A (new) role for business - promoting the United Nations' Sustainable Development Goals through the internet-of-things and blockchain technology

Charl de Villiers
(corresponding author, charl.devilliers@auckland.ac.nz)
The University of Auckland, New Zealand, and University of Pretoria, South Africa

Sanjaya Kuruppu
(Sanjaya.Kuruppu@unisa.edu.au)
UniSA Business
University of South Australia, Adelaide, Australia

Dinithi Dissanayake
(Dinithi.Dissanayake@unisa.edu.au)
UniSA Business
University of South Australia, Adelaide, Australia

Please cite as:
De Villiers, C., Kuruppu, S. & Dissanayake, D. 2020. A (new) role for business - promoting the United Nations' Sustainable Development Goals through the internet-of-things and blockchain technology, *Journal of Business Research*, 131, 598-609. https://doi.org/10.1016/j.jbusres.2020.11.066.

Abstract

We outline the business opportunity for the provision of measurement technology, linked to the internet, i.e. the internet-of-things (IoT), which feeds information into blockchains, providing reliable and trusted data and an incentive for others to contribute towards progress on the United Nations' Sustainable Development Goals (SDGs). Both existing businesses and start-ups could exploit these new opportunities, which could inspire the participation of employees, volunteers, donors, and other participants. We provide a conceptual framework for the different ways business can play a role in facilitating measurement of SDGs, and trust in these measurements, by harnessing technology.

Keywords

Internet-of-things
Blockchain
Sustainable development goals
Innovation

1. Introduction

> *The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, …recognize[s] that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests.* (United Nations, 2020a)

The United Nations' Sustainable Development Goals (SDGs) articulate the major issues facing humanity. If these goals can be addressed in a systematic way, the world would be a better place. However, progress on these goals are hampered by a lack of proper measurement of the 232 SDG indicators (United Nations, 2020b) identified to represent the 17 SDGs, as well as a lack of trust in the measurements performed by others. For example, vast sums of money are transferred from developed to developing nations each year to support a variety of SDG related projects, such as carbon offset schemes (SDG 13 – Climate Action), yet there is a lack of trust in measurements performed in developing countries due to endemic corruption and weak governance (Mehta et al. 2018). A lack of trust impedes cooperation. The SDG indicators are classified into those with 1) established methodology and available data; 2) established methodology but challenges with data availability, and 3) no established methodology (MacFeely, 2018). Given these measurement challenges, the UN's Global Partnership for Sustainable Development Data (GPSDD) calls for "a data revolution for sustainable development, with a new international initiative to improve the quality of statistics and information" (Yayboke, 2017 p.10). This is especially important given the devastating COVID-19 pandemic, which affects the SDGs and has accelerated digitization and engagement with technology to minimise human contact and the need to travel (see, for example, Barnes, 2020). In this paper, we outline the business opportunity for enterprises to provide measurement technology, linked to the internet, i.e. the internet-of-things (IoT), which feeds information into (a) blockchain(s), providing reliable and trusted data and an incentive for other parties around the globe to contribute towards progress on the SDGs. These new opportunities can be exploited by existing businesses or start-ups, which could inspire the participation of employees, volunteers, and other participants.

The IoT consists of a network of (semi)autonomous objects or devices that can communicate with each other in such a way that the sharing of information optimises resource use and the user experience. A blockchain can be introduced to record the measurements and transactions between devices. These distributed ledger systems enable different types of transactions to be recorded, reported and audited simultaneously in ways that significantly reduce the possibility of fraud or error, which is especially helpful in situations where there is a lack of trust between users (Issa, Sun & Vaserhelyi, 2016; Yermack, 2017).

Increasingly, companies are seen as a medium to effect positive social and environmental change, alongside their pursuit of economic goals (Bebbington and Unerman, 2018). The United Nations 2030 Agenda for Sustainable Development specifically envisions a role for private sector organisations to contribute to global development and sustainability challenges through the Sustainable Development Goals (SDGs) (United Nations, 2015). Involvement in the measurement and tracking of SDGs will enable existing companies to differentiate themselves from competitors

and create space to innovate their business processes and relationships with stakeholders in fundamental ways (van Tulder, 2018), and could equally be exploited by start-ups. Integrating business and sustainability goals can create 'win-win' situations for economic progress as well as sustainable development (Burritt and Schaltegger, 2010).

Deloitte's (2018) business survey found that 77% of respondents rate citizenship and social impact as mission critical. Furthermore, there has been a rapid increase in start-ups, which are specifically created as social enterprises. While social enterprises also pursue revenues and profits and create jobs, the key focus is to create social value. Integrating technology to expressly promote the SDGs can enable existing businesses, or start-ups, to capture market opportunities linked to goals that are broader than pure economic concerns. Business can thus tap into new social aspirations to innovate through the adoption of new technology, responding to growing public sentiment for environmentally and socially responsible goals. However, managing SDGs continue to present challenges around measurement and trust (Subramaniam, Mori, Akbar, Ji & Situ, 2019).

This paper seeks to address these challenges, and show how harnessing new technologies, such as the IoT and blockchain, can facilitate more transparent SDG measurement and increase trust in the measurement systems, while providing opportunities for business. Previously, the importance of technology on sustainability reporting and communication has been shown (Lodhia, 2018; Lodhia & Stone, 2017). We build off this foundation to explore how technology can be integrated within and throughout existing and new business models to improve sustainability (see, for example, Massaro et al., 2020). This is an important contribution, as rapid technological advances in the last decade have and will cause significant disruption to business models and structures, making this exploratory study prescient in identifying opportunities for businesses to evolve (McKinsey Global Institute, 2013; Frey and Osborne, 2017).

The following research question guides this research:

How can businesses innovate by promoting the UN SDGs through the internet-of-things and blockchain technology?

This paper will provide a conceptual framework for the different ways business can play a role in facilitating measurement of SDGs and trust in these measurements by harnessing technology. The rest of the paper is structured as follows. First, we provide an overview of the SDGs and the measurement and management issues involved. Next, we discuss distributed ledger and blockchain technology, including its most valuable characteristics. Third, we discuss how IoT and blockchain technology can be, and are being, used in conjunction. Next, we discuss and provide a conceptual framework for the many ways business can harness IoT and blockchain technology to promote SDG measurement and management.

2. SDG measurement and management

While the SDGs were introduced in 2015, and national governments have been concerned with how to achieve the SDGs since then, businesses have only recently showed an interest in the SDGs as a common framework which they can adopt to demonstrate the wider social, environmental and

economic impacts of their operations. Nevertheless, current literature primarily focuses on how SDGs are disclosed through external corporate reporting practice. Minimal attention has been paid to SDG measurement, which underpins external corporate reporting practice. However, some scholars have identified this as a significant gap, noting that there is a lack of transparency and clarity of how SDGs fit with or enhance current businesses practices (see, for example, Subramaniam et al., 2019). In this paper, we investigate how business can use IoT and blockchain technologies to improve the integrity of SDG reporting, which will enhance trust and cooperation, while spurring business innovation.

The UN SDGs were developed to provide a multifaceted framework to define global development challenges and encourage a multi-sector approach to addressing these issues. The SDGs provide a platform for the private sector to align with 'societal needs and long-term priorities', with the added benefit of maintaining a license to operate (Pedersen, 2018 p. 22). Addressing significant development challenges also has the potential to help businesses innovate (see, for example, Morioka et al., 2017). One stream of literature focuses on the external reporting of business enterprises' contribution towards SDGs, which businesses are increasingly interested in doing (Accenture, 2016). Rosati and Faria (2019, p. 1) argue that "business reporting on the SDGs can support organizations in planning, implementing, measuring, and communicating their SDG efforts". However, the extent and quality of SDG reporting remains limited and represents a shift in nomenclature rather than a transformation of business operations and practices (see, for example, Subramaniam et al., 2019).

We agree with Grant F. Reid, CEO/President of Mars Inc., who recently said: "Instead of dabbling in all of the SDGs, businesses can more effectively contribute if they pick the ones that are most relevant to their core operations and make strong commitments to achieving those goals" (Accenture/UNGC, 2019, p. 33). Tracking progress towards achieving the SDGs is challenging, and can be very expensive to measure, especially at the country level (International Institute for Sustainable Development, 2018). The UN's 'SDG Tracker' site use country-level data from UN agencies and other international organisations from the 'Our World in Data' database to highlight regions in the world where development is on track or lagging behind. However, country rankings can be problematic, because a country's relative position depends strongly on the methodology and indicators that are chosen (Miola and Schiltz, 2019). The Statistics Division of the UN Economic and Social Commission for Asia and the Pacific have indicated that SDG indicators can be classified into three tiers. Tier 1 refers to indicators with an established methodology and widely available data; Tier 2 refers to indicators with an established methodology but data availability is more challenging; and Tier 3 is for indicators with no established methodology yet (MacFeely, 2018). To address concerns with data measurement and collection, the UN has formed the Global Partnership for Sustainable Development Data (GPSDD) responding to calls for "a data revolution for sustainable development, with a new international initiative to improve the quality of statistics and information available to people and governments" (Yayboke, 2017, p.10).

SDG measurement is also needed at the organizational level. The joint UNGC and GRI report emphasizes thinking about and collecting data about indicators at a range of different levels within organizations, classified as inputs, activities, outputs, outcomes and impacts (UNGC/GRI, 2017).

For instance, for indicators relating to water purification, inputs would be classified as 'money spent on manufacturing and R&D', outputs could be considered as 'number of water purification tablets sold and consumer information provided' and outcomes as 'purified water consumed in percentage' (UNGC/GRI, 2017 p. 20). Data collection is promoted as both a qualitative and quantitative activity with regularity of collection intervals and engagement with a range of stakeholders seen as key in this process. Table 1 provides an example of a data collection process for SDG 8 on decent work and economic growth, highlighting the complexities involved in measuring and managing SDG indicators. Monitoring performance on SDGs and Millennium Development Goals requires an understanding of both qualitative and quantitative as well as monetary and non-monetary indicators (Haliscelik and Soytas, 2018, p. 1).

Table 1: Complexities related to measuring and managing SDG indicators

Disclosure	**Unit**	**Data availability**	**Data quality**	**Extra resources required**	**Management ambition related to data quality**	**Stop/start/ improve/no action**
Total number and rate of new employees hires during the reporting period, by age group, gender and region	Number and %	Yes	Medium	Improve data specificity	High	Improve
Total number of employees, disaggregated by female and male employees	Number and %	Yes	High	Monitor process and set up controls	High	No action
Explicit recognition of living wage payment	$ currency	No	N/A	Start measuring and monitoring	High	Start

Source: Adapted from UNCG/GRI (2017, p. 21)

To date, there is limited research on how business can contribute to achieving the SDGs (Ike et al., 2019). PWC (2018) also notes that further guidance is required for companies to understand how to measure impacts and how to connect these to SDGs and targets, and Unerman et al. (2018, p. 516) argue that further research is necessary to explore:

> *[w]ays in which innovations in technology and data analytics can be harnessed to produce more reliable and open externalities information. For example, investigating the potential of blockchain technology to provide open ledgers of individual types of externalities impacts…*

Businesses are often focused on SDG measurement for the purpose of reporting their impacts (Grainger-Brown and Malekpour, 2019), and "it is not directly apparent where the advantage for business lies in pursuit of these actions within the prevailing economic paradigm" (Sullivan,

Thomas & Rosana, 2018, p. 237). However, we propose that combining blockchain technology and the IoT offers a solution to the problem of measuring organisations' impacts on SDGs, and could act as a catalyst for business innovation. After all, innovation "is a key component of knowledge management, as it helps in codifying the repository of available knowledge" and it provides competitive advantage (Huang, Wu, Lu and Lin, 2016, p. 2188). Big Data can also support the measurement of SDGs (Perera-Gomez and Lokanathan, 2019) along with blockchain and the IoT. Big Data and concepts like data philanthropy have been touted as solutions to share data for public benefit, allowing for "quicker updates, more granular detail and possibly lower cost" when measuring and reporting on SDGs and targets (Perera-Gomez and Lokanathan, 2019, p. 2). Despite these benefits, privacy issues and concerns around surveillance and competition prevail (ibid, p. 2). However, IoT combined with blockchain technology can ensure privacy by creating novel identity management (e.g. who the user is) and access management (e.g. what the user can see) systems for data. This also ensures that there is no single point of system failure by using an encrypted, decentralised database of records (Kshetri, 2017). The following sections synthesizes key concepts related to blockchain and the IoT, based on the prior literature.

3. Blockchain

Blockchain technology is a subset of distributed ledger technology, which decentralizes the control of transaction data using an application of cryptography. This produces three overall outcomes: 1) veracity - multiple copies of a transaction confirm the historical record; 2) transparency - all participants are able to view transactions as a public record, and 3) disintermediation - blockchains operating on a peer-to-peer network with no central authority that needs to be trusted (Chartered Accountants, 2017 p. 2; see also, Schmitz and Leoni, 2019). Interest in blockchain technology has increased dramatically (Zhao, Fan and Yan, 2016) and it is most famously used to underpin the way that Bitcoin (and other cryptocurrencies) transact. When users transact using the blockchain, they upload the cryptographically sealed details of their transaction to the peer-to-peer network. A system of private and public keys is used to do so, ensuring that the identities of the transacting parties are verified yet kept anonymous (to a certain degree). These transactions are grouped into blocks, which are given a unique identifier that is based on the data contained within that block, known as a cryptographic hash.

Cryptographic hashes enable transactions to be linked to each other in sequence, where even a small change in a transaction detail creates a significant change in the final hash output (see, Bonsón & Bednárová, 2019). This makes identifying error or fraud within a transaction block straightforward. In public blockchains, blocks are then 'audited' by special nodes on the peer-to-peer network called 'miners'. Miners are tasked with solving a complex mathematical puzzle that verifies each transaction, using cryptographical hash functions; this is called 'Proof of Work', and is a mechanism to reach consensus that transactions are correct. This expends significant computing power and means that, for instance, on the Bitcoin network, only one block of transactions is successfully 'mined' (verified) every 10 minutes. Once a miner solves the cryptographic puzzle, the other users on the network agree the solution is legitimate and the block is mined by adding it to the existing chain of transaction blocks (hence its name: the blockchain).

Then the next sequence of transactions are blocked for verification. Permissioned or private blockchains can use less intensive mechanisms than mining to achieve consensus e.g. voting agreements between known parties (see, for example, Nguyen & Kim, 2018). Permissioned chains allow filtered information to be shared between the parties involved. For instance, Kshetri (2018, p. 69) refers to the IBM Watson IoT Platform's capability of only sharing relevant IoT sensor data with a blockchain. Technologies to improve data filtration of sensitive information via the blockchain continue to evolve (see, for example, Ren et al., 2019). This will eventually allow different 'tiers' of permissions to be encoded onto blockchains based on an entities role; for instance, external financial auditors will have access to sensitive company information (protected by client confidentiality arrangements) compared to a government body responsible for collating sector-wide SDG information.

Smart contracts and decentralized autonomous organisations are technologies within distributed ledger systems that can create space for significant business disruption and innovation. For instance, smart contracts are essentially pre-programmed principles that execute once certain conditions are satisfied. Bodo, Gervais and Quintais (2018) outlines how a smart contract system can be used to essentially decentralize copyright licensing, enabling rights holders to automatically be paid when revenue is received from the sale of works. Decentralised Autonomous Organisations, on the other hand, enable revolutionary governance practices where businesses may even be run without the need for management or employees (Van Rijmenam, Schweitzer and Williams, 2017). Mechanisms such as smart contracts can potentially revolutionise how socially and environmentally responsible behaviour can be incentivised, monitored and punished.

Blockchain has been touted as a technology that will lead to significant disruptions in business, e.g. the accounting and auditing profession's business model, as transactions are now automatically audited and immutable (Schmitz and Leoni, 2019; Carlin, 2019; Ferri et al., 2020). Presently, blockchain technology is nascent although there is significant business and government interest in its varied applications (Hughes et al. 2019). These include using blockchain to significantly disrupt existing business models and drive innovation, for example through 'crowdfunded' companies and reducing the costs of international payments (Nowinksi and Kozma, 2017). Similarly, blockchain technologies are being applied by companies to establish supply chain provenance, which provides "a robust system to trace origin, certifying authenticity, tracking custody, and verifying integrity of products" (Montecchi, Plangger & Etter, 2019 p. 284). This is particularly important in industries, such as diamond mining and the certification of luxury goods, which hold resale value, and has the added benefit of potentially reducing business costs (Choi, 2019). Blockchains can also be applied to services. For instance, an insurance platform called *Insurwave* is providing innovating commercial marine insurance, by using blockchain to manage hundreds of thousands of transactions and relationships with stakeholders, including clients, insurers and brokers (Pournader, Shi, Seuring & Koh, 2019). This enables insurance companies to track the validity of claims faster and to perform analyses, such as whether a particular cargo carrier represents higher risk.

As a result, Pan et al. (2019, p. 8) argue that "establishing a supply chain management platform based on [blockchain technology] can connect the supply chain alliance effectively, build a trusting

supply chain ecosystem, and improve [operational capabilities] of supply chain members". They outline the following applications for blockchain in business including 'purchasing services', where order management, warehouse management and logistics management takes place on the blockchain. The SDG impacts at each of these stages could be measured; for instance, relating to carbon reductions achieved via logistics management. Financial services include project and finance management, which can be controlled through, for instance, smart contracts on blockchains. Risk control services such as credit scores, and risk warnings are possible through reporting algorithms. All of these functions can operate on blockchains as mechanisms to manage operational services, reporting services, data management and data analysis, which links directly to our problem of measuring and managing SDGs with blockchain technology (see, for example, Tan & Low, 2019). Ultimately, this enables blockchains to reduce cost and risk, while increasing speed, reliability, flexibility and sustainability (Kshetri, 2017). Consequently, Pan et al. (2019) show how interconnections between a physical supply chain and related blockchain components are possible, increasing the efficiency and opportunities for innovation across organizational boundaries. However, for some of these opportunities to be realized, blockchains need to be integrated with IoT technology to enable real-time tracking and ensure trust across suppliers and customers (Kshetri, 2017). This is the key feature that blockchain brings to the IoT, enabling trust in a trustless environment using unique identifiers, digital signatures and cryptography (Pournader, Shi, Seuring & Koh, 2019), thus allowing complex targets such as SDGs to be effectively monitored.

The embryonic literature on the interfaces between the IoT and blockchain can provide valuable lessons that can be used in the context of the SDGs, and therefore, we will introduce this in the next section.

4. The IoT and blockchain

The IoT has made inanimate objects and tools capable of sensing and responding to the needs of human users without prompting. The IoT enables devices to 'sense' and then 'act' by communicating and coordinating with each other (Salman and Jain, 2017). Ouaddah, Elkalam & Ouahman (2016, p. 5943) argue that the IoT has "extended the digital world to our real and social life by enabling any things and objects that surround us, to be connected to the Internet". Gubbi et al. (2013, p. 1647) offer a generic definition of IoT and its capabilities as the:

> *Interconnection of sensing and actuating devices providing the ability to share information across platforms through a unified framework, developing a common operating picture for enabling innovative applications. This is achieved by seamless ubiquitous sensing, data analytics and information representation with Cloud computing as the unifying framework.*

Three elements are needed for IoT's potential to be realised: 1) hardware (sensor and communication technology), 2) 'middleware' consisting of storage and computer processing, and 3) knowledge/semantic tools such as visualisation and interpretation tools (Gubbi et al., 2013). We argue that blockchain may also be added as a secure, unifying framework for data storage,

processing and reporting (points 2 and 3), especially in relation to sensitive information between different parties.

IoT can be applied to almost any setting for which appropriate sensors can be developed. For instance, IoT can be applied to industry, by monitoring manufacturing and logistics processes; the environment, through monitoring of recycling and energy management; and society, through understanding how vulnerable communities engage with government services etc. (see, for example, Sundmaeker et al., 2010 p. 49; see also, Gubbi et al., 2013). IoT devices are presently centrally administered, leading to high maintenance costs for suppliers of this technology (e.g. in distributing software updates) (Christdis & Devetsikiotis, 2016). There is also significant consumer uncertainty about security and privacy when their IoT devices are communicating with each other and to outside organisations (Alphand et al., 2018).

As a result, Ouaddah et al. (2016) propose a modified blockchain platform as a way of storing data access rights in order to develop an access control model. This is similar to other proposals for using blockchain technology to manage transactions between 'things' (objects) in a secure manner, using tools such as smart contracts to ensure that actions consistent with user specified goals are realized (Saghiri et al., 2018). Wang et al. (2019) argue that "potential applications of Blockchain in IoT include recording events (such as temperature, moisture or location changes) and creating tamper-resistant ledgers that are readable only to certain parties, e.g., specific participants in a supply chain". The innovative potential of blockchain and IoT synthesis, while still largely untapped, could lead to an evolution in the marketplace of services between devices (Christdis & Devetsikiotis, 2016). For example, in micro energy trading between IoT devices, where residential solar panels generate energy, which is recorded on a blockchain and then bought and sold on the local or national grid, i.e. a peer-to-peer market via smart contracts. This enables recording, measurement, management and autonomy. The characteristics of this kind of system can be incorporated into blockchain and IoT systems that relate to the measurement and management of the SDGs.

In these systems, it is important that the data provided by IoT devices is accurate, and there is potential for accuracy and malicious behaviour of IoT devices to be managed by blockchain verification and authentication algorithms (Wang et al., 2019, p. 16). Indeed, the decentralized and trustless nature of blockchain can be seen as enhancing the privacy and security of IoT systems (Kouzinopoulos et al., 2018). This is done, for instance, by creating unique, verifiable and secure identities on a system that can allow users or objects to interact with each other (see, for instance, Zhu & Badr, 2018). The blockchain has also been suggested as a way forward in sharing potentially sensitive IoT datasets in a secure manner (Banerjee, Lee & Choo, 2018). This could also potentially apply to SDG measurement and management of information confidentially between companies, government bodies and other actors. However, presently, integration of the IoT with blockchain has been most prominent in 'transaction or sharing systems' relating to energy, data and products; 'ownership', relating to data and goods, 'identity management' and 'access control' settings. Possible limitations of the blockchain when integrated with a large number of IoT devices relate to non-homogeneous network structures, and challenges with computing power and available bandwidth (Wang et al., 2019).

A potential systems architecture for integrating blockchain (Ethereum network) with an array of sensors and information is presented by Bocek, et al. (2017, p. 775). Figure 1 is adapted from Bocek et al. (2017) and shows how a blockchain network is used to accurately convey 'back-end' temperature data (for the storage of medicines) to the 'front-end', which is where users interact with the system. Each time a new shipment is ordered by a user, a smart contract is created to ensure compliance of a shipment with the temperature requirements for the medicine (e.g. 2-4 degrees Celsius). In this case, IoT sensors, using Bluetooth communications, monitor and report the temperature of the package from warehouse to final destination. The 'back-end' reconciles this temperature information with user identities to ensure traceability and verifiability (similar to parcel tracking with a courier service). Each medication has its own temperature requirements, and the system automatically calibrate IoT sensors and issues smart contracts accordingly.

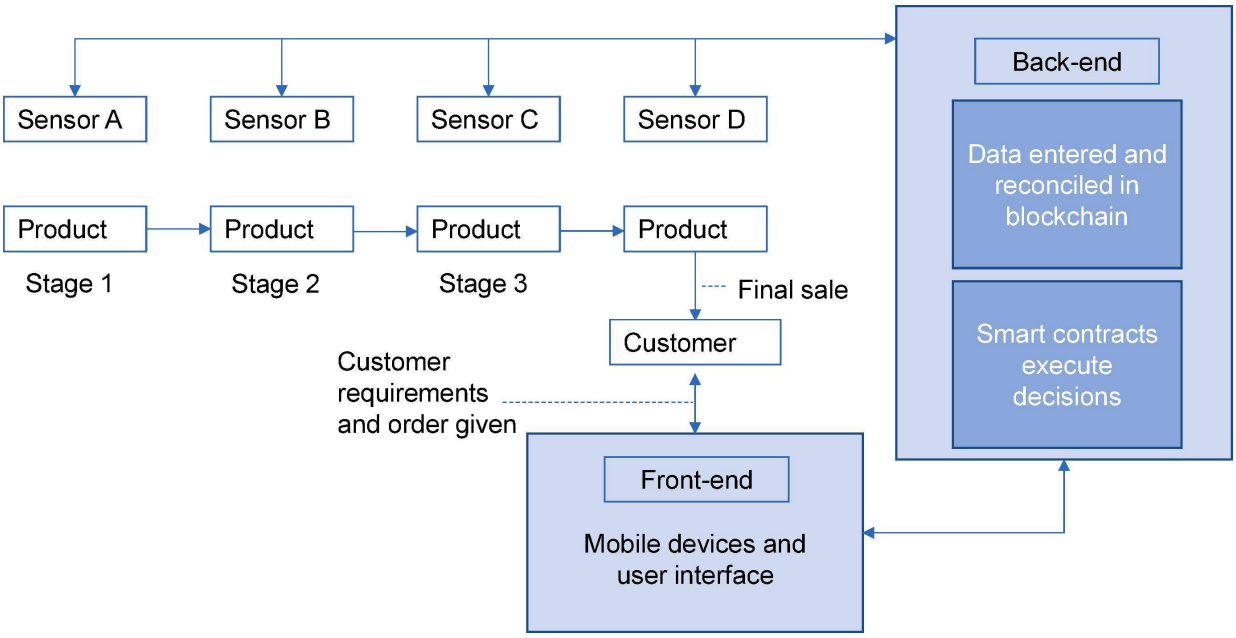

Figure 1: Blockchain in a supply chain. Adapted from Bocek et al. (2017)

The next section introduces concise case examples of the use of these technologies in business. This provides a foundation on which to develop our framework for spurring innovation by integrating the IoT and blockchain to manage SDG performance.

5. Case studies on the IoT and blockchain

The following two case examples illustrate the potential for blockchain and IoT technologies to help businesses innovate through engagement with the measurement and management of SDGs. These cases provide a platform for the example we provide in a subsequent section where we fully apply these ideas to the context of using the IoT and blockchain to measure and manage SDGs.

5.1 The IoT and smart factories

The following example of the use of IoT in 'smart factories' is used to explain how IoT devices are revolutionizing manufacturing and performance measurement. Combined with blockchain technology, applying the IoT to SDG measurement can provide real-time, detailed, and trusted data. The IoT allows the management of manufacturing companies better understand the dynamics of their operations, and provides them with the information needed to adapt and innovate.

IoT technology enables data capture in real-time in performance measurement systems. The authors in Hwang, Lee, Park and Chang (2017) have developed an IoT-based performance measurement model in line with ISA-95 and ISO-22400 by focusing on Overall Equipment Effectiveness (OEE) to gain an understanding of efficiency and productivity. Key Performance Indicators were selected and integrated into a newly designed performance measurement system. Business Process Modelling was then used to implement IoT architecture (Hwang et al., 2017). Finally, the model was evaluated using a virtual factory simulation emphasizing that, at a conceptual level at least, these systems are on business horizons. Even in this case, it is conceivable that increases in efficiency may lead to improvements in SDG impacts. For instance, water consumption can be reduced if a particular tool which uses water is optimised using IoT. This water saving measure (using IoT water sensors for accuracy), or calculated savings via a proxy (number of litres used per batch), can then be encoded on performance measurement systems and reported against SDG 6 – Clean Water and Sanitation. Smart contracts can monitor environmental standards according to pre-set conditions. For example, a buyer may request that a supplier keep the number of 'litres used per product' below a certain limit. If a product falls within agreed standards, then a premium can be automatically paid via a smart contract. Otherwise, a penalty (discount price) may be coded into the smart contract, providing feedback to the supplier to improve water management performance. Ultimately, this type of enhancement to existing performance measurement/management systems could improve organisational accountability by concretising the 'implicit social contract' between firms, society and the environment (see, for example, Giovannucci & Ponte, 2005).

Timestamp data of deliveries was also captured in the model, showing how this type of process can be integrated with blockchain technology to create an immutable and auditable record of events and transactions. This data can then feed into existing performance measurement systems and external reporting. Importantly, the conceptual model developed by Hwang et al. (2017) also creates a platform for extrapolating the capture of SDG specific data using IoT sensors to feed into performance measurement systems, which can then be actively managed by companies. This allows company management to widen their attention to their business operations, creating space for innovation to take place. Companies like Bosch with its Cross Domain Development Kit are already developing commercial IoT sensors and software solutions for other companies to use to collect real-time data (see, Bosch, https://xdk.bosch-connectivity.com/).

As a result, Zhang and Weng (2015) argue that traditional business models need to innovate in order to cope with future e-business activities. They propose an 'e-business' model architecture which redesigns existing business elements to integrate IoT technology. The authors suggest that this remodelling also opens up possibilities for transactions, such as those involving the secure

exchange of property and the peer-to-peer trade of IoT data using the blockchain and smart contracts. Using smart contracts in business performance management and measurement has the ability to allow organisations to better engage with their stakeholders (such as suppliers and customers), "positively improving the financial openness of a firm, by promoting safety, security, accuracy and integrity of the organizational financial transactions" (Allam, 2018 p.144). Ultimately, this allows performance measurement and management to cross organisational boundaries. For instance, it can be envisaged that a business can incentivize proper reuse and recycling behaviour by using smart contracts to automatically provide a rebate to those customers who recycle their used products correctly using blockchain technology.

The key issues identified by the above examples are the tracking and tracing potential of using the IoT with blockchain technology and how this can feed into performance measurement systems. IoT sensors can capture a range of data such as temperature or water consumption at the time a specific product was made and enter this data automatically into a blockchain to create an immutable record. This data can then be aggregated to provide insight into the way that company operations impact particular SDGs, such as water conservation (SDG 6). This can then lead to company management having a much stronger insight into the full costs (Unerman et al. 2018) of their products, leading to behaviours to drive costs down and thereby achieve stronger SDG performance. However, organisational performance measurement systems will need to evolve to capture cross-boundary interactions, which affect SDG outcomes. Performance measurement and management systems are already shifting to support broader sustainability reporting processes (see, Traxler, Schrack & Greiling, 2020). Permissioned blockchains may blur organisational boundaries by reporting water usage, for example, throughout a supply chain. This could lead to a drastic rethinking of water management across interconnected firms, and spur innovation by forcing organisations to view performance holistically.

5.2 Blockchains in pharmaceutical and construction supply chains

This case study describes how blockchains are being used in supply chains. Combined with IoT technology, it demonstrates how traceability, transparency, and trust can enable marketplaces for novel goods and services (see also, Pournader et al., 2019). The security that blockchain offers, together with the measurement capabilities of new IoT devices and sensors, enables a variety of SDGs to potentially be measured in the future, as explained in a subsequent section.

Blockchains are the subject of significant interest from start-up firms. While financial applications have seen the most interest, blockchains usage in other areas is starting to increase. Bocek et al. (2017) explores modium.io, a start-up, which applies both blockchain and IoT technology to the pharmaceutical industry supply chain. Quality control is of primary importance in the medical industry, where strict regulations and standards apply. The paper documents how modium.io uses IoT sensors to constantly monitor the temperature of medicines to ensure compliance with standards. Data is registered on blockchains, which then monitors the supply chain using smart contract systems. For instance, smart contracts are executed based on assessing monitoring conditions are met. Ultimately, Bocek et al. (2017) outline how a system of integrating blockchains management and accountability aspects with the sensing and measurement capabilities of the IoT can significantly reduce administrative burden and ultimately save costs. These elements highlight

the ability for technology to improve quality and accountability in existing supply chain management, enabling business innovation that may ultimately allow modium.io to compete with much larger businesses, especially in sensitive or specialist areas.

Heiskanen (2017) also supports these benefits in their application of the IoT and blockchain in the construction industry. A construction project is complex, involving many different processes, people and products. Information and workflow management is crucial in such a setting where communication issues, wastage and the potential for legal ramifications exist. Heiskanen (2017) provides a framework for integrating blockchain and the IoT in the construction industry, which would lead to collaboration between multiple businesses and significant increases in productivity. For instance, integrating IoT tracking and blockchain smart contracts could increase the responsiveness and flexibility of just-in-time production systems by many orders of magnitude. Researchers are already working in this space, designing new integrated blockchain and IoT architectures to improve security using private/permissioned blockchains and providing useful information to manage performance (see, for example, Hang & Kim, 2019).

In a similar vein, specialist blockchain platforms, such as VeChain, have created a unique business model where the blockchain "derives its value from activities created by members within the ecosystem solving real world economic problems" (vechain.org 2019). VeChain is enabling application developers to tackle a wide range of issues. Its recent whitepaper identified a number of case studies where the IoT and blockchain were being successfully integrated. For instance, counterfeiting of luxury goods has been identified as a problem costing more than $1 trillion USD (VeChain Foundation, 2019). VeChain's application solution essentially creates a 'double chain' linking physical products with a digital blockchain identifier, which uses Near Frequency Contact tags. This ensures that physical goods can be tracked across lifecycles of production and across all levels of the supply chain, which VeChain argues, is "powerful tool for authentication, traceability, storytelling and digital marketing purposes. In addition, the ownership of the product on the blockchain is tied to the user's account and can be transferred on the B2C and C2C markets to provide consumers with a personalized experience" (VeChain Foundation, 2019).

These examples highlight how blockchain and the IoT can increase trust, transparency and innovation across supply chains. By opening up relationships between customer and buyer, blockchain and the IoT create integrity in all parts of the value chain. This enables final retail consumers to verify the exact origin of goods. These characteristics could enable documentation of the product or service on a SDG, for example contributing to SDG 12, responsible consumption and production. Such tracing across supply chains (and integrity) allows new markets to be created, e.g. in ethical consumption, or to verify organic produce that does not use synthetic fertilizers, contributing to SDG 15, life on land. Therefore, trust itself can become a valuable commodity for businesses that are willing to engage and innovate using the SDGs.

Table 2: Conceptual framework for IoT and blockchain usage

		Start-up companies		Mature companies	
		Create new tech	**Use existing tech**	**Create new tech**	**Use existing tech**
Non-SDG engaged	**Block-chain**	Use blockchain to create new applications that transform society and the way that stakeholders interact with each other **(1)**	Use permissioned blockchains to increase transaction efficiency, reduce administration and streamline governance structures by using smart contracts **(2)**	Use blockchain to evolve the way existing products and services are created and delivered **(3)**	Use public blockchains to conduct transactions (receive payments from Bitcoin) **(4)**
	IoT	Create new sensors, interfaces and software platforms that enable business and consumer interactions **(5)**	Invest in existing sensor technology to gather data on existing business operations and gain competitive advantage compared to mature firms **(6)**	Invest in or joint ventures with other firms to develop sensor technology based on existing products and services and knowledge of markets **(7)**	Limited integration of the IoT to reduce business costs e.g. power sensors **(8)**
SDG engaged	**Block-chain**	Use blockchains to create new governance structures using smart contracts and decentralized autonomous organisations that specifically partner to engage and manage the SDGs e.g. a portion of each transaction is donated to a social cause **(9)**	Use blockchain to reimagine existing business processes and performance measurement systems, with a specific focus on engaging with SDGs or social outcomes e.g. social enterprises like Plastic Bank using IBM Blockchain Platform to change recycling practices **(10)**	Invest into blockchain development to create new solutions to monitor, track and manage SDGs between existing customers and suppliers **(11)**	Use permissioned and public blockchains to monitor and manage issues like provenance across global supply chains and verified information and reporting to manage SDGs. Use this to gain advantage – lower risk and access new equity/debt opportunities **(12)**
	IoT	Develop new IoT sensors that specifically enable various SDG targets to be tracked. Relationships can then be managed using this new IoT data using smart contracts and the blockchain **(13)**	Use existing sensor technology to monitor material SDGs relevant to start-ups and use this to build B2B relationships and develop customer loyalty on social and environmental issues **(14)**	Develop IoT technologies which transform data capture for existing social and environmental performance measurement systems (PMS), or use IoT and blockchain to create new PMS that monitor SDGs across span organisational boundaries **(15)**	Extensive integration of the IoT to track, monitor and reduce impacts related to SDGs such as GHG emissions **(16)**

6. SDG management with the IoT and blockchain

The conceptual framework we propose in Table 2 exposes and explores the different ways SDG management can be integrated with the IoT and blockchain to achieve business innovation. Our framework suggests various layers of technology integration can largely mirror (and extend) existing company measurement and reporting practices. As we have shown, business interest in the SDGs has often been superficial and companies often do not proactively manage SDGs. Our framework highlights the many ways that businesses could engage with, and manage, SDGs providing access to rich data in real-time that can spur innovation, including uncovering new business opportunities.

Innovation takes different forms and organizations along a continuum from start-ups to mature companies can access opportunities. In Table 2, "create new tech" refers to firms (including start-ups) creating a blockchain or IoT product or service to sell to others, while "use existing tech" involves integrating existing blockchain or IoT solutions into current product or service delivery. The framework shows that there are many opportunities to innovate by engaging with technology to reconceptualise existing business processes and practices. We use a narrow definition of start-ups and mature companies. Start-ups are typically within the first years of inception, have limited capital to invest, and are likely to be in the 'tech' sector. Mature companies have typically been operating for many years and have substantial capital reserves and access to extensive supply chains and markets. The table is further split between SDG engaged and non-SDG engaged businesses. The former refers to businesses, which seek to integrate SDG management and reporting into their business operations, whereas the latter, are not yet involved in doing so. Non-SDG engaged businesses are still embryonic in their understanding of and engagement with social and environmental issues, or are presently focused on 'traditional' business-as-usual pathways for growth. As we show, engagement with the SDGs can spur innovation. This offers practical ways for management to consider their business impacts and use technology to address unwanted negative externalities, while at the same time gaining information to enhance their competitive position. As Sullivan, Thomas and Rosano (2018, p. 243) states: "…innovation in the pursuit of sustainability outcomes can also lead to a competitive advantage for business, through the opening of new markets, products, and business models".

Furthermore, how SDGs are measured and managed can be transformed with technology. As noted earlier, how easily an SDG indicator can be measured is represented by three tiers. The boundaries separating the various tiers of SDG indicators will reduce as blockchain and IoT technologies develop. New IoT sensors may introduce previously unknown information/variables (e.g. sensors combined with Artificial Intelligence) to refine the existing measurement methodologies for Tier 1 indicators. Using IoT and blockchain to measure Tier 1 indicators is feasible within present business models (e.g. kilowatts of energy consumed by a device). Data availability for the more challenging Tier 2 indicators will improve with appropriate incentives to develop new IoT sensors. This will shift Tier 2 indicators into the Tier 1 category, and eventually, narrow the gap to measuring Tier 3 indicators.

Sector **(1)** on Table 2 discusses how a start-up company can produce blockchain solutions for other companies or clients, while not necessarily integrating any aspects of SDGs into their

applications/platforms. BitCoin, the now famous cryptocurrency that spurred interest in the blockchain could be such an example. Since its inception, BitCoin has revolutionised the way that some customers and businesses interact, with the total value of all Bitcoin transactions exceeding $100bn USD in 2018 as noted on the platform's website – recently, even small cafés have started to accept BitCoin as a payment option (see, for example, www.bitcoin.org/en/spend-bitcoin). However, BitCoin as a platform does not specifically engage with SDGs as part of its core purpose, and concerns have been raised about how the cryptocurrency can be used to trade in illicit material and potentially cause significant environmental harm due to the vast amount of electricity required to produce and manage the cryptocurrency (Popper, 20 January 2018). New start-ups, which are not explicitly SDG engaged, but are driven by broader social and ethical values are emerging. Cryptocurrencies such as FairCoin, who have developed a mechanism to reduce energy consumption in running a blockchain and argues it only deals with 'fair' products and services using a grassroots approach (fair-coin.org/en/comparing-currencies). This type of company can be classified in sector **(9)** of Table 2. Other companies or social enterprises, can potentially use platforms like FairCoin to interact with customers, and could donate money to social and environmental causes aligned with SDGs. Or use existing solutions such as IBM's Blockchain Platform to transform the way that people interact on SDG issues e.g. Plastic Bank which uses blockchain to revolutionise recycling (https://plasticbank.com/about/). Such organisations are operating in sector **(10)** of our framework (see also section 7 example 2).

Concepts such as VeChain outlined above can be used by mature companies in sectors **(11)** and **(12)** to ensure supply chain provenance (traceability), signify authenticity and document contributions to SDGs. Combining the 'double chain' system that VeChain proposes, mature companies can integrate IoT sensors to track the physical flow of goods and reconcile this with blockchain records in sectors **(12)** and **(16)** of the framework. Mature companies such as Bosch, as outlined earlier, have already developed IoT sensor technology, which they are selling commercially to other firms illustrating sector **(7)**. As an example of a sector **(8)** company, some of this sensor technology has immediate applications in industries such as mining to ensure condition monitoring, to ensure asset performance and compliance to regulations (see, for example, Australian Mining, 20 March 2017). Fu, Shu & Liu (2018) discuss how blockchain and IoT technology can be used to reduce carbon emissions in the clothing manufacturing lifecycle, providing a sense of companies working in sectors **(15)** and **(16)**.

Please note that the cells provided in the diagram are meant to illustrate potential opportunities and are not intended to be mutually exclusive. For instance, a start-up may create innovations to the way that existing products and services are delivered **(3)** (e.g. in the rise of food delivery companies because of the COVID-19 pandemic)**.** However, it is more likely that mature companies fall into **(3)** as they may have invested more resources in understanding existing markets, customers, products/services etc. This may better position them to understand ways for blockchain solutions to be integrated into existing value chains.

In the next section, we provide more complete examples to illustrate how both mature and start-up businesses can take advantage of the opportunities represented in the framework (Table 2).

7. Examples of the use of IoT and blockchain technology by a (social) enterprise to facilitate SDG indicator measurement

One of the key challenges with the SDGs is that activities in developing countries cannot be measured accurately, and there is a lack of trust because of endemic corruption and governance issues (Mehta et al. 2018). Nonetheless, vast sums of money are transferred from developed to developing nations each year to support a variety of SDG related projects, such as carbon offset schemes (SDG 13 – Climate Action) and recycling and re-use schemes (SDG 12 – Responsible Consumption and Production). However, understanding the impact of these initiatives is often impossible, other than to document broad qualitative impacts on communities in developing countries. The use of IoT and blockchain technologies can offer a solution to these issues, and consequently, highlight opportunities for business innovation to create new markets, services and products, as shown in Table 2.

7.1 Example 1: Solar-powered electricity production and trading (SDG 13)

PowerLedger is a blockchain based energy trading platform that, in its own words:

> "…allows for peer-to-peer energy trading from rooftop solar panels. Using blockchain technology we empower households to trade their excess rooftop solar power with their neighbours. Our technology can also be used to trade renewable energy and environmental commodities. We want to create new markets for energy from renewable sources" (www.powerledger.io).

IoT devices that connect to communication nodes (Christdis & Devetsikiotis, 2016) and integrate with blockchain platforms can help mature companies track carbon emission reductions for SDG 13 (sector **(16)** of Table 2). For instance, using a blockchain system like PowerLedger with solar panels, mature companies (in both developing and developed countries) can, for instance, invest in solar energy carbon offset schemes in developing countries. For example, Qantas currently offers its customers an opportunity to pay an extra fee on top of the flight fare to offset the carbon emissions caused by the customer's flight. However, to improve trust and the transparency of this scheme, this additional fee could be registered on a blockchain as a credit token (e.g. sector **(11)**). When sufficient credits are received, a smart contract can transfer these credit tokens to fund a village or neighbourhood solar offset project run by a start-up company or a non-governmental organisation (NGO) operating in a developing country. The use of fireplaces for heating and cooking cause significant carbon emissions and has other negative environmental consequences, such as deforestation and subsequent soil erosion, in certain regions in the world. The purpose of a solar offset project could be to reduce the need for firewood and carbon emissions for heating and cooking. Such a project, through start-ups or NGOs in developing countries, could install solar panels on roofs in a neighbourhood and set up the trading infrastructure required (e.g. smart meters to people's homes that allows them to monitor energy usage) (e.g. sectors **(13)** or **(14)**). These smart meters (IoT) can either connect to the internet individually or connect to a communication node, i.e. the neighbourhood's shared Wi-Fi router, which records and reports on energy use within the neighbourhood through a blockchain. The blockchain acts as the mechanism by which households in the neighbourhood can buy and sell energy as required (e.g. sector **(9)** or **(10)**).

An IoT based electric heating system installed in a household can trade energy with the neighbourhood through the blockchain. In doing so, the blockchain is able to monitor carbon emissions saved from the use of renewable solar energy rather than firewood (e.g. sector **(16)**). An organization, such as Qantas (and its customers), would then be able to track the impact of their offset spending and measure the impact on SDG 13, climate action (e.g. sector **(11)**).

Using Table 2, this example shows how IoT and blockchain technology can provide new innovative solutions in developing countries via start-ups, and how mature businesses such as Qantas can also leverage this to integrate SDG impact measurement and verify the outcomes of its carbon investments. It also illustrates how this technology can innovate the way that firms and consumers interact from both a production and consumption perspective.

7.2 Example 2: Ethical consumption and production of cocoa (SDG 12)

The following kind of system represents new business opportunities from ethical consumption and production. Individuals in developed countries purchase a small product or service, which provides them with immediate utility, and can also contribute to a social and environmental cause. For example, the customer pays for a cup of coffee or the use of an electric scooter. Their payment is used to provide the product/service, as well as to subsidise individuals in developing countries to undertake activities that contributes to one of the SDG indicators. An automated measurement system records this action in the developing country and feeds it into a blockchain. In addition to the income stream from paying customers, the business promoting and underpinning this blockchain receives donations from other businesses on the basis that these donations contribute towards a SDG indicator (e.g. sectors **(9)** or **(11)**). The incentive for other businesses to provide funding is that they will be able to claim that they are contributing towards a SDG, which is preferably closely related to their core business (e.g. sectors **(10)** and **(12)**).

The characteristics described here, can be found in a United Nations Development Program and FairChain Foundation funded project involving Ecuadorian cocoa farmers. This project developed 'The Other Bar', which has been touted as the world's first blockchain shared value bar (United Nations Development Programme, 2020). When a consumer buys one of these chocolate bars, they are able to scan a blockchain-based token, which can be used to purchase carbon offsets (e.g. plant a tree) or receive a discount on their next purchase, driving consumer based ethical consumption (SDG 12) (sector **(10)**). Figure 2 illustrates how this system operates. As the blockchain records value across the supply chain, farmers receive significantly more money than through normal market systems, which is claimed to generate profits so that:

> "…farmers can hire people to help during the vital harvest period, and the tree planting component of the project enables more carbon dioxide storage, helping to combat climate change. High wages are translating to more jobs, training, skills, and opportunities for young people" (United Nations Development Programme, 2020).

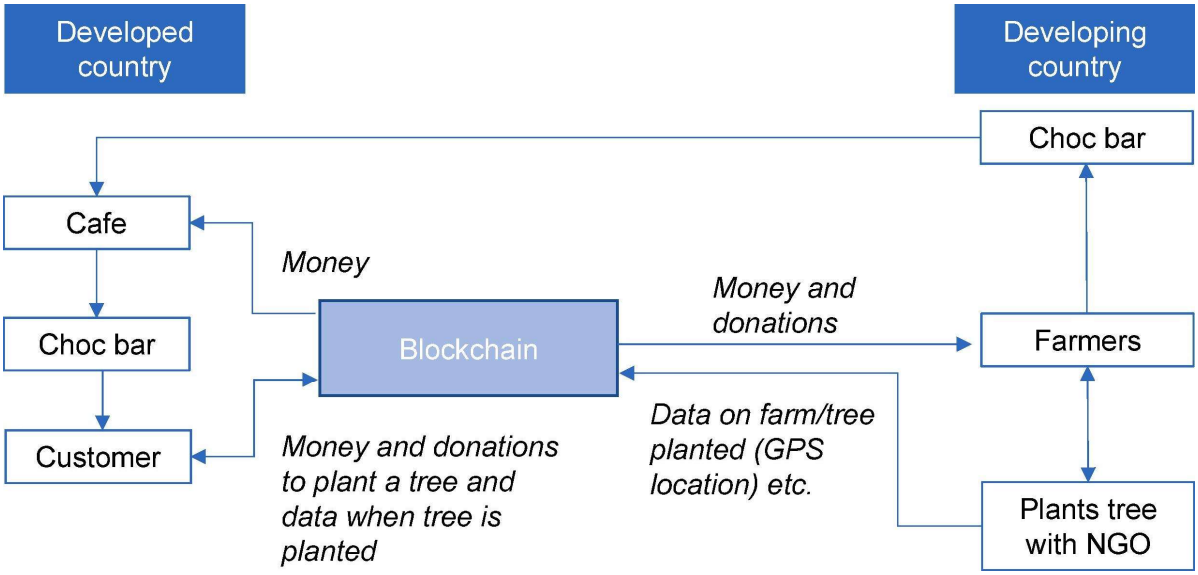

Figure 2: Example blockchain system for SDG12

Furthermore, with the introduction of IoT and blockchain technology, the savings delivered by carbon offsets can be quantified, and verified (e.g. sector **(16)**). Even staff employed and the training/skills they have can be recorded on blockchains, enabling SDG 8, decent work and economic growth, to also be monitored. In our framework (Table 2), this example fits into the SDG engaged blockchain start-ups section (sector **(9)** and **(10)**), but can evolve into other areas. For example, integrating IoT technology into the production and distribution of cocoa and chocolates can lead to a focus on production side dynamics (sector **(13)**) and stronger, more transparent B2B relationships (e.g. sector **(14)**).

8. Discussion and conclusion

This paper produces a conceptual framework that shows how business can use IoT and blockchain technology to drive innovation and new business opportunities related to the promotion of the UN SDGs. Developments in IoT and blockchain technology are rapidly transforming the way that mature and existing business models function, while creating new space for start-up companies to innovate and for social enterprises (which have a stronger social purpose) to emerge. IoT technology enables instantaneous and accurate measurement of data (such as temperature, weight, carbon emissions, etc.) by enabling various devices to relay information across a wide network of users. Blockchain technology enables data to be accurately and immutably recorded, transparently reported and maintains integrity by distributing this data to a network, ensuring trust in the accuracy of the data. The characteristics of these technologies have the potential to provide novel solutions for measuring and managing activities.

At the same time, there is growing societal and business interest in engaging with the UN SDGs. These Goals set an ambitious agenda for the key social, environmental and economic concerns that need to be addressed to ensure a prosperous and peaceful world. While there is interest in the

SDGs, firms are often engaging with these goals in a superficial manner, leaving many of the opportunities we highlight in our framework, shown in Table 2, untapped.

While Table 2 delineated between IoT and the blockchain, the true potential of both of these technologies is likely to be realised when they are integrated. Using IoT as an accurate data measurement tool with blockchain as an accurate/immutable data storage/management/reporting system can significantly improve the way that complex SDG data is captured across organisational boundaries. SDG targets can then be used as a mechanism to reward/punish certain types of behaviour by using blockchain smart contracts. This would fundamentally change the narrow scope of existing organisational performance measurement systems, and alter the implicit social contract organisations' have with society to one that is more explicit and actionable. Ultimately, these new systems could change how different stakeholders interact with each other, and hold each other accountable e.g. via ethical consumption as explained in Example 2. Ultimately, these changes may create opportunities for innovation in mature businesses, as well as opportunities for start-ups and new social enterprises.

We make a number of contributions to the literature. First, we show pathways for how businesses can engage with the SDGs, and incorporate technology, to exploit novel opportunities in existing markets and develop new markets. This adds to important, emerging work on sustainable business models and blockchain technology (Massaro et al., 2020). Furthermore, we highlight mechanisms for cooperation between firms, other organisations, and stakeholders, who may all have different goals, but could find common ground through the kind of IoT/blockchain networks we foresee and provide examples of, e.g. airline carbon offset schemes partnering with solar electricity social enterprises in developing country. This provides an important perspective into possibilities for collaboration and partnership between companies, which will be increasingly important during the post-COVID 19 economic recovery (see, for example, Kuckertz et al., 2020). The role of technology on developing sustainability reporting and communication has been recognised (see, Lodhia & Stone, 2017; Lodhia, 2018). This paper explains how IoT and blockchain technologies can be used by businesses to transform business practices and promote SDGs to create 'win-win-win' outcomes (Burritt and Schaltegger, 2010). Finally, we outline how challenges regarding the lack of existing SDG measurement capabilities can be improved at the organisational level, enhancing credibility and trust concerning sustainability activities.

The application of these technologies are, however, nascent and further work needs to be done to examine and develop the conceptual ideas furnished in our framework (Table 2). In particular, there are still limitations about how blockchain technology can be embedded into business practices (Kend and Nguyen, 2020) and concerns about the energy consumption, scalability and complexity of integrating IoT with blockchain (Rejeb, Keogh & Treiblmaier, 2019). The proliferation of IoT devices has also created diverse network structures and issues with computing power and bandwidth (Wang et al., 2019). However, there is a growing body of research, which seeks to address these issues, and show pathways forward (Makhdoom et al., 2019). Prior research also illustrates the difficulties in deploying existing organisational processes to measure and report on SDGs (see, for example, Yaybroke, 2017), and therefore, alludes to the problems that may arise with adding further technological complexity to the process. This may be in the form of

organisational inertia to change, characterised by a reluctance by company employees to engage with new technology. Nonetheless, the COVID-19 pandemic may have accelerated trends for greater engagement with technology (Barnes, 2020), and opened up new possibilities for businesses to integrate technology into sustainable practices (Massaro et al., 2020). Therefore, from a business perspective, we call for empirical work on how the interface between the IoT and blockchain is leading to business innovation, both intended and emergent, specifically:

1. How do start-ups use the IoT or blockchain in their business models and how has this transformed relationships with stakeholders in society and driven business innovation?
2. How are large and mature firms adopting IoT or blockchain technology to transform existing business models and create new ones?
3. How and to what extent has technology, such as the IoT and blockchain, led to stronger business relationships across supply chains and what are the potential implications of this on competition and growth?
4. How have IoT and blockchain technology led to better measurement and management of SDGs? And how and to what extent has this enabled 'win-win-win' situations for business, society and the environment?
5. What are the challenges (e.g. changing stakeholder attitudes) and limitations of integrating IoT and blockchain technology into new and existing businesses?

These are broad calls to action meant to spur the in-depth, engaged and cross-disciplinary research needed for sustainable business innovation. Given the rapid growth of many start-ups during the COVID-19 pandemic, it is important to understand the potential for IoT and blockchain technologies to drive innovation in new companies. This can then be contrasted with mature organisations, which most likely have greater resource bases, yet are probably less nimble in terms of organisational structures and processes. The way these different types of businesses engage with technology will also fundamentally affect how SDG impacts are measured, managed and used to innovate. Addressing these questions will advance our knowledge of how technology may play a stronger role in the way that business evolves in the future to build bridges between the profit motive and broader societal concerns, as articulated in the SDGs.

References

Accenture & United Nations Global Compact [UNCG] (2019). *The decade to deliver: A call to business action*. Available at: https://www.accenture.com/_acnmedia/PDF-109/Accenture-UNGC-CEO-Study.pdf [accessed 26 March 2020].

Accenture (2016*). The UN Global Compact-Accenture Strategy CEO Study 2016 Agenda 2030: A Window of Opportunity Accenture Strategy*. Available at: www.accenture.com/us-en/insight-un-global-compact-ceo-study [accessed 15 February 2019].

Allam, Z. (2018), 'On smart contracts and organisational performance: a review of smart contracts through the blockchain technology', *Review of Economic and Business Studies*, vol. 11 no. 2, pp. 137-156.

Alphand, O., Amoretti, M., Claeys, T., Dall'Asta, S., Duda, A., Ferrari, G., Rousseau, F., Tourancheau, B., Veltri, L. & Zanichelli, F. (2018, April), *IoTChain: A blockchain security architecture for the Internet of Things*. In 2018 IEEE Wireless Communications and Networking Conference (WCNC) (pp. 1-6). IEEE.

Banerjee, M., Lee, J., Choo, K-K. R. (2018), 'A blockchain future for internet of things security: a position paper', *Digital Communications and Networks*, vol. 4 no. 3, pp. 149-160.

Barnes, S. J. (2020), 'Information management research and practice in the post-COVID-19 world', *International Journal of Information Management*, online first.

Bebbington, J. & Unerman, J. (2018), 'Achieving the United Nations Sustainable Development Goals: An enabling role for accounting research', *Accounting, Auditing & Accountability Journal*, vol. 31 no. 1, pp. 2-24.

Bocek, T., Rodrigues, B.B., Strasser, T. & Stiller, B. (2017), 'Blockchains everywhere—A use-case of blockchains in the pharma supply-chain', Proceedings of IFIP/IEEE Symposium on. Integrated Network and Service Management (IM), Lisbon, Portugal, May 2017, pp. 772–777.

Bodó, B., Gervais, D., & Quintais, J. P. (2018), 'Blockchain and smart contracts: the missing link in copyright licensing?', *International Journal of Law and Information Technology*, vol. 26 no. 4, pp. 311–336.

Bosch. XDK Cross Domain Development Kit. Available at: https://xdk.bosch-connectivity.com/

Bonsón, E., & Bednárová, M. (2019), 'Blockchain and its implications for accounting and auditing', *Meditari Accountancy Research*, vol. 27 no. 5, pp. 725–740.

Burritt, R., & Schaltegger, S. (2010), 'Sustainability accounting and reporting: fad or trend?', *Accounting, Auditing & Accountability Journal*, vol. 23 no. 7, pp. 829-846.

Carlin, T. (2019), 'Blockchain and the Journey Beyond Double Entry', *Australian Accounting Review*, vol. 29 no. 2, pp. 305–311.

Chartered Accountants (2017). *The future of Blockchain: Applications and implications of distributed ledger technology*. Available at https://www2.deloitte.com/content/dam/Deloitte/au/Documents/Economics/deloitte-au-economics-future-inc-caanz-blockchain-010217.pdf [accessed 26 March 2020].

Choi, T-M. (2019), 'Blockchain-technology-supported platforms for diamond authentication and certification in luxury supply chains', *Transportation Research Part E: Logistics and Transportation Review*, vol. 128, pp. 17-29.

Christidis, K., & Devetsikiotis, M., (2016), 'Blockchains and Smart Contracts for the Internet of Things', IEEE Access, vol. 4, pp. 2292-2303.

Dai, J. & Vasarhelyi. (2017), 'Toward Blockchain-Based Accounting and Assurance. *Journal of Information Systems'*, vol. 31 no. 3, pp. 5-21.

Deloitte (2018). *The rise of the social enterprise: 2018 Deloitte Global Human Capital Trends*. Available at: https://www2.deloitte.com/content/dam/insights/us/articles/HCTrends2018/2018-HCtrends_Rise-of-the-social-enterprise.pdf [accessed 26 March 2020].

Frey, C.B. & Osborne, M. (2017), 'The future of employment: How susceptible are jobs to computerisation?', *Technological Forecasting and Social Change*, vol. 114, pp. 254-280.

Fu, B., Shu, Z., & Liu, X. (2018), 'Blockchain enhanced emission trading framework in fashion apparel manufacturing industry', *Sustainability*, vol. 10 no. 4, 1105.

Giovannucci, D., & Ponte, S. (2005), 'Standards as a new form of social contract? Sustainability initiatives in the coffee industry', *Food Policy*, vol. 30 no. 3, pp. 284–301.

Grainger-Brown, J. & Malekpour, S. (2019), 'Implementing the Sustainable Development Goals: A Review of Strategic Tools and Frameworks Available to Organisations', *Sustainability*, vol. 11 no. 5, pp. 1-18.

GRI & UNGC (2017). *Business reporting on the SDGs: An analysis of the goals and targets*. *GRI & UNCG*. Available at: https://www.unglobalcompact.org/docs/publications/GRI_UNGC_SDG_Reporting_An_Analysis_of_Goals_and_Targets_2017.pdf [accessed 21 February 2019].

Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013), 'Internet of Things (IoT): A vision, architectural elements, and future directions. Future Generation Computer Systems', vol. 29 no. 7, pp. 1645–1660.

Halisçelik, E. & Soytas, M. A. (2019), 'Sustainable development from millennium 2015 to Sustainable Development Goals 2030', *Sustainable Development*, online first.

Hammi, M. T., Hammi, B., Bellot, P., & Serhrouchni, A. (2018), 'Bubbles of Trust: A decentralized blockchain-based authentication system for IoT', *Computers & Security*, vol. 78, pp. 126-142.

Hang, L. & Kim, D.-H. (2019), 'Design and implementation of an integrated IoT blockchain platform for sensing data integrity', *Sensors*, vol. 19, 2228.

Heiskanen, A. (2017), 'The technology of trust: How the Internet of Things and blockchain could usher in a new era of construction productivity', *Construction Research and Innovation*, vol. 8 no. 2, pp. 66-70.

Huang, K-E., Wu, J-H., Lu, S-Y., & Lin, Y-C. (2016), 'Innovation and technology creation effects on organizational performance', *Journal of Business Research*, vol. 69 no. 6, pp. 2187-2192.

Hughes, A., Park, A., Kietzmann, J., Archer-Brown, C. (2019), 'Beyond Bitcoin: What blockchain and distributed ledger technologies mean for firms', *Business Horizons*, vol. 62 no. 3, pp. 273-281.

Hwang, G., Lee, J., Park, J. & Chang, T-W. (2017), 'Developing performance measurement system for Internet of Things and smart factory environment', *International Journal of Production Research*, vol. 55 no. 9, pp. 2590-2602.

Ike, M., Donovan, J. D., Topple, C. & Masli, E. M. (2019), 'The process of selecting and prioritising corporate sustainability issues: Insights for achieving the Sustainable Development Goals', *Journal of Cleaner Production*, vol. 236, online first.

International Institute for Sustainable Development [IISD] (2018, December 11). *Paper Outlines SDG Measurement Challenges*. Available at: https://sdg.iisd.org/news/paper-outlines-sdg-measurement-challenges/ [accessed 26 March 2020].

Issa, H., Sun, T., & Vasarhelyi, M. A. (2016), 'Research ideas for artificial intelligence in auditing: The formalization of audit and workforce supplementation', *Journal of Emerging Technologies in Accounting*, vol. 13 no. 2, pp. 1-20.

Kend, M., & Nguyen, L. A. (2020), 'Big Data Analytics and Other Emerging Technologies: The Impact on the Australian Audit and Assurance Profession', *Australian Accounting Review*, online first. auar.12305.

Košťál, K., Helebrandt, P., Belluš, M., Ries, M., & Kotuliak, I. (2019), 'Management and Monitoring of IoT Devices Using Blockchain', *Sensors*, vol. 19 no. 4, pp. 856.

Kouzinopoulos C.S. et al. (2018). *Using Blockchains to Strengthen the Security of Internet of Things*. In Gelenbe, E. et al. (Eds.), *Security in Computer and Information Sciences*. Euro-CYBERSEC 2018. Communications in Computer and Information Science, vol 821. Springer, Cham.

Kshetri, N. (2017), 'Can Blockchain Strengthen the Internet of Things?,' *IT Professional*, vol. 19, no. 4, pp. 68-72.

Kshetri, N. (2018), 'Blockchain's roles in meeting key supply chain management objectives', *International Journal of Information Management*, vol. 39, pp. 80-89.

Kuckertz, A., Brändle, L., Gaudig, A., Hinderer, S., Morales Reyes, C. A., Prochotta, A., … Berger, E. S. C. (2020). 'Startups in times of crisis – A rapid response to the COVID-19 pandemic', *Journal of Business Venturing Insights*, vol. 13, e00169.

Lodhia, S. (2018), 'Is the medium the message?: Advancing the research agenda on the role of communication media in sustainability reporting', *Meditari Accountancy Research*, vol. 26 no. 1, pp. 2-12.

Lodhia, S., & Stone, G. (2017), 'Integrated Reporting in an Internet and Social Media Communication Environment: Conceptual Insights', *Australian Accounting Review*, vol. 27 no. 1, pp. 17-33.

MacFeely, S. (2018), 'The 2030 Agenda: An unprecedented statistical challenge', Friedrich Ebert Stiftung, New York, available at: http://library.fes.de/pdf-files/iez/14796.pdf

Makhdoom, I., Abolhasan, M., Abbas, H., & Ni, W. (2019). 'Blockchain's adoption in IoT: The challenges, and a way forward', *Journal of Network and Computer Applications*, vol. 125, pp. 251–279.

Massaro, M, Mas, F, Jabbour, CJ, Bagnoli, C. (2020). 'Crypto-economy and new sustainable business models: Reflections and projections using a case study analysis', *Corporate Social Responsibility and Environmental Management*, online first.

McKinsey Global Institute (2013). *Disruptive technologies: Advances that will transform life, business, and the global economy*. McKinsey Global Institute. Available at: https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/disruptive-technologies [accessed 17 July 2019].

Mehta, S., Kumar, V., & Kumar, A. (2018). 'The Way Forward: Advancing UN Sustainable Development Goals in India and Bangladesh'. In *Lessons in Sustainable Development from Bangladesh and India* (pp. 103-121). Palgrave Pivot, Cham.

Miola, A. & Schiltz, F. (2019), 'Measuring sustainable development goals performance: How to monitor policy action in the 2030 Agenda implementation?', *Ecological Economics*, vol. 164, online first.

Montecchi, M., Plangger, K. & Etter, M. (2019), 'It's real, trust me! Establishing supply chain provenance using blockchain', *Business Horizons*, vol. 62 no. 3, pp. 283-293.

Morioka, S.N., Bolis, I., Evans, S., Carvalho, M. M. (2017), 'Transforming sustainability challenges into competitive advantage: multiple case studies kaleidoscope converging into sustainable business models'. *Journal of Cleaner Production*, vol. 167, pp. 723-738.

Nguyen, G. T., & Kim, K. (2018). 'A survey about consensus algorithms used in Blockchain. Journal of Information Processing Systems', vol. 14 no. 1, pp. 101–128.

Nia, A. B. (n.d.), *Measuring progress: Monitoring SDGs, Linking Development Finance with Results: AP-DEF Consutation for the GPEDC*, 26-27 October, Bangkok, available at: https://www.undp.org/content/dam/rbap/docs/meetTheSDGs/UNESCAP%20Measuring%20progress%20-%20Monitoring%20the%20SDGs.pdf

Nowiński, W. & Kozma, M. (2017), 'How Can Blockchain Technology Disrupt the Existing Business Models?', *Entrepreneurial Business and Economics Review*, vol. 5 no. 3, p. 173-188.

Ouaddah, A., Elkalam, A.A., & Ouahman, A.A. (2016), 'FairAccess: a new Blockchain-based access control framework for the Internet of Things', *Security and Communication Networks*, vol. 9, pp. 5943– 5964.

Pan, X., Pan, X., Song, M., Ai, B., & Ming, Y. (2019), 'Blockchain technology and enterprise operational capabilities: An empirical test', *International Journal of Information Management*, vol. 52, 101946, online first. 2019, 101946.

Panarello, A., Tapas, N., Merlino, G., Longo, F., & Puliafito, A. (2018), 'Blockchain and IoT integration: A systematic survey', *Sensors*, vol. 18 no. 8, pp. 2575.

Pedersen, C. S. (2018), 'The UN Sustainable Development Goals (SDGs) are a great gift to business!', *Procedia CIRP*, vol. 69, pp. 21-24.

Perera-Gomez, T. & Lokanathan, S. (2019), *Big data and SDGs : the state of play in Sri Lanka and India*, International Development Research Centre. Available at: https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/56907/IDL-56907.pdf?sequence=2&isAllowed=y [accessed 26 March 2020].

Pournader, M., Shi, Y., Seuring, S., & Koh, S.C.L. (2019), 'Blockchain applications in supply chains, transport and logistics: a systematic review of the literature', *International Journal of Production Research*, online first.

Price WaterHouse Coopers [PWC] (2018). *From promise to reality: Does business really care about the SDGs?*. Available at: https://www.pwc.com/gx/en/sustainability/SDG/sdg-reporting-2018.pdf [accessed 21 February 2019].

Rejeb, A., Keogh, J. G., & Treiblmaier, H. (2019), 'Leveraging the Internet of Things and Blockchain Technology in Supply Chain Management. Future Internet', vol. 11 no. 7, pp. 161. https://doi.org/10.3390/fi11070161

Ren, Y., Zhu, F., Sharma, P. K., Wang, T., Wang, J., Alfarraj, O., & Tolba, A. (2019), 'Data Query Mechanism Based on Hash Computing Power of Blockchain in Internet of Things', *Sensors*, vol. 20 no. 1, pp. 207.

Rosati, F. & Faria, L. G. D. (2019), Addressing the SDGs in sustainability reports: The relationship with institutional factors, *Journal of Cleaner Production*, vol. 215, pp. 1312-1326.

Saghiri A.M., HamlAbadi K.G., Vahdati M. (2020), 'The Internet of Things, Artificial Intelligence, and Blockchain: Implementation Perspectives'. In Kim S., Deka G. (Eds), *Advanced Applications of Blockchain Technology*. Studies in Big Data, vol 60. Springer, Singapore.

Salman, T. & Jain, R. (2016), 'Networking protocols and standards for internet of things'. In *Internet of Things and Data Analytics Handbook* (Chapter 13), H. Geng (Ed.), pp. 215-238.

Schmitz, J., & Leoni, G. (2019), 'Accounting and Auditing at the Time of Blockchain Technology: A Research Agenda', *Australian Accounting Review*, vol. 29 no. 2, pp. 331–342.

Subramaniam, N., Mori, R., Akbar, S., Ji, S. & Situ, H. (2019). *SDG Measurement and Disclosure 2.0: A study of ASX150 companies.* RMIT University. Available at: https://www.unaa.org.au/wp-content/uploads/2020/08/UNAA-RMIT-ASX-150-SDG-Report.pdf

Sullivan, K., Thomas, S. & Rosano, M. (2018), 'Using industrial ecology and strategic management concepts to pursue the Sustainable Development Goals', *Journal of Cleaner Production*, vol. 174, pp. 237-246.

Sundmaeker, H., Guillemin, P., Friess, P., Woelfflé, S. (2010), *Vision and challenges for realising the Internet of Things*, Cluster of European Research Projects on the Internet of Things, CERP IoT, 2010.

Tan, B.S. & Low, K.Y. (2019), 'Blockchain as the Database Engine in the Accounting System', *Australian Accounting Review*, vol. 29 no. 2, pp. 312-318.

Traxler, A. A., Schrack, D. & Greiling, D. (2020), 'Sustainability reporting and management control – A systematic exploratory literature review', Journal of Cleaner Production, vol. 276, *online first*.

Unerman, J., Bebbington, J., & O'Dwyer, B. (2018), 'Corporate reporting and accounting for externalities'. *Accounting and Business Research*, vol. 48 no. 5, pp. 497-522.

United Nations. (2020a). *Sustainable Development Goals*. Available at: https://sustainabledevelopment.un.org/?menu=1300 [accessed 13 February 2020].

United Nations. (2020b), *SDG Indicators*, Available at: https://unstats.un.org/sdgs/indicators/indicators-list/ [accessed 13 February 2020].

United Nations Development Programme. (2020), *How blockchain has transformed the lives of Ecuadorean cocoa farmers*. Available at: https://undp.medium.com/how-blockchain-has-transformed-the-lives-of-ecuadorean-cocoa-farmers-1c89941f549c

Van Rijmenam, M., Schweitzer, J. and Williams, M.-A. (2017), 'A distributed future: how blockchain affects strategic management, organisation design & governance', *Academy of Management Annual Meeting Proceedings*, Vol. 2017 No. 1, pp. 14807.

Van Tulder, R. (2018), *Business & The Sustainable Development Goals: A Framework for Effective Corporate Involvement*, Rotterdam School of Management, Erasmus University, Rotterdam.,

VeChain Foundation (2019), *VeChain Whitepaper 2.0: Creating valuable TXs*. Available at: http://www.vechain.org/qfy-content/uploads/2020/01/VeChainWhitepaper_2.0_en.pdf

vechain.org. VeChainThor. Available at: https://www.vechain.org/ [accessed 26 March 2020].

Wang H., Wang Y., Cao Z., Li Z., & Xiong G. (2019), 'An Overview of Blockchain Security Analysis'. In Yun, X. et al. (Eds), *Cyber Security*. CNCERT 2018. Communications in Computer and Information Science, vol 970. Springer, Singapore.

Yayboke, E. (2017), *Harnessing the Data Revolution to Achieve the Sustainable Development Goals: Enabling Frogs to Leap*, Centre for Strategic and International Studies, Washington, USA.

Yermack, D. (2017). 'Corporate Governance and Blockchains', *Review of Finance*, vol. 21 no. 1, pp. 7-31.

Zhang, Y. & Wen, J. (2015), *An IoT electric business model based on the protocol of bitcoin', 18th International Conference on Intelligence in Next Generation Networks*, Paris, 2015, pp. 184-191.

Zhang, Y., Wen, J. (2017), 'The IoT electric business model: Using blockchain technology for the internet of things', *Peer-to-Peer Networking and Applications*, vol. 10**,** pp. 983–994.
Zhao, J.L., Fan, S. & Yan, J. (2016), 'Overview of business innovations and research opportunities in blockchain and introduction to the special issue', *Financial Innovation,* vol. 2 no. 28, *online first*.
Zhu, X., & Badr, Y. (2018), 'Identity Management Systems for the Internet of Things: A Survey Towards Blockchain Solutions', *Sensors*, vol. 18 no. 12, pp. 4215.