conditions.[64] Some firms are already doing exactly this.

A key challenge is consumer skepticism regarding companies' sustainable efforts. Consumers, thus, seek proof of such claims and make sure that companies are transparent. Blockchain solutions can help put spotlight on the artisans and other people behind the products and design.

Prior researchers have suggested that the lack of environmental competencies may act as an impediment to the growth of developing world–based enterprises. For instance, foreign firms may show unwillingness to engage with firms that lack good environmental records.[65] Thus, documentation of environmental competencies has become a critical prerequisite for entry into foreign markets.[66] Recent laws in many industrialized countries (Table 8.1) have increased the importance of identifying, mitigating, and addressing human rights risks such as child labor in SCs. In early 2017, Apple announced that it stopped buying cobalt from artisanal mines supplied by Chinese firm Zhejiang Huayou Cobalt Company, which is the largest buyer of artisanal cobalt in the DRC.[67] An obvious response of firms such as Huayou Cobalt has been to join blockchain consortiums.

8.8 Companies' response to ESG pressures

Motivations such as managing stakeholders and manipulating stakeholders' perceptions may lead organizations' ESG measures and reporting of relevant information.[68] The goals are to gain support, approval, and legitimacy of various stakeholder groups or to avoid their opposition and disapproval.[69]

8.8.1 Mineral and mining industries

Many firms are responding to ESG issues by integrating blockchain in their SC networks. Mineral and mining industries have been a sector in which serious ESG violations such as environmental degradation, natural resources exploration, and child labor practices have occurred. Emphasizing the seriousness and urgency of this issue, Everledger CEO Leanne Kemp said: "We saw that the next most potentially conflicted supply chain is going to be in rare earths and batteries. We're not interested in tracking lettuce. That's not where the world needs us to be."[70]

About 10%–20% of lithium ion batteries consist of cobalt.[71] Batteries of each electric car require 10–20 kg of cobalt.[72] Likewise, an average laptop battery uses about one ounce of cobalt.[73] The wide media coverage has brought to light highly unethical practices in cobalt mining activities including the use of child labor, human rights violation, and environmental damages.

About two-thirds of cobalt is mined from the DRC. As discussed above, there are reports that children as young as six work in the mines, who are exposed to unsafe working conditions. They include skin and respiratory toxicity that are potentially life-threatening.[74] The wages are as low as $0.75/day. A large number of preventable deaths have been reported in the country's cobalt mining industry.[75]

Unsurprisingly, many blockchain solutions have been launched to reduce potential use of unethically sourced minerals such as cobalt and tantalum from the DRC and other countries in Africa. For instance, Volvo has adopted blockchain in its battery SCs to ensure that unethical practices are not being implemented by its upstream SC partners. As of July 2020, Volvo claimed that the cobalt used in its first fully electric car Volvo XC40 Recharge P8 was 100% traceable. The model is manufactured in Belgium, and is scheduled to be launched by the end of 2020.[76]

In 2019, Volvo reached into agreements with its two global battery suppliers—China's Contemporary Amperex Technology Co Ltd. (CATL) and South Korea's LG Chem to implement blockchain-enabled cobalt traceability (Table 8.2). The agreements involve Volvo models and electric cars made by its Polestar brand for a decade.

Table 8.2 A comparison of the world's two biggest electric vehicle (EV) battery suppliers and their blockchain-based traceability systems.

	China's CATL	South Korea's LG chem.
Key players	Blockchain company Circulor and technology firm Oracle.[77]	RSBN, RCS Global, and IBM.
Market share	2019: 27.9% (SNE Research)[78] January 2020: 26.6% July 2020: 23.8%[79]	2019: 10.5% (SNE Research)[78] January 2020: 10.6% May 2020: 24% f[80] July 2020: 25.1%[79]
Pilot blockchain projects	Summer 2019: Traced cobalt for Volvo Cars' batteries.[77] Early 2020: Joint pilot project with Mercedes-Benz to measure the emissions of climate-damaging gases and the proportion of secondary material.[81]	Early to mid-year 2019: Conducted based on a simulated sourcing scenario; Cobalt from Huayou's mine site in the DRC to smelter, then to LG Chem's cathode plant and battery plant in South Korea, and finally into a Ford plant in the United States.[82]
Live/commercial launch of blockchain projects	November 2020: Volvo announced the implementation of blockchain across CATL's SC.[83]	Originally scheduled to go live by mid-2020.[84]

8.8.1.1 The Responsible Sourcing Blockchain Network

The Responsible Sourcing Blockchain Network (RSBN) is an industry collaboration that aims to support sustainable and responsible sourcing and production practices. RSBN members include IBM, Ford, Volkswagen, Huayou Cobalt, RCS Global, Fiat Chrysler, Volvo, LG Chem, and British–Swiss commodities trading company Glencore.[85] The RSBN blockchain platform is built on Hyperledger Fabric and is overseen by responsible-sourcing group RCS Global.[86] In the future, Volvo plans to apply RSBN to other minerals found in batteries such as nickel and lithium.[86]

In southern Congo, RCS traces cobalt using blockchain.[3] At the point, where cobalt is bagged and tagged, the miner (Huayou) adds data into the blockchain. For successive stages and key events such as smelting and refining, data related to inputs and corresponding outputs are added to the

blockchain. Shipping and other details are added from partners along the SC route. The record is automatically updated each time a transaction is added and made visible to the permissioned participants in real time.[87] In an initial test, the RSBN demonstrated the use of blockchain to track cobalt produced at Huayou's mine site in the DRC. The flow of 1.5 ton batch of cobalt in the SC was traced through mines in the DRC which was refined in China.[88] The refined mineral was then sent to LG Chem's cathode and battery plant in South Korea, and then to a US-based Ford plant.[89]

When minerals are smelted, they are often combined with metals from various sources. This increases the difficulty of tracking. It was reported that IBM was exploring the possibility of performing chemical analysis using artificial intelligence (AI) to pinpoint the origin of cobalt. This process allegedly ensures that "clean" batches of cobalt are not smelted with minerals that have been sourced unethically.[90]

8.8.1.2 Circulor's blockchain across CATL's supply chain

The traceability-as-a-service (TaaS) provider Circulor operates a blockchain platform across CATL*'s* supply chain.[91] Circulor's platform uses Oracle's blockchain technology, which is combined with AI algorithms to perform due diligence, identify data anomalies, and identify actions that need further investigation. Data captured include the cobalt's origin, attributes (e.g., weight and size), the chain of custody, and other information to establish SC participants' actions comply with globally recognized supply chain guidelines.[72] The application's field test was carried out for Tantalum mined in Rwanda and then for Cobalt used in Volvo Cars' electric vehicle batteries.[92] As of November 2019, Volvo, CATL, and other SC participants were reported to record about 28 million material scans and other production events per month on the Oracle platform.[72]

8.8.2 Proactive steps to ensure SCs' readiness to comply with new regulations

Some companies are proactively taking steps to ensure that their SCs are ready to comply with new regulations. With the debate about legislation aimed toward reducing carbon leakage risks and the possibility of CO_2 taxes in EU economies in the near future, organizations that have systems in place to calculate and track their CO_2 footprints will be in advantage.[93] In this way, blockchain solutions offer a proactive way to manage regulatory demands and the impact of new regulations.

To take an example, the carmaker Volvo's goal has been to generate 50% of its global car sales from fully electric models by 2025. It also aims to achieve a 50% reduction in tailpipe carbon emissions per car between 2018 and 2025.[94] The carmaker has embraced blockchain to achieve these goals and to demonstrate environmental and social responsibility of its activities.

Another carmaker Mercedes-Benz has also explored blockchain's potential to promote sustainability with a primary focus on environmental sustainability. Mercedes-Benz teamed up with Circulor to conduct a pilot project that involves the use of blockchain to track CO_2 emissions in cobalt supply chains of its battery cell manufacturers. It also tracks Secondary Materials, which are materials that are used, recycled, and sold for use in manufacturing. The goal is also to document whether Daimler's sustainability standards are passed on throughout the supply chain. A blockchain-based system records the production flow of the materials and CO_2 emissions. It also records the amount of recycled material in the SC. The network also displays working conditions, environmental protection, safety, business ethics, compliance, and human rights. The company's goal it to evaluate whether these indicators meet Daimler's sustainability requirements. Daimler will ask its direct suppliers to comply with the relevant standards. Upstream value chains are also expected to comply.[95] Pressures can be passed down to upstream value chains.

8.8.3 Regulatory compliance as a selling point

Blockchain services providers have been using regulatory compliance as a selling point. The Australian software-as-a-service (SaaS) company Lumachain has argued that its solutions will help food companies comply with the Modern Slavery Act 2018.[96] Blockchain, AI, and Internet of things (IoT) devices are used to create visibility, reduce wastage, and deliver traceability. Its solutions can find and track items in the food SC which could be unethically sourced or relied on forced labor.

Australian supermarket, retail and consumer services chain, Coles uses Lumachain in some of its premium beef products such as Coles Graze and Coles Finest brands to achieve full SC visibility. Some of these are supplied by JBS Australia. Blockchain-based solutions also help to answer questions related to animal welfare practices.[97]

8.9 Chapter summary and conclusion

Current systems are insufficient to validate firms' claims they are sourcing ethically. Blockchains have the potential to overcome many of the drawbacks of these systems. In the mineral and metal SCs, for instance, blockchain systems can tell consumers the location where the gold was mined, identity of the workers, their working conditions, and amount paid to the workers.

Blockchain undoubtedly forces some SC actors to change their behaviors and practices. Significant technological innovations such as blockchain do not take place in a vacuum. The above discussion makes it clear that it is important to bring changes in regulatory and government policy in order to benefit from blockchain.

Our discussion above highlights two important aspects of regulations and their effects on blockchain's use in SCs. First, the nascent and heterogeneous state of regulations in the areas of blockchain and smart contract is also challenging in order to incorporate blockchain in complex global SCs. Second, recent regulations directed at protecting the environment and preventing child labor and human rights misuse have increased the attractiveness of blockchain. An encouraging trend is that most of the major world economies are introducing legislations that are increasing the value proposition of blockchain. Several legislative measures address SC due diligence. Many of them are sector- or issue-specific. Public trading platforms and commodity exchanges such as LME are also intensifying efforts to enhance traceability of commodities such as metals traded on their platforms.

Some regulators are also providing funding to develop blockchain solutions to deal with ESG issues. For instance, the Modern Slavery Act 2015 in the United Kingdom is a factor that led to British Embassy's funding of the eMin tool.

Implementation of responsible sourcing initiative is easier said than done. For instance, support from metal producers with LME-approved brands is the key for the success of LME's initiatives to address child labor and other abuses. China's indifference toward this issue has been a key barrier to the implementation of this initiative.

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CHAPTER 9

Discussion, conclusion, and recommendations

9.1 Introduction

Modern supply chains (SCs) are extremely complex. Some companies rely on thousands of suppliers at many tiers of SCs. In the nonblockchain SCs, most firms lack visibility beyond their direct or tier 1 suppliers. The lack of SC visibility hampers firms' ability to respond to changes appropriately and quickly and in a flexible manner. The class action lawsuit against Apple, Alphabet, Dell, Microsoft, and Tesla discussed in Chapter 8 also indicates that this situation can also lead to reputational loss and legal liability.

Firms' manufacturing and logistics activities are also susceptible to various risks that include those associated with health emergencies such as pandemic outbreaks, economic events such as recession and various political events. Supply chain disruptions resulting from such risks can lead to undesirable operational consequences such as product shortage. Especially the COVID-19 pandemic has acted as a jolt that has awakened global firms. When the pandemic hit China in the early months of 2020 and carmakers were forced to close down their factories across Europe and North America, due to the difficulty of sourcing parts from further down the SC in China, they realized the danger of the lack of SC visibility.[1]

For modern SC to work better, information silos must be connected. Blockchain is in the best position to achieve this goal. Blockchain's value proposition vis-à-vis a nonblockchain system in an SC is especially higher in a long SC, in which the probability of information being tampered increases. Blockchain is largely likely to address this concern.[2]

Blockchain's combination with advanced automation needs to be evaluated in terms of technical feasibility and economic viability. Opportunities to transform SCs are functions of a number of factors including the business problem companies that are trying to solve specific use cases and technology capabilities that are available. Assets in supply chains have a high transformation potential using the power of Internet of things (IoT),

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artificial intelligence (AI), and blockchain if the asset value justifies the effort of physical–digital tags, connectivity is feasible, and to which intelligent automation can be applied.[3]

The technology has a promising future to have an impact on consumers soon.[4] Some companies have already realized the importance of using blockchain to provide detailed information about a product to consumers. San Francisco–based diamonds and fine jewelry retailer Brilliant Earth has incorporated Everledger's blockchain technology in its SCs. As of August 2020, Brilliant Earth had about 800 blockchain-enabled diamonds. Brilliant Earth's website allows customers to search for diamonds that are blockchain-enabled. Such diamonds have more detailed information such as place of origin, benefits of diamond mining to that region, and manufacturing process that provide assurances of the supply chain.[5] Additional informations provided include the rough carat weight, the rough diamond's image, and the polished diamond's 360-degree video. Customers that purchase blockchain-enabled diamonds can gain access to a secure digital vault, which is password-protected. They can see additional details including the chain of custody information for the diamonds they purchased.[6]

The use of blockchain to provide detailed information about a product is especially valued by millennials. According to the Nielsen Company's survey, three-quarters of millennials reported that they would alter their buying habits in order to reduce environmental impact compared to only 34% of baby boomers.[7] This has an important implication for firms since millennials and Generation Z will account for about four-fifths of luxury industry growth in the near future.[8] Firms are realizing that blockchain can play a crucial role to increase consumer confidence and trust in their products (See: In Focus 9.1: Alrosa's adoption of blockchain in order to increase the consumers' confidence).

Different jurisdictions are taking regulatory actions to ensure that multinational corporations do not shift their environmental polluting activities to countries with less stringent environmental standards. Blockchain can make certain that regulations have been followed.

9.2 Blockchain's attractiveness in big industries to solve significant problems

Developing blockchain solutions for supply chain management (SCM) to deal with unique business problems usually requires significant investments.

In Focus 9.1 Alrosa's adoption of blockchain in order to increase the consumers' confidence

Russia's Alrosa, which is the world's largest diamond mining firm, has adopted blockchain in order to increase consumers' confidence that they purchased conflict-free diamonds. In December 2019, Alrosa teamed up with blockchain platform Everledger and Tencent to launch a diamond-focused retail mini-program with WeChat.[9] Note that WeChat Mini Program provides advanced features such as e-commerce, task management, and coupons to users. Diamonds from ALROSA sold in the WeChat Mini Program would enable full traceability from mine to consumer.

In May 2018, Alrosa started an initiative to tokenize diamonds in partnership with KGK Diamonds and blockchain start-up D1 Mint.[10] It also joined a diamond SC pilot started by blockchain platform Tracr.[11] Alrosa and De Beers together account for about half of the world's diamond supply.[12]

Fig. 9.1 presents investments made by each member in different consortia formed to deal with various SC issues. It is also worth noting that members that join the Consortium later often pay more than the founding members. For instance, VAKT was formed in 2018. Saudi Aramco's Energy Ventures needed to invest US$5 million in new shares to join the consortium as a new member in January 2020.[14]

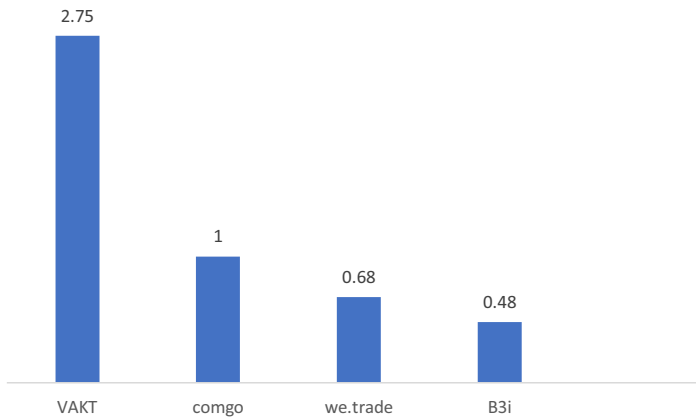

Figure 9.1 Average investment per member in some blockchain consortium (US$, million) (January 2019). *(Based on Morris N.* The cost of enterprise blockchain membership*: Ledger Insights; 2018. https://www.ledgerinsights.com/enterprise-blockchain-cost/).*

Some of the world's biggest industries in which significant problems can be solved with blockchain are the most likely candidates for the adoption of this technology. For instance, the oil and gas exploration and production (E&P) industry generated US$2.47 trillion in revenues globally in 2019.[15] Key components of physical trading activities in this industry include the negotiation of promises to deliver a commodity of a given quality level, at a location and given date specified in the negotiation. In oil trading, actors and processes involved include terminal or pipeline operators, port agents, and inspection companies. The blockchain platform for energy companies VAKT aims to facilitate these processes. It is built on the enterprise blockchain platform Quorum, which is JP Morgan's version of Ethereum.[16] VAKT manages the cycle from posttrade entry to final settlement in order to eliminate reconciliation-related errors and paper-based processes. It digitizes documents related to deal recap, confirmation, contract, logistics, and invoicing.[17] Shell uses VAKT to manage invoicing and scheduling. Compared with manual methods, the system has been reported to save users as much as half their time. It also cuts costs by 40%.[18]

The selection of materials and products to deploy blockchain depends on an assessment of the urgency, costs, and benefits to SCs, as well as the costs of inaction. Many blockchain platforms have been created to track diamond and 3TG minerals and metals. The global diamond jewelry market was estimated at US$76 billion in 2018.[19] Likewise, 3TG is a US$600 billion industry.[20] Similarly, tuna and Patagonian toothfish, which are being tracked with blockchain, are high-value fish species.[21] Patagonian toothfish has a history of being illegally poached.[22]

9.3 The future of blockchain in supply chains

Blockchain technology has a bright future in SCM. The investment in this technology is increasing rapidly. According to an August 2019 report by London-based venture capital firm Outlier Ventures, blockchain start-ups had raised US$23.7 billion in early stage rounds during 2013—mid-2019. The focus of such investments was moving to new applications from the earlier focus on purely cryptocurrency investments.[23] Likewise, according to Premium Market Insights (PMI), worldwide investment in blockchain in the energy sector was US$156.5 million in 2016, which is expected to reach US$34.7 billion by 2025.[24]

Thanks to these massive investments, the ease of use has been improving rapidly. Companies that want to use blockchain in SCs can just plug in applications such as VeChain's ToolChain and start using the technology.

Significant progresses have also been made over the past few years in blockchain standardizations. For instance, the main purpose of TradeLens is arguably to promote interoperability between various players in the ecosystem. For TradeLens to work, the most important prerequisite is that the systems used by carriers, freight forwarders, custom offices, ports, and other participants must be able to communicate with each other. That is happening by connecting with their legacy systems using APIs that support industry standards.[25]

A further encouraging development is that more diverse categories of participants are now entering this ecosystem. EY and Guardtime established Insurwave, which is arguable the world's first blockchain-enabled insurance platform. They collaborated with software corporation Microsoft, shipping company AP Møller-Maersk, and many companies in the insurance industry. Insurwave started its commercial operations in June 2018. Insurwave integrates and secures data from large number of sources. It uses blockchain and distributed ledger technologies based on Microsoft Azure infrastructure. The Association for Cooperative Operations Research and Development (ACORD) data standards are followed.[26] The project took about 1 year to complete following a 12-week proof-of-concept phase.[27] By September 2019, Insurwave platform processed about 30,000 transactions and insured more than 1000 vessels.[27] Insurwave's permissioned distributed ledger was built on the Corda platform, created by R3CEV, which developed Corda. It connects participants such as buyers, brokers, insurers, and reinsurers in a secure, private network.[27]

It is envisioned that public blockchains in the future can function as a ubiquitous and decentralized, "world computer," which will automate every aspect of human lives using data that are delivered through 5G or higher generation cellular networks. For instance, satellites can capture real-time road usage data, record in blockchain, and send to autonomous vehicles. Weather stations can send data related to temperature, wind, and rain in remote areas, which can be used to automatically price weather-based crop insurance contracts for farmers.[28] All these developments will be facilitated by superfast data processing. For instance, in 2019, most advanced systems used in the world were 300,000 times more powerful than those used in 2012 in terms of processing capacity.[29]

There have also been efforts to enhance integration and interoperability of various blockchain systems. For instance, IBM's VP of Blockchain Global Trade Todd Scott discussed the possibility of integration between Food Trust and TradeLens. IBM reportedly had detailed discussions with its clients about the potential integration.[25]

Blockchain-based tools are becoming more accessible to smaller players. In some cases, costs associated with using a system are covered by big corporations. For instance, as discussed earlier, Everledger and Swiss-based jewelry retailer Gübelin provide a no-cost solution to track colored gems produced or manufactured by artisanal and small-scale minings (ASMs). ASMs can use Everledger's blockchain platform to create traceability and document retention for free.[30] Likewise, as discussed in Chapter 6, the supply chain finance (SCF) platform Chained Finance charges peer-to-peer (P2P) lenders a fee to access to the system instead of charging to suppliers, which are often small.

Some technology companies have identified increasing opportunities in blockchain as a key priority area for action. They are growing the blockchain workforce. For instance, as of early 2020, Deloitte had 1400 full-time employees working on blockchain. Likewise, the blockchain unit India's Tata employed 1000 employees and 600 of them worked full-time.[31]

Companies are also facing external pressures from regulators and consumers to ensure that their SCs are free of conflict minerals. By focusing on the emotional issues of violence and children working under dangerous conditions, nongovernmental organizations (NGOs) have established causal relationship between the consumption of products such as cell phones and cars with conflict minerals from the Democratic Republic of the Congo (DRC) making consumers feel guilty. On the policy front, the 2010 Dodd–Frank Act has required companies to include conflict minerals reporting.[32] Some jurisdictions such as France and the European Union (EU) have passed more wide-ranging and even stricter regulations to protect disadvantaged workers from various abuses.

9.4 Different levels of difficulties in ensuring tamperproof tracking

An analysis of conflict minerals reports submitted to the *securities and exchange commission* (SEC) in 2014 and 2015 found that only 1% of filing companies claimed that their minerals were DRC conflict-free. Majority of them were not able to determine their raw materials' country of origin (Fig. 9.2). The companies' inability to determine the country of origin of their minerals is understandable considering the complexity involved.

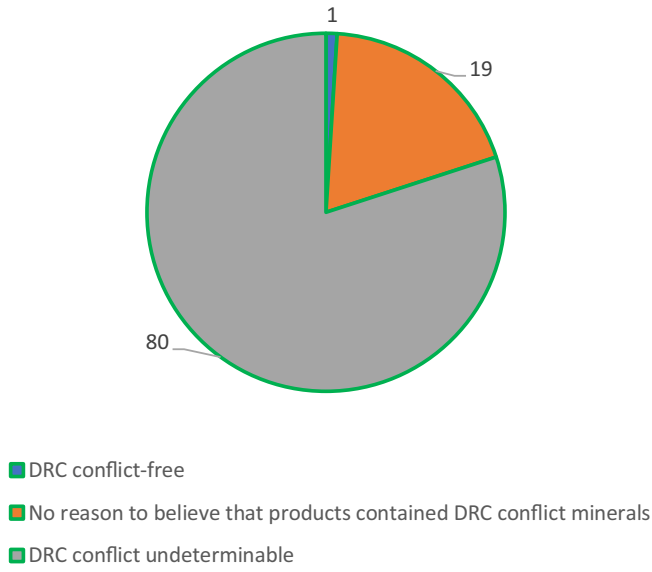

Figure 9.2 Responses of companies filing conflict minerals report to the SEC (%, 2014 and 2015).

Some products change physical characteristics, chemical composition, and other features along the SC. Commenting on the challenges involved in tracking tantalum, Circulor CEO and cofounder Doug Johnson-Poensgen put the issue this way: "This isn't a simple track and trace. It's complicated, because we start with ore and end up with smartphones. Food traceability is much simpler. A banana doesn't change into a diamond halfway through its journey to a consumer."[33]

Different materials in SCs pose different levels of difficulties in ensuring tamperproof tracking of the production and distribution process. For instance, compared to diamonds, metals and other minerals that rely on smelting and refining process technology are more difficult to track. Each individual diamond cut has unique elements, which can be translated into data attributes to ensure the immutability of every transaction.[34]

For metals that require refining, the refiner logs into a blockchain system and identifies the batch before and after refining. The refined metal is then repackaged, which has the original serial number. Similar procedure is followed in the next stage at production facility. A refinery often refines raw metals from many sources in a batch. While providers of such solutions claim that the serialized raw metal is refined as an isolated batch so that

visibility is maintained, the nature of this activity increases the susceptibility to tampering. For instance, the smelting process utilizes pressure, high heat, and chemicals.

9.5 Recommendations to policymakers

It is important for policymakers to understand that technologies such as blockchain alone cannot address social challenges. Accompanying policy is essential to ensure that blockchain systems are deployed to addresse the limitations.[35] In some settings, available technologies are not being effectively used to verify transactions in a tamperproof manner. For instance, in Societe Miniere de Bisunzu's (SMB) mining site near DRC's Rubaya town, barcoded tags are put on sacks of ore rich in tantalum by government officials.[36] The officials are stationed in a shack in the mining site, who use a handheld device linked to a cloud server to scan the barcode. Detailed data such as the sealed bag's weight, day and time of tagging, and person uploading the information are entered into the system. A limitation of the system is that it does not make use of available technology to pinpoint the global positioning system (GPS) coordinates in real time of the location where the ore was tagged. RCS Global, which audits SMB's supply chains cited high costs as the reason behind not using such technology. Another challenge is that corrupt government officials, who tag the bags with ores, may collude with smugglers. A blockchain system is corrupted if false information about ores is entered.[36]

From this perspective, Circulor's system used to monitor mines in Rwanda is superior. It uses smartphones with GPS capability to pinpoint exactly the location where the ore was tagged. It also utilizes facial recognition software, which confirms the identities of miners.[37] Implementation of appropriate policies can lead to the adoption of more tamperproof systems such as those used by Circulor in Rwanda.

Among several benefits of blockchain systems in international trades, the potential to reduce the level of congestion in customs clearance to developing economies deserves mention. Such a problem is especially prevalent in Central Asian countries due to cross-border e-commerce—led rapid growth in parcel flows.[38] Customs handling processes in Uzbekistan and other countries in the region are often paper-based. Many developing economies lack a well-developed system to assess and deal with new global antiterrorism rules and antimoney laundering rules.[39] Many of these challenges can be overcome with blockchain-based systems.

Blockchain is also being used to enhance the reputation of nations. Rwanda has been using blockchain in an attempt to fight the allegation that smuggled minerals are being blended with legitimate mineral resources from the country, which has helped to escalate conflicts in neighboring DRC.[40]

Blockchain can also be utilized as a way to overcome a negative country of origin effect of a product associated with a country. Note that a negative country of origin effect is related to mechanisms by which buyers of a products develop negative attitudes and perceptions about products originated from a country, which lead to unfavorable purchasing decisions. Conflict minerals such as tantalum originated in certain African countries have negative perception in the West because they are viewed as the causes of violence and fighting. By promoting transparency, blockchain can serve as a powerful force to overcome a negative country of origin effect.

Favorable government policies can help organizations to take advantage of various benefits blockchain offers in SCM. For instance, Rwandan government has been supportive of blockchain. The country's government thinks that accelerating the development of new technologies such as blockchain will help the country to become a continental hub for innovations. The National Bank of Rwanda and Rwanda Utility and Regulatory Authority (RURA) have established a sandbox facility around blockchain technology.[41]

We noted earlier that blockchain systems completely do not address trust problems. Mineral exporting countries from Africa and elsewhere can still benefit from the deployment of blockchain systems to track such minerals as long as the buyers perceive that the minerals tracked by such systems are conflict-free.

Lynne Zucker has identified three ways to produce trust: (1) institution-based trust is linked to institutions such as government bureaucracies and other formal mechanisms, trade associations, and professions[42]; (2) process-based trust is produced from the engagement in trustworthy relationships; and (3) characteristic-based trust is generated by identifiable attributes that are linked with trustworthy behavior. Blockchain deployment to track minerals can help produce characteristic-based trust, which is critical since the difficulties of producing the first two types of trust.

Regarding (1), institutional trust-producing structures are not well-developed in many resource-rich African countries. As explained in Chapter 7, due to factors such as corruption and political patronage, there is a low degree of trust in the government and its institutions. The artisanal

extraction of cobalt in the DRC has been linked to toxic harm to vulnerable local communities.[43] There have been instances of untrustworthy transactions. Most companies rely on a paper-based certification. United Nations (UN) experts have documented cases in which tags used to identify clean minerals were stolen in eastern Congo and sold to smugglers. Ore from blacklisted mines was sold as responsibly sourced.[36] There is, thus, the lack of process-based trust, which is produced from the engagement in trustworthy relationships. Blockchain, thus, helps to produce characteristic-based trust.

International efforts have produced some positive results. It is reported that more mines and more mineral transactions in the DRC have come under civilian control. They have generated economic opportunities for the Congolese population.[44] With blockchain-based system's affordability and higher effectiveness, it can be expected to further improve this situation.

Estimates suggest that 70%–80% of workers in small-scale mining in Africa are informal employees. Most of them lack legal mining licenses and are not provided economic and health security.[45] The deployment of blockchain in tracking conflict minerals would not only help destigmatize ASMs but also formalize the informal economy.[46] Conversely by taking measures to formalize ASMs, it will be easier to implement blockchain. All these measures would help downstream SC partners to verify that the minerals they buy are from legitimate mining companies and know the conditions under which they were produced.[46] A large informal sector would reduce a country's development potential and act as a constraining factor to fight against poverty.[47] Formalization, on the other hand, can encourage and stimulate entrepreneurial activities.

As discussed in Chapter 7, a low degree of digitization has been a major barrier facing many African economies to benefit from blockchain. For instance, mobile network coverage is only 30% of the total population in Burundi. The situation can be contrasted with Singapore, which has its digital twin. The government department National Research Foundation (NRF) has created a Virtual Singapore to offer a 3D semantic model of the city. In such a model, the data's meaning can be related to the real world, displaying land attributes or the characteristics of different forms of transport, or the components of buildings and infrastructures.[48] Policymakers, thus, should work toward developing digital infrastructures in order to take advantage of the potential of blockchain and other technologies.

While some blockchain systems have enabled disadvantaged groups, such as farmers and ASMs to connect to SCs of bigger companies, benefits

of the systems to these groups have been far from satisfactory. For instance, a farmer supplying to Anheuser-Busch receives a digital payment through BanQu's platform. The crypto tokens can be redeemed for cash or applied for payment to other transactions such as paying energy bills [49]. BanQu claims that farmers may benefit from the immutable records of economic activities that are linked with their digital profiles. For instance, with this record, farmers can connect with NGOs, local cooperatives, microfinance institutions (MFIs), and banks to receive loans, grants, and trainings. However, constraints related to information flows, transaction costs, and market access would prevent them from realizing such benefits. For instance, the farmers may not be able to present the information in a way that meets the requirement of banks. They may also lack persons in their social network who possess capability to understand the various available loan services. Due to the lack of education, many potential borrowers cannot fill out loan applications. Poor people often need loans in small amounts. It is costly for financial institutions to deal with small transactions. In some cases, poor people may face prejudice and stereotypes. Some banks refuse their admission to bank branch offices.[49] These challenges need to be creatively addressed through education, awareness, and other relevant measures, so that real benefits can be delivered to disadvantaged groups.

Blockchain deployment in SCs could help prevent corrupt behavior. For instance, there may be an incentive for local authorities to tamper with water quality data. They may also withhold such data.[50] Blockchain ensures that they cannot do so without being noticed by other relevant parties.

Laws in the Western world such as Dodd–Frank Wall Street Reform and Consumer Protection Act have resulted in the economic hardship of ASMs. Thus, legislative measures taken to solve one problem may create another one. Blockchain-based solutions could save ASMs from such hardship.

Actions of Western governments and multinational companies (MNCs) have attempted to address merely a symptom rather than the root of the problem. Avoiding mineral sources that employ child labor is not necessarily the best solution. It is critical to introduce regulations against child labor and bring a broader change in societal attitudes toward such practices. Research has also found that the political support for child labor regulation is likely to increase with an increase in the return to education.[51]

9.6 Recommendations to companies

Blockchain in SCM is increasingly becoming a necessity rather than a choice. Blockchain facilitates close cooperation and deep engagement with suppliers. In combination with other technologies, it ensures meaningful improvement in SC practices. Blockchain-based SC systems are more efficient. For instance, with Toyota Blockchain Lab's identity and access management (Chapter 2), there is no need for users to sign up and verify themselves for each platform or service, which can be time-consuming and costly. In addition to being time- and cost-efficient, the system performs better in cybersecurity than other existing systems.

SC applications need data on physical products that are shipped across multiple tiers of operations. The most critical step is to determine what data are needed, how SC events can be digitalized for sharing across stakeholders that are a part of a blockchain-enabled ecosystem.[52]

While blockchain can have bigger impacts on larger supply chains, there are also most inertias in such SCs. For instance, a Fortune 500 company's SC manager was quoted as saying that their firm had more than 1000 first-tier suppliers. These suppliers in turn has 8000 s-tier suppliers. An estimated 30,000 third-tier suppliers were in the SCs of the second-tier suppliers[53] Likewise, Apple has at least 200 suppliers and 242 smelters and refineries worldwide. Convincing hundreds, or even tens of thousands, of SC partners to adopt blockchain may not be an easy task. It might be better to test with small-to-medium use cases and build success stories. Subsequently, value proposition can be compelling for larger networks.[54] Blockchain's full benefits, however, cannot be exploited in the absence of a rich ecosystem consisting of other SC partners.

Many definitions currently maintain corporate social responsibility (CSR) as a voluntary initiative.[55] However, the expectations regarding CSR of different stakeholder groups are changing rapidly. For instance, the EU conducted a survey 334 EU businesses to understand their viewpoints about mandatory due diligence requirement for the impacts on human rights and the environment. The survey respondents were asked whether they agreed or disagreed that EU-level regulation on a general due diligence requirement for these issues could benefit business by creating a level playing field "by holding EU competitors to the same standard." 71.64% respondents agreed with the requirement of EU regulation on mandatory due diligence and resulting benefits to business. Only 10.45% disagreed with the statement.[56] The same survey was also conducted among civil

society respondents, among which 94.19% agreed with the statement and 3.49% disagreed. The expectation regarding the role of corporations in society has been rapidly changing due primarily to increasing concerns for CSR.[55] Blockchain is among the most effective ways to improve firms' CSR performance.

Many revolutionary digital technologies are developing rapidly but have not yet reached their commercial breakthrough. Even the most developed Asian Development Bank (ADB) members are far from harnessing the full potential of these technologies. Developing an understanding of how these technologies can help take actions to address climate change mitigation and adaptation, environmental sustainability, and disaster risk reduction and management (DRRM) is timely and important because their applications are evolving rapidly, and the climatic and environmental significance is expanding.

As discussed in Chapter 8, the European Commission intends to revise the internal Energy Tax Directive by introducing a carbon border adjustment mechanism.

This means that firms need to develop strategies to minimize carbon dioxide emissions and assess their performance in a measurable way. Blockchain is likely to play key roles in these processes.

Prior research has noted a number of factors that have led to corporate interest in CSR. Improved corporate reputations is among the most important benefits that companies can gain from their CSR initiatives.[59] Additional benefits include complying with and avoiding government regulation, attracting positive media coverage and reducing resistance, and increasing engagement in the brand from consumers and other stakeholders.[59] The cases of companies such as Bumble Bee indicate that blockchain could be an effective public relations tool. In 2017, Greenpeace's ranking of 20 tuna brands has put Bumble Bee at the 17th place for its sustainability practices. Greenpeace accused the sea food giant of greenwashing unsustainable practices.[31] The company hopes that blockchain may help address negative perceptions of the company and possible negative branding impacts of its past bad behaviors. Consumers are likely to be more confident that their tune in Bumble Bee Food coming from the South Pacific was caught by a fisherman and not by a factory ship.

Prior researchers have argued that there are three attributes of stakeholders that are important in identifying and responding to pressures from various stakeholder groups: power, legitimacy, and urgency. Organizations are likely to be more attentive, responsive, and accommodating to the

needs of stakeholder if they are viewed to be powerful and their claims are seen as legitimate by the society.[60] Also, problems that are considered to be urgent are likely to be responded to by other stakeholders. Various sources of power to influence the interfirm relationships in SCs have been recognized.[61] Proponents of dependency theory contend that organizations are embedded within larger interorganizational networks, which generate formal and informal pressures.[62] Especially one's power arguably "resides implicitly in the other's dependency".[63] This means that small firms such as ASMs in Africa, which have a low bargaining power, often have no choice but to comply with demands from industrialized world-based trading partners.

In order to illustrate this point, we consider Circulor's blockchain-based mineral tracking system in Rwanda. Power Resources Group (PRG), a tier-two supplier of Apple was Circulor's first client in Rwanda. PRG provides refined material to KEMET Corporation,[40] which is a tier-one Apple supplier.[64] KEMET is a publicly traded US-based manufacturer of capacitors, sensors, actuators, electromagnetic compatibility solutions, and other electronic components.[65] Apple was not a part of the network. If big companies such as Apple become paying customers, blockchain's use in tracking mineral is likely to increase significantly.[64]

Different minerals face different levels of challenges to implement blockchain. For instance, it is relatively simple to track diamonds compared with ores such as cobalt and columbite—tantalum (coltan) that need to be refined to produce tantalum. The refining process increases the risk of clean batches of materials being mixed with other batches of products potentially containing conflict minerals.[40] It is important to take into account these factors in decisions related to blockchain solutions and designing such solutions.

Industrialized world-based firms often apply coercive pressures in an attempt to induce conformity from less powerful firms in developing countries. In the domain of Information and Communications Technology (ICTs), evidence of coercive pressures related to dominant suppliers and customers is more readily apparent in dyadic technologies such as electronic data interchange (EDI) that link business partners compared to a nondyadic technology such as enterprise resources planning (ERP).[66] Schware and Kimberley (1995) found that some organizations from developed countries accepted new suppliers only if they can demonstrate an EDI capability. This finding pointed out the cases of companies "who have gone out of business because of inability, or unwillingness to comply or disbelief in the need to

comply".[67] When big firms use coercive power, the less powerful partners may be left vulnerable.[68] Many small firms soon will have no choice but to use blockchains in SC activities. For instance, in 2018, Walmart announced that it would require its suppliers of leafy green vegetable to upload their data to the blockchain system by September 2019.[69] As of early 2020, its blockchain-based Food Traceability Initiative tracked fresh leafy greens and green bell peppers along its SC.[70] Likewise, in April 2020, the US agricultural MNC Dole Food Company announced its plan to launch blockchain-based tracking and other "advanced traceability solutions" in its three business divisions by 2025—tropical fruits, fresh vegetables, and other diversified products.[71] This means that adopting blockchain is the essential prerequisite to be a supplier of Dole or Walmart.

Food products logged via blockchain can be instantly tracked back through the SC. It gives retailers and consumers confidence in case of a recall. A study of PricewaterhouseCoopers (PWC) indicated that food recall and other costs associated with a single foodborne illness incident can cost a company as much as 15% of annual revenue.[72] Blockchain is an important mechanism to reduce such costs.

Some MNCs have shown preference for avoiding DRC cobalt rather than trying to solve problems related to human rights abuse and child abuse in the country. In April 2019, BMW said that it would source its cobalt required for its electric cars from Morocco and Australia rather than from the DRC.[73] If businesses and consumers in industrialized countries in North America, Europe, and Asia stop buying minerals and gemstones due to their association with human rights violations, it will make things worse. For instance, 55% of exports of Sierra Leone come from mineral resources.[74] A more sensible approach would be to help the DRC and other resource-rich African countries to integrate blockchain in their mineral SCs by taking measures to overcome political, technical, and other barriers. Lauren Armistead of Amnesty International put the issue this way: "Due diligence isn't about avoiding risk, it's about identifying risk and addressing it, and being transparent about that. Then all the actors in a supply chain can work together on the issue."[46] Western MNCs also need to make investment in infrastructural development and governance issues in mine sites.[75]

One argument that has been put forward is that enterprises in developing countries should not go beyond compliance requirements in developing environmental competencies. If a developing world-based firm invests too much in new technologies, training of employees, and

purchasing of international certification, it may find that its products are too expensive.[76] Consequently, the firm becomes less competitive. However, this situation is changing with the pressure faced by developing world-based firms from MNCs. External institutional factors such as pressure from international organizations have forced MNCs and local firms operating in developing countries to adopt international certification and take other sustainability measures.[77] As noted earlier, carmaker Volvo discontinued at least one supplier from its network due to noncompliance with its demand to connect to blockchain networks.

Finally, organizational values and norms can also serve as especially salient barriers that prevent organizations' adoption of blockchain. Key decision-makers need to be educated by the benefits of blockchain in SCM as well as the risks of not adopting this technology.

9.7 Future research implications

In this section, we suggest several potentially fruitful avenues for future research. There is some anecdotal evidence to support the hypothesis that consumers prefer to buy products from companies that have adopted blockchain in their SCs. For instance, as stated in Chapter 4, Carrefour's blockchain's deployment to food products from farms to stores led to increase in sales of these products.[78] However, there has been little research in this area. It is reasonable to expect that consumers with different demographic and socioeconomic characteristics might develop different levels of preferences and different attitudes toward firms using blockchain in SCM. Different consumers may also differ in terms of the price premiums that they are willing to pay. An intriguing avenue for future research is to examine the linkage between consumer characteristics and their attitudinal and behavioral responses toward products that have been tracked using blockchain.

In some cases, firms' uses of blockchain and other technologies such as big data in SCM are motivated by similar goals, but achieve them in very different ways. For instance, blockchain is touted as a technology that is likely to facilitate optimization of resources and sustainable production.[79] Big data also make organizations more efficient by improving operations, facilitating innovation and adaptability, and optimizing resources allocations.[80] To take an example, big data analytics allowed the yogurt company, Danone, to forecast the demand of its retailer customers more accurately, which led to higher consumer satisfaction, less wastes, and a

higher profitability.[81] In this regard, a second area of future research might be to compare blockchain and technologies such as big data in terms of the source, type, and amount of data used.

Blockchain systems discussed in this book track various categories of information. They include environmental conditions such as temperature and humidity, economic variables such as earnings of SC participants, personal information such as identity information. They use multiple sources of information. For instance, some of the information is entered by human users. Other sources of information include machine vision, and other AI technologies, radio frequency identification (RFID) devices, IoT, GPS, and satellites. In order to provide a systematic understanding of these phenomena, future researchers might develop typology of indicators and sources of information in various blockchain systems used in SCM.

Prior researchers have noted that while MNCs' CSR activities in developing countries has attracted increasing research attention in recent year, Africa has been relatively underrepresented in this research area compared to other regions. Moreover, existing studies dealing with this topic about Africa have mainly focused on two biggest economies in the region: South Africa and Nigeria.[82] This is arguably due to the fact that these two economies represent most of the foreign direct investment (FDI) patterns and, thus, the presence of MNCs in Africa.[83]

Mineral and metal industries in less represented African economies such as Rwanda, the DRC, and Sierra Leone have been picked up with enthusiasm by commercial organizations developing blockchain solutions to help MNCs to track their CSR activities and performance. These MNCs' adoption of blockchain to track CSR are shaped by diverse motivations and circumstances. These diverse CSR issues affecting developing countries and least developed countries (LDCs) in Africa need to be explored in future research in the context of blockchain.

The current approach to CSR research in the developing word has been criticized on the grounds that it has largely failed to critically engage with the government's roles in CSR and analyze the nature and character of the state.[83] Hamann (2006)[84] argued that while compliance with local rules and regulations is a key component of CSR in developing countries, due to poor regulatory enforcement, CSR remains no more than a voluntary commitment. Consequently, the so-called CSR activities provide little or no benefits to the intended beneficiaries. CSR research would benefit by looking at the implication of government inadequacies for CSR practices as well as ways to strengthen regulative institutions. It has been suggested that

various actors involved can engage in collaborative strategies to enhance government capacities.[83] In the context of these discussions, future research can examine how blockchain can help to bridge the enforcement gap and enhance government capacities in developing countries. Future research also needs to evaluate blockchain deployment's potential to empower consumers and other stakeholders.

Firms in an SC need to deal with various types of conflicts and violations. In a mining company in the DRC, for instance, conflicts were found at three levels: company-government, company-local communities, and company-local employees.[85] Future research might also examine the nature of challenges these conflicts and their consequences pose to firms seeking to develop blockchain solutions to trace and track products in SCs.

In future, research scholars also need to consider blockchain's uses in promoting social, ethical, and environmental responsibility in SCs. For instance, prior researchers have noted that supply chain managers and scholars have neglected the issue of modern slavery international SCs.[86] Thus, blockchain's potential roles in tackling ethical trade issues such as the promotion of human rights and decent work and elimination of modern slavery need to be explored in future research. Blockchain-based solutions to protect the natural environment could be another related area of exploration.

9.8 Final thought

Blockchain does not provide the final, ultimate, absolute, and universal truth about the world. This technology, however, increases transparency and provides one shared single source of truth in SCs. A key challenge that the proponents and promoters of blockchain face is, therefore, the need to ensure that the shared single source of truth is close to the real truth. And this is the most difficult challenge of all. However, there have been significant advancements in a number of fields ranging from chemistry to computer science and software engineering, the incorporation of which in blockchain solutions is likely to increase its potential to function as a truth machine.

Despite some challenges, the global economy has seen a wave of significant investment in blockchain services and solutions. Blockchain is facilitating positive transformations and changes in SCM. By enabling secure, reliable, and decentralized record-keeping, this technology can reduce paperwork, human errors, operational costs, and fraudulent

activities, and promote transparency. By integrating with IoTs and other 4R technologies, it can improve traceability and real-time tracking. Blockchain provides higher accuracy because data are verified by multiple participants. The Nile Breweries example presented in Chapter 4 demonstrates the challenges involving to assess the true quality of crops due to lack of sophistication and accuracy of systems involved in less digitized SCs. Technologies such as AI can help to develop a fully digitized supply chain.

Blockchain deployment in SCs can enhance firms' brand reputation and strengthen their brand positions. By promoting trust and transparency, blockchain can help fight against efforts undertaken by some actors to undermine trust in other countries' products and services such as cobalt from the DRC and pharmaceutical products from India.

Blockchain systems in SCs also empower consumers and citizens. Consumers do not have to take their word for it when companies say that they engage in sustainable practices. In this way, blockchain empowers consumers. Ordinary citizens and activists can also verify companies' various sustainability-related claims themselves.

Blockchain provides firms with an opportunity to demonstrate that they have incorporated social equity and environmental justice in their SC activities. This technology, thus, can promote a "race to the top" in terms of firms' social and environmental sustainability performance. With blockchain, there is the opportunity to improve the society by pursuing moral objectives such as human rights.

The costs associated with setting up a blockchain system for SCM are a function of the use case, complexity of the project, and the approach followed including the type of blockchain used. In general, blockchain-based systems are increasingly accessible to a broad spectrum of readers. People with minimal IT skills and those who do not have any prior knowledge of blockchain can enter data in blockchain systems. Blockchain could, thus, be the most effective way for firms such as ASMs to comply with regulations such as the *Dodd–Frank Wall Street Reform and Consumer Protection Act*. Blockchain can also save firms from lawsuits and reputation loss.

In order to understand the impact of blockchain, this technology needs to be viewed in relation to governance issues in supply chains. The role of blockchain in providing effective governance in SCs depends on broader technological, contextual, and institutional factors such as digitization of SCs and legislative and law enforcement efforts to ensure that false information is not recorded in blockchain ledgers.

Some actors can see an opportunity to distort the truth for profitable gain. Blockchains with a smaller number of nodes can distort the truth more easily than those with a higher number of nodes. In order to get close to the truth, there is the need to ensure the quality of data entered in the blockchain system. For instance, a verified participant may decide to take to nefarious actors' pressure to distort the truth and register minerals obtained from illicit mining operations as legitimate ones. It is also possible that data manipulation is culturally accepted in some societies. Blockchain's goal of establishing trust cannot be achieved under these conditions.

A key challenge currently is that blockchain systems do not link a physical product to what is recorded on the ledger. By utilizing AI and machine learning (ML) to fully digitize SCs and by creating digital twins of the physical products, the real benefits of blockchain systems can be realized.

The immutability feature makes it possible for interested participants to double-check the data in the ledger against the real-world condition to make sure that data in the ledger are not misrepresented. For instance, it is possible for consumers to verify that a crop was actually grown where the farmer claims that it was grown. For this purpose, interested parties can visit the field, or satellite imageries can provide the relevant data.

In closing, while the real truth is impossible to verify directly, by combining blockchain with other technologies, parties in an SC can try to reach as close to the real truth as possible. With higher digitization and measures to address various institutional issues, the technology is likely to bring us closer to the truth.

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