Can Blockchain revolutionize international trade?

By Emmanuelle Ganne

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World Trade Organization

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Executive summary

Blockchain is much more than Bitcoin.

Blockchain's first implementation as the technology underpinning Bitcoin has led many to associate Blockchain with Bitcoin. However, the potential use of Blockchain goes well beyond the world of cryptocurrencies. For some, it is a technology that will change our lives, while for others it is a pipe dream; no technology has stirred up so much debate since the advent of the internet. However, despite the numerous headlines on Blockchain, the technology remains difficult to apprehend for many.

Blockchain: a tamper-proof, decentralized and distributed digital record of transactions that creates trust and is said to be highly resilient.

A blockchain is a decentralized, distributed record or "ledger" of transactions in which the transactions are stored in a permanent and near inalterable way using cryptographic*[1] techniques. Unlike traditional databases, which are administered by a central entity, blockchains rely on a peer-to-peer network that no single party can control. Authentication of transactions is achieved through cryptographic means and a mathematical "consensus protocol"* that determines the rules by which the ledger is updated, which allows participants with no particular trust in each other to collaborate without having to rely on a single trusted third party. Thus, Blockchain is, as The Economist calls it, a "trust machine". Participants in a blockchain can access and check the ledger at any time.

Blockchain therefore ensures immediate, across-the-board transparency, and as transactions added to the blockchain are time-stamped* and cannot easily be tampered with, blockchain technology allows products and transactions to be traced easily. Smart contracts* – i.e. computer programmes that self-execute when certain conditions are met – can be used to automate processes, further reducing costs. Because of their decentralized and distributed nature and the use of cryptographic techniques, blockchains are said to be highly resilient to cyber-attacks compared to traditional databases – although there is no such thing as perfect resilience.

Blockchains can be public, private or managed by a consortium of companies, and they can be accessible by everyone (permissionless) or restricted (permissioned).

There are various ways to categorize blockchains. Blockchains are often classified as public (no specific entity manages the platform), private (the platform is controlled by a single entity), or managed by a consortium of companies. Another commonly used classification is permissionless (the blockchain is open to everyone – the most well-known example being the Bitcoin platform) or permissioned (restrictions can be imposed on who can read and/or write on the blockchain). There are, in practice, many variants of blockchains depending on the objectives being sought. Many applications in the field of international trade fall into the category of permissioned/consortium blockchains. While, strictly speaking, Blockchain is only one type of distributed ledger technology (DLT), the term is now commonly used to refer to distributed ledger technologies in general.

Blockchain's potential trade-related applications are numerous and could significantly transform international trade… but the technology is not a solution to everything.

From finance, including trade finance, to customs and certification processes, transportation and logistics, insurance, distribution, intellectual property (IP) and government procurement, possible applications of Blockchain encompass a diverse set of areas related to WTO work. While the technology opens interesting opportunities to enhance the efficiency of a number of processes and cut costs in these areas, it is not a panacea. Carefully weighing the costs and benefits is essential.

Blockchain could open new opportunities to enhance the efficiency of processes in a number of areas related to WTO work.

Blockchain could help trade move closer to becoming paperless.

From trade finance to customs clearance, transportation and logistics, trade in goods involves multiple actors and remains paper-intensive. Blockchain is seen by many as an interesting tool to improve the efficiency of trade processes and help move towards paperless trade. However, the challenges to overcome are equivalent to the opportunities offered by the technology.

Blockchain is seen as a possible game-changer to digitalize and automate trade finance processes, in particular letters of credit, and to ease supply chain finance. An array of banks working with financial technology (fintech) startups and information technology (IT) companies are investigating the potential of the technology. Pilot projects are encouraging, but a number of technical and regulatory issues need to be addressed before the technology can be used on a wide scale.

The intrinsic characteristics of the technology also make it a potentially interesting tool to help implement the WTO Trade Facilitation Agreement (TFA) and to facilitate business-to-government (B2G) and government-to-government (G2G) processes at the national level. Blockchain and smart contracts could help administer border procedures and national single windows (a single point of entry through which trade stakeholders can submit documentation and other information to complete customs procedures) in a more efficient, transparent and secure manner, and improve the accuracy of trade data. The real challenge will be to make cross-border G2G processes more efficient. This will not only require settling interoperability issues at a technical level – an issue on which the Blockchain community is working actively – it will also require standardization and political will to create a regulatory framework that is conducive to paperless trade.

Finally, the technology will only be able to work to its full potential if all aspects of cross-border trade transactions are digitalized, from trade finance to customs, transportation and logistics, and if the semantics are aligned (i.e. what specific information is communicated by the data elements). The transportation and logistics sector, which constitutes a fertile ground for blockchain implementation due to the large number of actors involved, is actively looking into ways to leverage the technology in order to develop trade platforms that could connect all actors along the supply chain, including banks and customs authorities.

If the projects that are under development succeed, Blockchain could well become the future of trade infrastructure and the biggest disruptor to the shipping industry and to international trade since the invention of the container. However, much remains to be done. Such projects require complex integration work and a conducive regulatory environment. They also raise issues of interoperability and standardization. A dialogue between all stakeholders, including regulators, is essential.

Blockchain could give rise to a new generation of services.

Beyond Blockchain's pilot projects related to trade finance, an increasing number of startups are developing products and blockchain applications to provide for quicker, easier and cheaper cross-border payments, putting pressure on well-established financial institutions to rethink the way they have been doing business.

However, a complete overhaul of the financial landscape is unlikely. Ironically, the technology could serve to strengthen those financial institutions that "Satoshi Nakamoto", the pseudonymous founder or founders of Blockchain, wanted to make superfluous.

Another area that could be significantly impacted by the use of blockchain technology is insurance. The automation of processes through the use of smart contracts could help reduce administrative procedures and costs, handle claims, and administer multinational insurance contracts. Of particular interest for international trade are pilot projects being tested in the maritime insurance sector.

Blockchain is also just starting to enter the e-commerce world. While the technology may not revolutionize e-commerce *per se*, it could give it a further boost and impact existing business models.

If the initiatives underway prove conclusive, and technical and legal issues are solved, Blockchain could become the future "infrastructure" of the services industry. Because of its automation capabilities, thanks to the use of smart contracts, Blockchain could be to the services sector what robots have been to manufacturing. A significant shake-up of relationships within a sector is, however, unlikely. Blockchain's main impact will most likely be felt in terms of cost reductions.

Blockchain could help administer intellectual property (IP) rights in a more efficient and transparent way, and help fight counterfeits.

A rapidly growing ecosystem of companies is looking at how blockchain technology can be used to improve the administration and enforcement of IP rights across multiple jurisdictions. Blockchain applications in the IP field are numerous and could impact both the governance of IP rights and the IP industry itself. Blockchain for registered and unregistered rights could arguably be used to provide proof of creation, existence, ownership and/or first use, to register IP rights, to facilitate the administration and management of IP rights on a global scale, thereby potentially contributing to the emergence of "global IP chains", and to enforce IP rights and fight counterfeits in a more efficient way.

While applications of blockchain technology could help to alleviate some of the challenges that rights-holders face, the technology will not solve all issues. But one thing is certain: the disruptive nature of the technology, the multiplicity of potential applications emerging, and their practical and legal implications deserve the attention of regulators and legislators.

Blockchain could enhance government procurement processes, but it is essential to weigh the costs and benefits carefully.

Blockchain holds interesting promises to enhance government procurement processes, manage public contracts more efficiently, and fight fraud, but it remains to be seen whether current proofs of concept are conclusive and whether the use of Blockchain can bring e-government procurement systems to a more secure and automated level at a cost that justifies the transition to a blockchain-based scheme.

Beyond sectoral specific applications, Blockchain opens multifaceted cross-cutting opportunities. Blockchain could help build trust and enhance the transparency of supply chains.

Because it provides new ways to track the journey of products, Blockchain can be a powerful tool to promote transparency and traceability of supply chains, help fight counterfeits and build consumers' trust. Numerous startups and well-established companies are developing blockchain applications to track the origin of products, prove their authenticity and quality, and assert ethical claims and fair trade practices. Following the various scandals that have shaken the food industry in recent years, major food and retail companies are turning to Blockchain, not only to enhance transparency of the food supply chain, but also to enable them to track tainted products quickly and help restore trust in food quality. However, establishing a credible link between offline and online events is essential – and can be costly. Indeed, information added to the blockchain is only as good as the offline verification process that guarantees that the relevant requirements have been met offline.

Blockchain has the potential to reduce a variety of trade costs substantially.

By increasing transparency and making it possible to automate processes and payments, Blockchain has the potential to reduce trade costs significantly, including verification, networking, processing, coordination, transportation and logistics, as well as financial intermediation and exchange rate costs. Although it is difficult to assess the extent to which the deployment of blockchain technology will affect trade costs, preliminary indications at hand tend to point to a notable impact. Cost reduction estimates in the financial sector and the shipping industry range from 15 to 30 per cent of total costs. According to the World Economic Forum, the removal of barriers due to Blockchain could result in more than US$ 1 trillion of new trade in the next decade.

Blockchain opens up new opportunities for micro, small and medium-sized enterprises (MSMEs) and small producers from developing countries.

Blockchain could be a powerful tool to facilitate MSMEs' participation in international trade, by facilitating access to trade finance, facilitating trade procedures, and reducing trade costs. It could help to lower barriers to entry, making it easier for small companies and producers to participate in international trade.

However, these opportunities can only be realized if small firms and producers have the right technical skills and enjoy adequate internet access. Addressing the digital gap – both in terms of access and bandwidth – is therefore of key importance. In addition, like any innovation, Blockchain carries with it the risk of disrupting some sectors and categories of workers. Opportunities and benefits may not be equally shared.

However, these opportunities will only be realized if several key challenges are addressed, including technical issues such as scalability, ...

Many observers point to the limited scalability of blockchains due to the predetermined size of blocks and energy consumption issues. While scalability is a serious issue for public blockchains, it is less so for consortium permissioned ones, which do not face the same limitations. Consortium permissioned blockchains, which have great potential for international trade, are more easily scalable. The heated controversy surrounding the level of energy consumption of blockchains is above all a "permissionless issue". In addition, new algorithms – many of which are moving away from the concept of blocks – are being developed that are quicker and less energy-intensive, and that can therefore be more easily scaled up.

Another potential long-term technical challenge relates to security issues. Although blockchains are highly resilient compared to traditional databases due to their decentralized and distributed nature and the use of cryptographic techniques, they are not completely immune from traditional security challenges, and advances in technologies, in particular the rise of quantum computing, could, in the long term, represent a threat to blockchain technologies. "Post-quantum" algorithms that would be resistant to quantum computing are being actively researched.

… interoperability, …

One of the key technical challenges facing Blockchain is the question of interoperability, at the technical level as well as at the level of semantics (i.e. what information is communicated by the data element). Numerous platforms are being developed that use different technical interfaces and algorithms and that do not “talk to each other”. This “digital island problem” is the subject of active research within the Blockchain community. Technical solutions are emerging, but are still in their infancy for the time being.

The semantics of the information exchanged are also being actively addressed, in order to ensure that sender, receiver and anyone consulting understand the same data in the same way. International organizations such as the International Chamber of Commerce (ICC), International Organization for Standardization (ISO), United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT) and the World Customs Organization (WCO), have created working groups to initiate discussions to look into the issue and develop interoperability standards.

… and legal issues.

The wide-scale deployment of Blockchain requires a conducive regulatory framework that recognizes the legal validity of blockchain transactions, clarifies applicable law and liabilities, and regulates the way data can be accessed and used. The most critical issue relates to the legal status of blockchain transactions. Legislation that recognizes the validity of e-signatures, e-documents and e-transactions, in particular blockchain transactions, is crucial. In 2017, the United Nations Commission on International Trade Law (UNCITRAL) adopted the Model Law on Electronic Transferable Records, and various governments are working on legislation to recognize blockchain transactions, but much remains to be done. Issues related to applicable jurisdiction and liability, while problematic in the case of permissionless blockchains, often allow for a technical workaround in the context of permissioned blockchains.

Another potentially challenging legal issue is the question of data privacy and the right to be forgotten embodied in some legislation. The principles of Blockchain and of the right to be forgotten seem *a priori* incompatible. Some observers note, however, that both pursue the same goal of giving individuals more control over their personal data, but through different mechanisms.

Finally, two legal issues could act as enablers of blockchain technology: the codification of law, which aims at making laws machine-readable in order to facilitate the transposition of contractual obligations into digital contract code (smart contracts), and the development of a global legal identification of companies.

Given the transformational impact that the technology could have on global trade, understanding its legal implications and striving to develop collective solutions to enable the technology to be deployed while addressing legal concerns is key.

The development of a comprehensive ecosystem modelled on the internet governance approach, that brings together companies, civil society organizations, software developers, academics, governments and inter-governmental organizations in various settings to look into standardization, legal and policy issues, is critical to support the wide-scale deployment of the technology.

Likewise, it is also worth considering whether there would be value in initiating a discussion on the practical and legal implications of Blockchain in relevant international organizations such as the WTO to help shed light on the potential benefits of the technology, its limitations and the challenges that may arise if it is more widely deployed, and to help develop collective solutions to support the use of a technology that has the potential to impact global trade significantly.

Blockchain could make international trade smarter, but smart trade requires smart solutions and smart standardization – which can only be developed through cooperation. If we succeed in creating an ecosystem conducive to the wider development of Blockchain, international trade may look radically different in 10 to 15 years.

Endnote

1. Terms marked with an asterisk (*) are defined in the glossary.

Blockchain's key features

- **A decentralized, distributed and transparent architecture of trust:** Information added to the blockchain is immediately visible to all participants in the network and distributed – i.e. each peer keeps a complete copy of the data (or as close to it as possible), and updates, if any, are shared with the whole network without anyone having to trust a single central third party. Blockchain ensures immediate, across the board transparency – although in the case of permissioned blockchains (see Section 2.3), trust is more centralized and the readability of some information can be restricted to participants with permission to better suit the objectives of the blockchain.

- **High security, immutability and traceability:** The concomitant use of various cryptographic techniques and the decentralized and distributed nature of blockchain platforms make such platforms highly resistant to attacks compared to traditional databases. However, although the technology itself provides for a high level of security, weaknesses remain in relation to smart contracts, user interfaces and private keys used for encryption, which can be stolen via conventional attacks if they are saved on an individual user's computer or a centralized server.[1]

  Information, when added to the blockchain, is time-stamped and cannot be easily modified. This has several implications:

  - First, it makes it easy to track attempted changes. This is particularly important in a world where digital objects can be copied, modified and shared around at virtually no cost. Blockchain's immutability makes it possible to easily authenticate products and documents – however, it is important to note that, while Blockchain can help prevent fraud on the ledger, the tamper-resistance of the technology cannot prevent false information from being fed into the ledger.

  - Second, the immutable and distributed nature of the technology negates the need for database backups, thereby fundamentally changing disaster recovery. Once information is added to the blockchain, it is shared with the whole network and saved on all nodes, and it is near impossible to modify. If one node is affected by a disaster, information can easily be recovered.

- **Automation:** The use of smart contracts, i.e. self-executing computer programmes, makes it possible to automatize processes, payments, etc., thereby enhancing efficiency.

Endnote

1. Knowledge of a private key enables an attacker to transfer assets from the account of legitimate holder of the private key to the attacker's account. In the case of Blockchain, the absence of a central entity means that the transaction cannot be undone. Hacks of centralized entities within the Bitcoin and Ethereum networks have led to massive losses, but technical means exist that allow users to prevent theft of private keys, such as hardware wallets, i.e. a special type of wallet which stores the user's private keys in a secure hardware device.

1 Introduction

The world is continually changing, driven by technological innovations that affect the way we live and do business. The history of the world economy is intimately linked to technological progress. The invention of the steam engine mechanized production, the discovery of electricity enabled mass production, and the rise of the internet made it possible to coordinate various production stages at a distance, leading to a fragmentation of production that gave rise to global value chains.

However, while information and communication technologies have deeply affected the organization of production, they have not yet succeeded in digitalizing trade transactions. In spite of recent efforts to put in place electronic processes to handle some aspects of trade procedures, such as electronic single windows, trade transactions still remain heavily dependent on paper. A shipment of roses from Kenya to Rotterdam can generate a pile of paper 25 cm high, and the cost of handling it can be higher than the cost of moving the containers (Allison, 2016).

Security concerns and the difficulty of coordinating data flows across borders and between the multiple parties involved in an international trade transaction have hampered efforts to digitalize trade. A new technology, Blockchain, is seen by many as a possible game-changer. But what is Blockchain, and what is the potential of this technology for international trade?

A blockchain is a digital record of transactions – or ledger – that is decentralized (no single entity controls the network) and distributed (records are shared with all participants), and in which transactions are stored in a highly secure, verifiable and permanent way using various cryptographic* techniques. It is a continuously growing list of records, which are combined in "blocks" that are then "chained" to each other using cryptography – hence the term "blockchain". As transactions are shared, verified and validated on a peer-to-peer basis, blockchains can operate without the need for a central authority or trusted intermediaries, and information, once added to a blockchain, is time-stamped* and cannot easily be modified. Blockchain therefore enables the creation of a shared, trusted ledger that all participants can access and check at any time, but that no single party can control. Blockchain is, as The Economist (2015) calls it, a "trust machine". Because of the use of various cryptographic techniques and of their decentralized and distributed nature, blockchains are said to be highly resilient.

Originally developed as the technology underpinning the digital currency Bitcoin, blockchain applications soon started to spread beyond cryptocurrencies. The transparent, secure and immutable nature of Blockchain has sparked the interest of the private sector and government authorities alike. The number of proofs of concepts and pilot projects is skyrocketing, and applications touch all sectors of the economy and society, from finance to e-commerce, food safety, supply-chain management and even voting – with many such applications being "permissioned" blockchains that require authorization to transact on the ledger. Billions of funding dollars are being poured into blockchain companies, and blockchain-related patents are on the rise. Venture-capital funding for blockchain startups has been growing steadily and reached US$ 1 billion in 2017 (CB Insights, 2018), and the rate of blockchain patent applications tripled that year (Noonan, 2018). Is the hype justified?

An innovation, a game-changer, a revolution, a monument of untapped potential, the solution to all the problems, a silver bullet for some; old wine in a new bottle, a zero-sum game, much ado about nothing, a solution looking for a problem to solve, a pipe dream, the most overhyped technology for others. The list of hyperbolic statements making the headlines of blockchain-related literature is long. No technology has stirred up so much popular passion since the advent of the internet, and none has sparked so much controversy beyond the confines of the mysterious universe of information technology (IT) specialists. Everyone has an opinion, yet few understand what it is all about.

This publication seeks to demystify the Blockchain phenomenon by providing a basic understanding of the technology and its main functionalities.[1] It showcases some trade-related applications and analyses the relevance of this technology for international trade by reviewing how it is currently used or can be used in the various areas covered by the WTO. It provides a glimpse of whether the widespread adoption of this technology could affect cross-border trade transactions and, if so, to what extent, and it discusses various challenges that must be addressed before the technology can be used on a wide scale.[2]

Endnote

1. The present study focuses on the technology itself, not on cryptocurrencies.
2. The information provided in this publication is valid as of September 2018.

2 Blockchain in a nutshell

1. A brief history

Blockchain is a technology that first appeared in 2008 within the cryptography* expert community.[1] It was conceptualized by an as-of-yet unidentified individual or group of individuals under the alias Satoshi Nakamoto and first implemented in 2009 as a core component of the cryptocurrency Bitcoin.[2] While Blockchain and Bitcoin are historically linked, they are two different things. Blockchain is the technology underpinning Bitcoin; it is the virtual infrastructure that Bitcoin uses. Bitcoin is a cryptocurrency, but the term is often used to refer to both the cryptocurrency and the protocol underlying it – i.e. Blockchain. This confusion may be one of the reasons why it took so long for people to realize that Blockchain can be used in areas other than for cryptocurrencies.

The launch of Bitcoin in the wake of the 2008 financial crisis has caused it to be mistakenly considered as a direct consequence of the latter. The history of cryptocurrencies, however, started before the 2008 financial crisis.

Several older cryptocurrencies had failed to take off and never made it beyond the boundaries of the cryptography community. The ancestors of Bitcoin were developed by members of the “Cypherpunks”, a network of activists advocating for the widespread use of robust cryptography and privacy-enhancing technologies as a route to social and political change. The Cypherpunks used peer-to-peer systems and cryptography to process secure transactions without a “Big Brother” element, by which they meant the banking system.

The 2008 financial crisis provided a fertile ground for the operationalization, uptake and expansion of cryptocurrencies, and of Bitcoin in particular (Bustillos, 2013). In a context of loss of trust in the governance of the monetary system, and by extension in public governance in general, Bitcoin was seen by some as a desirable alternative, the achievement of all the ideals advocated by the Cypherpunks. Satoshi Nakamoto’s 2008 white paper, “Bitcoin: A Peer-to-Peer Electronic Cash System” (Nakamoto, 2008), described a new model of privacy – a model in which the trusted third party between the two parties undertaking the transaction is replaced by cryptographic evidence, provided and validated by peers, moving away from single points of failure that exist in the traditional model of privacy (i.e. the banks in fiat currency[3] systems). The new model, Satoshi Nakamoto argued, solved the issue of "double spending" – the fact that digital currencies can be spent more than once because the digital file can be duplicated. Furthermore, the new system allowed for transactions to be public while the parties involved are anonymous, thus enhancing transparency while preserving privacy. Finally, the immutability and time-stamping* features of Bitcoin offered appealing assurances against fraud at a juncture where big players in the financial system were in the headlines for tampering with book-keeping and market metrics.

While Bitcoin was the first real-life application of Blockchain, blockchain technology is in fact a combination of several underlying techniques that have been in existence for at least four decades. For the five years that followed the creation of Bitcoin, the history of Blockchain remained nearly synonymous with the history of Bitcoin. It was only from 2013 that the blockchain technology started to make a name for itself as a result of its use in other cryptocurrencies, such as Ethereum (see Investoo Group, 2017), and more recently beyond the financial technology (fintech) industry.

The creation of Ethereum marked the second milestone in the history of Blockchain. In 2013, a 19-year old programmer, Vitalik Buterin, published a white paper that laid out his plan for a blockchain system that could also facilitate "decentralized applications" (Buterin, 2013). He proposed to achieve this in large part by building a programming language into Ethereum that developers could customize to fit their purposes.

Ethereum, sometimes referred to as "Blockchain 2.0", was released in late 2015. Ethereum's quantum leap lies in the concept of smart contracts*, i.e. computer programmes that self-execute the terms of a contract when specific conditions are met. Smart contract applications run exactly as programmed without fraud, third-party interferences, or delay. Automating transactions in this way constituted a revolution within the revolution and is one of the most valuable features of Blockchain for trade.

Probably the next most memorable milestone in the history of blockchain was the attack of Ethereum's decentralized autonomous organization[4] (DAO) in mid-2016. The DAO was meant to operate like a venture capital fund for the cryptographic space and was built as a smart contract on top of the Ethereum blockchain. A few weeks after its launch, the DAO was subject to a hacker attack that siphoned off millions of dollars' worth of assets and led to its collapse, leading many blockchain sceptics to question the very premises of the technology, i.e. its immutability and resistance to attack (see also Siegel, 2016). The problem was not the blockchain technology itself; it was the coding of the contract programmes that powered the DAO. The programmes, which had been built on top of the Ethereum blockchain ledger, contained a fault that, under certain circumstances, allowed escrow accounts[5] to be emptied out (Brandon, 2016).

In spite of this unfortunate event, smart contracts are one of the blockchain characteristics that harness the most interest today in hundreds of applications in all domains because of their flexibility and the possibility to automate processes.

Over the last few years, an array of newer distributed ledger technologies has been developed to improve on the capabilities of the Bitcoin and Ethereum networks and promote new use cases[6] (see the next section for more information on the relationship between Blockchain and distributed ledger technology). IOTA, for example – which is a distributed ledger technology but not a blockchain *per se,* as it does not combine transactions in blocks, nor does it chain them in a linear manner – was launched in 2016 as a cryptocurrency platform designed for machine-to-machine communication.[7]

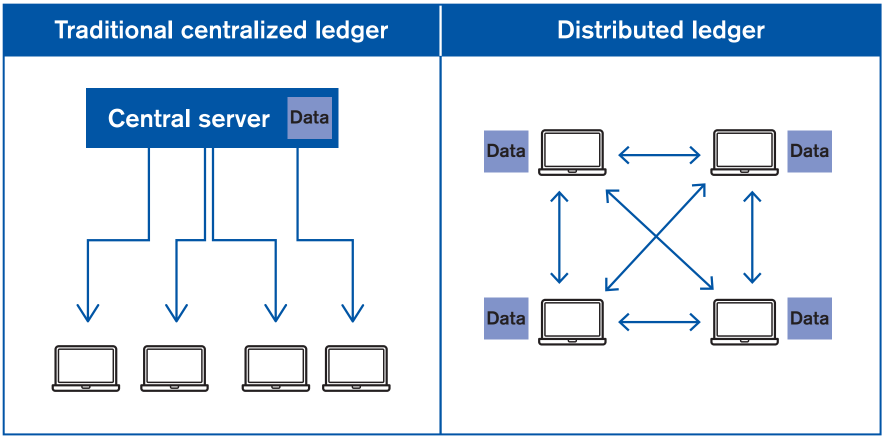
In addition, various consortia were formed to develop solutions tailored to the needs of businesses. The R3 consortium, for example, which brings together more than 200 companies, regulators and trade associations, developed its own distributed ledger platform called Corda, geared towards the financial world.[8]

Another well-known initiative is Hyperledger, which is hosted by the Linux Foundation, a non-profit organization that brings together industry leaders in finance, banking, Internet of Things (IoT) (i.e. machine-to-machine devices), supply chains, manufacturing and technology to advance cross-industry blockchain technologies. Hyperledger is a collaborative effort to develop enterprise blockchain-based frameworks and tools in open-source and related tools. Hyperledger is now widely used in various fields, including international trade.[9]

2. Blockchain 101

A blockchain is a digital record of transactions – or ledger – that is decentralized (no single entity controls the network – although "private" blockchains have emerged that provide for a greater degree of centralization – see Section 2.3), distributed (records are shared with all participants) and secured using a blend of proven cryptographic technologies. A blockchain is managed by computers or servers – called "nodes"* – on a peer-to-peer basis without the need for the intermediaries who traditionally authenticate transactions (such as banks in the case of financial transactions). Data added to the blockchain are shared with all participants in the network and are verified and validated by anyone with the appropriate permissions on the basis of the consensus protocol* of the blockchain (see Figure 1).

Figure 1 Centralized versus distributed ledger



Source: Author.

Data entered onto the blockchain are "hashed"*, i.e. converted into a new digital string of a fixed length using a mathematical function, and encrypted* to ensure data integrity, prevent forgery, and guarantee that the message was created and sent by the claimed sender and was not altered in transit. If the sender of the transaction does not wish other participants in the network to see the content of the message itself, i.e. the plaintext data contained in the documents submitted, he/she can choose to encrypt the message itself, thereby rendering the data unintelligible to individuals without authorized access.

Once validated, transactions are stored in "blocks" that are then "chained" to each other in chronological order using cryptographic techniques (see the Annex for a description of a typical blockchain transaction).[10] Data, once added to a blockchain, are time-stamped and near-impossible to modify. However, while blockchains can help prevent fraud on the ledger, the tamper-resistance of the technology cannot prevent false information from being fed into the ledger.

In a blockchain, each peer keeps a complete copy of the data (or as close to it as possible), and updates are shared with all participants simultaneously. Participants in a blockchain therefore all have access to the same information at any time. In other words, a blockchain is a shared, trusted ledger that all participants can access and check at any time, but that no single party can control (unless it is fully private – see next section), which allows people with no particular trust in each other to collaborate without relying on trusted intermediaries.

As data are replicated as many times as there are nodes, falsifying data or compromising the whole network would require compromising a large number of nodes, which would be difficult in practice, although not impossible. In theory, a blockchain network can be compromised if a validator or pool of validators control more than 50 per cent of the network's computing power, which is called a "51 per cent attack". While the 51 per cent attack is a problem common to all types of blockchains, it is particularly critical in the case of public blockchains, given the difficulty of determining who effectively validates blocks.

A particular feature of public blockchains is the considerable amount of computational power that most of them require to validate transactions, in particular those using the Proof of Work consensus mechanism, such as Bitcoin (see the Annex for more information). Though wasteful in terms of energy expense, Proof of Work is required to ensure the safety of the consensus process. It makes the public blockchain mathematically very hard to hack as the cost of hacking becomes too high for a system where every node connected is synchronized with the entire blockchain network. Hence, although hacking the system is not impossible, it is economically inefficient and practically extremely hard. However, computing power capacity is increasingly being aggregated. The 51 per cent vulnerability is, to date, still subject to heated debates regarding the severity of its potential consequences.

Interestingly, most recent developments could render discussions on so-called "51 per cent attacks" obsolete. In a paper released in August 2018, Vitalik Buterin, Ethereum's co-founder, proposes a new consensus algorithm that, allegedly, requires just 1 per cent of the nodes to be honest and eliminates the risk of a 51 per cent attack (Buterin, 2018). In other words, an attacker who wanted to control the network would have to control 99 per cent of the nodes of the blockchain and not just 51 per cent. The 51 per cent attack may soon be called a 99 per cent attack.

(a) Blockchain versus distributed ledger technology (DLT)

Because it is simple and catchy, the term "Blockchain" is often used to refer to distributed ledgers whatever their specific features are. Blockchain, however, is only one type of distributed ledger technology (DLT) – one that compiles transactions in blocks that are then chained to each other. Blockchain is the most well-known and most tested distributed ledger technology, but an increasing number of models of transaction flows are being developed which, like Blockchain, use a blend of cryptographic techniques, but which are moving away from the concept of "blocks" – or even from both the concepts of "blocks" and "chain". "New kids not on the blocks" include IOTA,[11] Ripple[12] and Hashgraph.[13] Although these new models are not blockchains *per se*, the term "Blockchain" is now commonly used to refer to distributed ledger technology in general and to the phenomenon surrounding DLT. In order to facilitate reading, the present publication, like many others, will use the term "Blockchain" to refer more generally to "distributed ledger technology".

3. Types of blockchains

Behind the simple and catchy term of “Blockchain”, there are in reality many different models that vary in terms of the degree of decentralization and access, the identity of participants, the consensus mechanism, speed, level of privacy, energy consumption, fees and scalability (see Table 1 on page 12).

Blockchains are often classified as public versus private. Under the private blockchain there is a sub-type called consortium or federated blockchain, sometimes considered as a type of blockchain in its own right (Buterin, 2015). Another commonly used classification of blockchain applications is permissionless versus permissioned platforms, i.e. the extent to which access to the platform is restricted – or not – to those with permission. These two classifications are sometimes conflated and it is not uncommon for people to associate public with permissionless and private/consortium blockchains with permissioned blockchains. The reality is, however, slightly more complicated as some public blockchains can be permissioned.

The world of Blockchain is nebulous, complex and fast-changing, and definitions and classifications are not cast in stone. As the technology matures and new models of transaction flows and applications are being developed, definitions and classifications continue to evolve.

(a) Permissionless versus permissioned blockchains

The distinction between permissionless and permissioned blockchains is mainly related to the issue of access to the platform. A permissionless blockchain is a blockchain that is open to anyone with a computer, with no restrictions imposed on who can access the platform and validate transactions.

In contrast, a permissioned blockchain is a blockchain in which access is restricted. Access can be restricted at various levels depending on the specificities of the platform, in particular whether it is a public, consortium or private platform: to read data, to propose a new transaction, or to validate transactions (BitFury Group, 2015). While permissionless blockchains such as Bitcoin are the ones that make the headlines, many blockchain use cases in the area of international trade are based on permissioned blockchains.

(b) Public versus private/consortium blockchains

The distinction between public, consortium and private blockchains is linked to the issue of management of the platform (who manages it) and user authentication (level of anonymity of participants). These different types of platforms distinguish themselves by their degree of decentralization (see Figure 2).

(i) Public blockchains

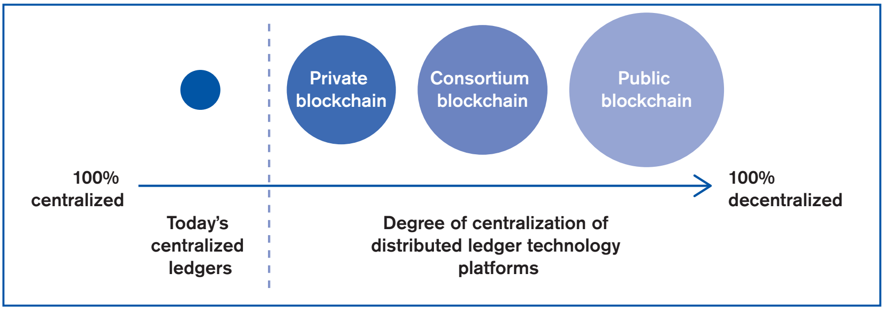
In a public platform, no specific entity/entities manage(s) the platform, transactions are public and individual users can maintain anonymity. No user is given special privileges on any decision. As such, it is a completely trustless system, in that it does not rely on a trusted party to validate the transactions but instead relies on the nodes to come to a consensus before any data (transaction record, block, etc.) are stored on the ledger.

Public blockchain platforms, however, need to ensure that users are incentivized to reach consensus. On the Bitcoin blockchain, for example, the verification process requires the performance of complex mathematical problems. The miner*, i.e. "validator", who first solves the mathematical problem, is rewarded through Bitcoins. Fees charged in return on users differ significantly between platforms. They are, by far, the highest on the Bitcoin platform.[14] In early November 2017, the average fee charged for Bitcoin transactions reached more than US$ 11 per transaction, leading some in the community to argue that the system had reached its limit (see Table 2 in Section 4.2(a), as well as Redman (2017), Chaparro (2017) and Bershidsky (2017)).

Most public blockchains are permissionless, i.e. they are open to everyone. Thus:

- Any individual can download the required software on their device without permission and start running a public node, validating transactions and thereby participating in the consensus protocol – the protocol that determines which blocks get added to the chain;

Figure 2 The degree of decentralization of distributed ledgers varies



Source: Author.

- Anyone can send transactions through the network; and
- Any individual can read and write relevant data on the blockchain.

Public permissionless blockchains are the closest application of what the blockchain technology was initially designed for by Bitcoin. Cryptocurrencies, and Bitcoin in particular, are the most typical illustration of public permissionless blockchains.

Some public blockchains, however, are permissioned. For example, in the case of the Proof of Stake* protocol – which Ethereum, the second biggest public blockchain, intends to introduce in 2018 – only those meeting certain preconditions can validate transactions based on their "stake" in the blockchain (in particular how many coins he/she has and for how long).

Because of their highly decentralized nature, public blockchains are considered particularly secure and resistant to malicious attacks, with no single point of failure*, but they face issues of scalability (see Section 4.2(a)).

(ii) Private blockchains

In fully private blockchains, the permissions to validate and write data onto the blockchain are controlled by one entity which is highly trusted by the other users, and participants are identified. In some situations, the entity may restrict the read permission to some users. Restricted read permissions provide a greater level of privacy to the users, a feature not available in public blockchains. The entity in control has the power to change the rules of the private blockchain and may decline transactions based on its established rules and regulations.

In a private blockchain, verification of the transactions is carried out by a very restricted number of nodes (according to the rules of the blockchain), which allows for greater efficiency and much faster processing of transactions than public blockchains, while requiring much less computing power. Transaction fees may apply for transaction validation as per the rules of the blockchain.

In addition, given that the validators are known, it is easier for human intervention to fix faulty nodes and risks of a 51 or 99 per cent attack arising from miner collusion do not apply; but the more centralized nature of these networks makes them less resilient to outside attacks, and there is a greater risk of human tampering of data.

The term "Blockchain" in the context of private ledgers is controversial and disputed, as such highly centralized ledgers have little in common with the original idea behind Blockchain.

(iii) Consortium blockchains

A consortium blockchain is a type of private blockchain that operates under the leadership of a group rather than a single entity and in which participants are identified. It is a "partially decentralized" platform (Buterin, 2015).

Instead of allowing anyone with an internet connection to participate in the transaction verification process or letting a single entity having full control, a few selected nodes are predetermined. These nodes control the consensus process. They can read and/or write the data and can decide who has access to the blockchain ledger. The right to read the blockchain may be public, or restricted to the participants (Buterin, 2015).

For example, a consortium blockchain could be formed among 10 companies, each of which operates a device connected to the blockchain network. If Company 2 only trades and shares its invoices with Companies 3, 4 and 5, it could be decided that permissions to read the shared data be given only to these companies.

The use of such platforms is often motivated by incentives to leverage the specific features of the distributed ledger technology, enhance cooperation and improve processes among institutions – e.g. banks, corporations and government agencies. Hyperledger Fabric, for example, is a blockchain framework implementation developed by IBM and donated to the Hyperledger Project of the Linux Foundation, which has been designed to develop permissioned blockchains that cater to the requirements of the participating enterprises.[15]

Private and consortium blockchains are usually permissioned blockchains, i.e. access to the platform is limited to those with permission, which allows participating institutions to maintain a certain level of control and privacy. Consortium permissioned blockchains are widely used in the field of international trade, not without reason – many institutions are reluctant to put private business information on a public, permissionless blockchain accessible to anyone. Some private/consortium blockchains can, however, be open to anyone interested. A platform like FastTrackTrade,[16] for example, which leverages the blockchain technology to build a digital trade network for Singapore micro, small and medium-sized enterprises (MSMEs), is open to all interested companies – although one could argue that only companies can join. In addition, permissioned private or consortium blockchains can have a public interface, i.e. anyone can read the data.

While these classifications capture the main features of the principal types of blockchains, there are many variants of blockchains. The actual design of blockchains depends on the objectives being sought and on how much decentralization and privacy are desired.

Table 1 Overview of the main characteristics of various types of blockchains

Degree of centralization	Public		Consortium		Private
Management	No centralized management		Multiple organizations		Single entity
Access	**Permissionless**	**Permissioned**	**Permissioned**	**Permissionless**	**Permissioned**
	Open read/open validation of transactions	Open read/permissioned validation of transactions	Permissioned OR open read/permissioned validation of transactions	Open read/open validation of transactions	Permissioned read/validation of transactions
Participants	Anonymous/pseudonymous	Anonymous/pseudonymous	Identified	Usually identified	Identified
Validation based on consensus protocol	Open to every participant in the network	Open to every participant in the network, subject to certain conditions	By pre-approved participants (across the organizations involved)	Depending on the consensus protocol chosen for the platform	By pre-approved participants (within the single entity)
Speed of validation	Slow	Quicker	Quick	Quick	Quick
Users' level of privacy	None	None	Tailored to the needs of participants	Tailored to the needs of participants	Tailored to the needs of participants
Computing power required (energy consumption)	High (but variable depending on the consensus mechanism)	Intermediate. Variable depending on the consensus mechanism	Lower	Lower	Lower
Transaction fees	Yes	Yes	Optional – depending on the rules of the blockchain	Optional – depending on the rules of the blockchain	Optional – depending on the rules of the blockchain
Scalability	Low	Slightly higher	Higher	Higher	Higher
Example(s)	Proof of Work (Bitcoin, Ethereum)	Proof of Stake (Nxt)	Blockchains built on Hyperledger Fabric. Permissioned blockchains built on Ethereum.	FastTrackTrade	Private blockchains built on Ethereum

Source: Author.

4. Smart contracts – a smart invention with no smart component

One of the most interesting features of blockchain technology, in particular in the context of international trade, is smart contracts. Smart contracts are not a type of blockchain *per se*, but rather a functionality of the blockchain technology.

The term “smart contract” is, in fact, a misnomer: smart contracts are neither “smart” (there is no cognitive or artificial intelligence component to them, only the automatic execution of a pre-defined task when certain conditions are met), nor are they contracts in a legal sense (Deloitte, 2018).

Smart contracts are computer programmes that automatically enforce themselves (self-execute) without the intervention of a third party when specific conditions are met (based on the “if… then…” logic – e.g., if the goods are unloaded at port of X, then funds are transferred). They state the obligations of each party to the “contract”, as well as the benefits and penalties that may be due to either party under different circumstances.

Unlike a traditional legal contract, they can also take information as an input, process it through the rules set out in the contract, and take any agreed action as a result. Such information is fed into the smart contract by so-called “oracles”*, i.e. data feeds – provided by third-party service providers – on the pre-defined conditions foreseen in the smart contract. Such conditions can be any external data like temperature, payment completion, price fluctuations, etc. A smart insurance contract could, for example, have as an oracle a sensor placed in a refrigerated container. If the temperature goes above a certain level, insurance payouts would automatically be triggered and a request for inspection sent. As blockchains cannot access data outside their network, oracles are the only way for smart contracts to “interact” with data outside of the blockchain environment. Smart contracts, in other words, usually work in conjunction with other technologies, in particular the IoT, i.e. networks of sensors and smart devices that are connected to the internet and that can send and receive data. Smart contracts generally use data generated from the IoT to trigger actions.

The concept of smart contracts was introduced and further fleshed out by cryptographer Nick Szabo in various publications during the period 1994-97, and was first introduced in the context of blockchain technology by Ethereum in 2015.[17] Today, many blockchains offer smart contract capabilities. Smart contracts can exist outside of Blockchain, but they then retain the same potential problems as centralized databases, i.e. a single point of failure and the possibility to change the data easily.

The automatic nature of smart contracts makes them a particularly interesting tool to use in international trade to automate transactions. However, the use of smart contracts does raise certain legal issues that are important to bear in mind, in particular issues of enforcement and liability that may need to be addressed if the contract has been miscoded (see Section 4.2.(c)). In addition, smart contracts are computer programmes, and, like any programming code, they may contain unintended mistakes (Delmolino *et al.*, 2015). The 2016 DAO attack mentioned earlier was the result of vulnerability within the smart contract programme code used in that case. Smart contracts are, along with the user interface (i.e. the mobile phone, tablet or computer used to access the internet), the layer where most security flaws occur in the blockchain ecosystem.

5. Multiple applications… but not a solution to everything

While, for many, Blockchain, as FT Technology Reporter Sally Davies has said, "is to Bitcoin, what the Internet is to email", the technology is more than simply the infrastructure supporting Bitcoin. The last few years have shown that Blockchain as a technology may be applicable to a large variety of industries and sectors, each with their own specificities. The technology can be deployed with customized features. Properties from security requirements to consensus protocols can be tailored to the specific needs and business requirements of a particular project. Customized blockchain development services have mushroomed in recent years, offering customers a wide array of options, including pre-built shells or totally bespoke systems, and open-source platforms (such as Ethereum and Hyperledger Fabric) offer the possibility to developers to build tailored blockchains choosing from a menu of functionalities and protocols.

While it presents interesting features, Blockchain cannot, however, solve everything, as the current hype surrounding it tends to lead us to believe. Companies and institutions interested in the technology need to ponder the costs and benefits of using it, and make sure that the technology is best suited to their needs. Building a blockchain platform is a task that requires careful consideration by and coordination among potential participants, in order to analyse the opportunities and limitations of Blockchain in comparison to other, less ambitious, alternatives, and agree on key parameters (e.g. the nature of the blockchain, the validating rules, etc.), not to mention the technological knowledge that the users of the system would need. A plethora of decision-tree models have been published on the web to enable businesses and institutions to make an informed decision on whether a blockchain is an appropriate solution to their needs and if so, what type of blockchain is most relevant to their situation.[18]

Endnotes

1. The concept of cryptographically secured chains of blocks was first described in 1991 by Haber and Stornetta (1991), but it was only in 2008-09 that the technology was effectively implemented.

2. A cryptocurrency is a digital currency that uses cryptography for security. See Nakamoto (2008).

3. A fiat currency is a currency that a government has declared to be legal tender, but that is not backed by a physical commodity such as gold or silver.

4. A decentralized autonomous organization (DAO) is an organization that is run autonomously through rules encoded in smart contracts. For more information, see: https://blockchainhub.net/dao-decentralized-autonomous-organization/

5. An escrow account is a special financial account for the temporary deposit of funds before they are paid out (or returned) at the conclusion of a specific transaction.

6. A use case is a software and system engineering term that describes how a user uses a system to accomplish a particular goal (definition from Techopedia).

7. See https://www.iota.org/

8. Corda is a shared ledger rather than a distributed ledger. Unlike blockchain networks, which replicate data across every member of the network, on the Corda platform, only those parties with a legitimate need to know can see the data within an agreement (see http://www.r3cev.com/blog/2016/4/4/introducing-r3-corda-a-distributed-ledger-designed-for-financial-services).

9. See https://www.hyperledger.org/about.

10. The term "Blockchain" can refer to the blockchain technology itself, or to an application using the technology, i.e. a specific platform or network of users (called nodes) to provide a specific service.

11. Launched in 2016 as a cryptocurrency designed for the Internet of Things, IOTA is a public ledger with no chains, no blocks and no fees. It uses a new technology called the Tangle: instead of being compiled in blocks and chained to each other, IOTA's transactions are connected in a big tangled web (see https://iota.readme.io/docs/what-is-iota).

12. Originally released in 2012, the Ripple protocol is meant to enable the near instant and direct transfer of money between two parties from any type of currency. While it is consensus-oriented, Ripple is technically not a blockchain. It summarizes the data into a single value rather than a block.

13. Hashgraph is a new consensus alternative to Blockchain that does not compile transactions in blocks. It uses a consensus protocol that, according to its developers, is faster, fairer and more secure than blockchains and has led many observers to ponder whether Hashgraph has made Blockchain obsolete. It is, however, not yet an open source, and proper analysis and benchmarking are still required before such claims can be upheld.

14. In fact, in the case of Bitcoin, the system as originally designed had anticipated that the transaction fee would be optional, at least as long as the miners are rewarded through Bitcoins (as Bitcoin was voluntarily designed to be deflationary, only a finite amount of Bitcoins can be generated in the system and the currency is bound to run out eventually). However, recent reports note that not only has a transaction fee become almost the only way for users to get their transactions into the blocks, but the amount of the fee for Bitcoin has soared dramatically. The scenarios have been somewhat different and less dramatic for other cryptocurrency platforms.

15. See https://www.hyperledger.org/projects/fabric

16. See https://www.fasttracktrade.co

17. Szabo defined smart contracts as follows: "A smart contract is a computerized transaction protocol that executes the terms of a contract. The general objectives of smart contract design are to satisfy common contractual conditions (such as payment of terms, liens, confidentiality, and even enforcement), minimize exceptions both malicious and accidental, and minimize the need for trusted intermediaries. Related economic goals include lowering fraud loss, arbitrations and enforcements costs, and other transaction costs (quoted in Tapscott and Tapscott, 2018).

18. See, for example, the IBM tree model presented at https://www.altoros.com/blog/how-hyperledger-fabric-delivers-security-to-enterprise-blockchain/, or the WEF white paper model available at: http://www3.weforum.org/docs/48423_Whether_Blockchain_WP.pdf

3 Can Blockchain revolutionize international trade?

The number of headlines claiming that Blockchain can revolutionize various areas of international trade, from trade finance to customs procedures and intellectual property, are legion. The transparent, decentralized and immutable nature of Blockchain has sparked the interest of private actors – and governments – to explore the potential of this technology to enhance the efficiency of trade processes, and a myriad of proofs of concepts and pilot projects using Blockchain have been developed in virtually all areas of international trade.

Does Blockchain really have the potential to revolutionize international trade? This chapter explores the relevance of Blockchain for cross-border trade transactions. It examines how blockchain technology can affect the various steps involved in international trade in goods, from trade finance to customs procedures, certification, and transportation and logistics, and help move toward greater digitalization of trade. It also discusses Blockchain's potential in other areas covered by the WTO, with a particular focus on some key services sectors, intellectual property and government procurement.

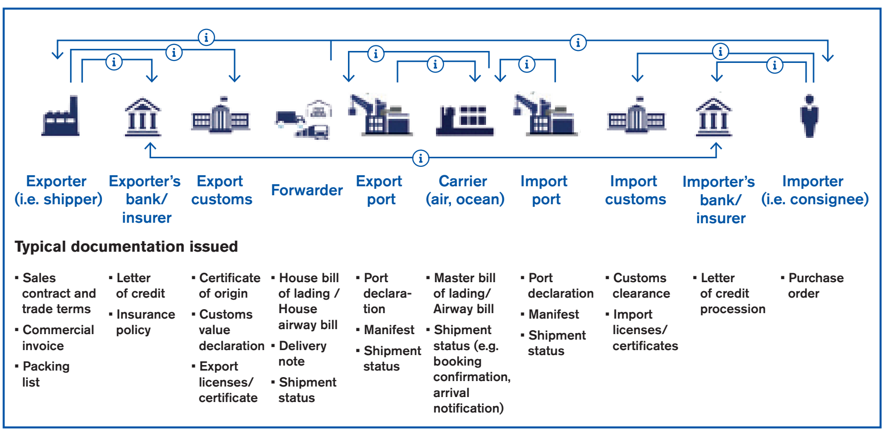
1. Towards paperless trade?

International trade transactions involve a multitude of actors and continue to rely extensively on paper. In 2014, shipping company Maersk followed a refrigerated container filled with roses and avocados from Kenya to the Netherlands to document the maze of physical processes and paperwork that impact every shipment. The numbers speak for themselves: they found that around 30 actors and more than 100 people were involved throughout the journey, with the number of interactions exceeding 200. The shipment took about 34 days to go from the farm to the retailers, including 10 days waiting for documents to be processed. One of the critical documents went missing, only to be found later amid a pile of paper (Park, 2018).

A multitude of documents have to be submitted in the context of international trade transactions (see Figure 3), which fall into four main categories (see Figure 4):

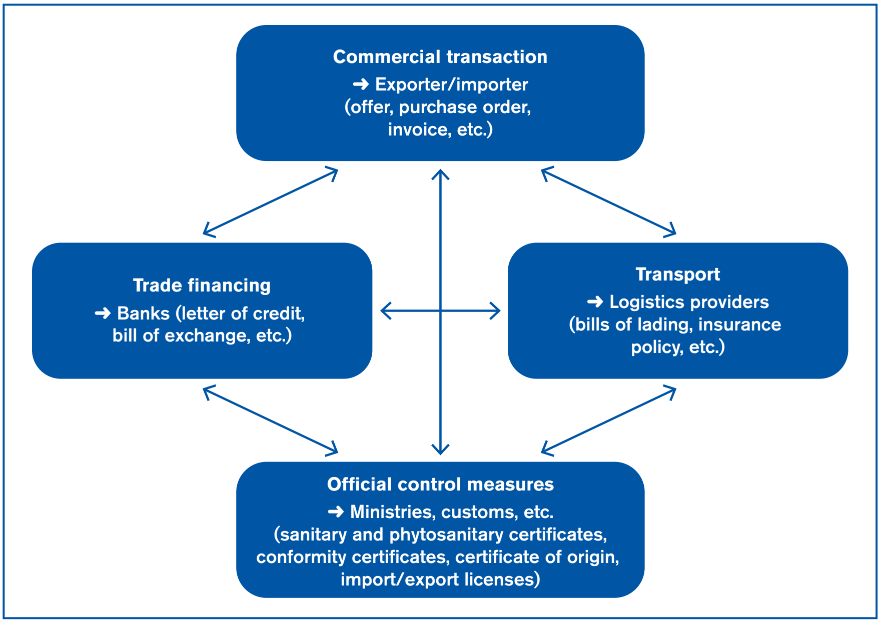
- documents related to the commercial transaction itself, including the sales contract, commercial invoices and if needed, a packing list submitted by the exporter prior to exportation;
- documents related to trade financing, such as letters of credit;
- transport documents, including bills of lading, etc.; and
- documents for border procedures, including:
  - certificates of origin – delivered by chambers of commerce, but other bodies such as ministries or customs authorities may also have this privilege in certain countries;
  - sanitary and phytosanitary certificates, in the case of food, plant and agricultural products – which are usually delivered by the ministries of health and agriculture;
  - certificates of conformity that certify that a product or service meets the requirements of a particular standard in the country of importation;
  - export or import licenses, if required by the authorities of the exporter's or importer's country;
  - customs declarations;
  - customs inspection documents.

Figure 3 **Typical international trade documentation issued**



Source: Accenture.

Figure 4 Four processes involved in cross-border trade transactions



Source: Author.

Not only do these various paper intensive processes increase coordination and administrative costs, they are also prone to errors, losses and fraud. Although notable progress has already been achieved, full digitalization of cross-border trade transactions of goods is not yet in sight. The complexity and costs associated with international trade in goods has led an increasing number of companies and governments to investigate how Blockchain could be used to cut paperwork and enhance processes involved in the export of goods, from trade finance to border procedures and transportation, with the hope of moving closer to truly paperless trade.

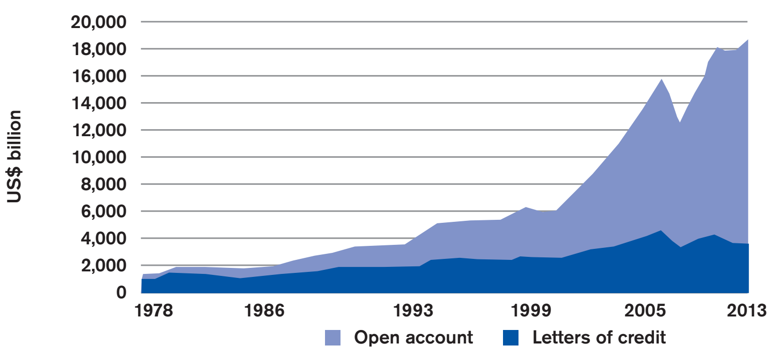
(a) Can Blockchain facilitate trade finance?

The availability of trade finance is crucial for trading activities. Only a small part of international trade transactions are paid cash in advance, as buyers usually want to pay only once the goods have been properly delivered. Up to 80 per cent of trade is financed by some form of financing (WTO, 2016b), which, broadly speaking, includes traditional mechanisms, such as letters of credit, and supply chain finance – a generic term that refers to a variety of financing instruments used to finance parties in a supply chain. While letters of credit have traditionally been a widely used form of trade finance, there is a growing trend to trade on open account terms using supply chain financing (see Figure 5).

Existing traditional trade finance is often associated with high costs and burdensome procedures, due to a paper-heavy process and the challenges of coordinating the multiple players involved in a trade transaction; trading on open account terms[1] using supply chain finance tools can be a risky game for exporters; and there are also the challenges related to trust, detection and prevention of fraud, and the authentication of parties. These shortcomings have led banks, fintech startups and IT companies to explore the potential of Blockchain to facilitate trade finance. The technology is seen by many as an interesting tool to improve the security of traditional trade finance transactions and to streamline and digitalize processes, especially letters of credit, as well as an opportunity to facilitate "know-your-customer" (KYC) processes and ease supply chain finance.

Traditional trade finance – in particular letter of credit transactions[2] – is labour- and paper-intensive and involves multiple players. One of the largest banks providing trade finance employs several thousands of people to verify millions of trade documents each year related to letters of credit requests, and recent research by the Boston Consulting Group finds that more than 20 players are usually party to a single trade finance transaction throughout the process, with data captured in 10 to

Figure 5 **Use of letters of credit versus open account (world trade volumes from 1978-2013)**



Note: World trade volumes have seen a startling increase in open account transaction over the recent years. Already today more than 80 per cent of the total world trade volume (export) is settled by clean payment. This impressive ratio is expected to grow even further in the future. As a consequence, banks are compelled to offer their corporate clients products that support fully automated processing as well as cost savings combined with payment assurance and financing options.

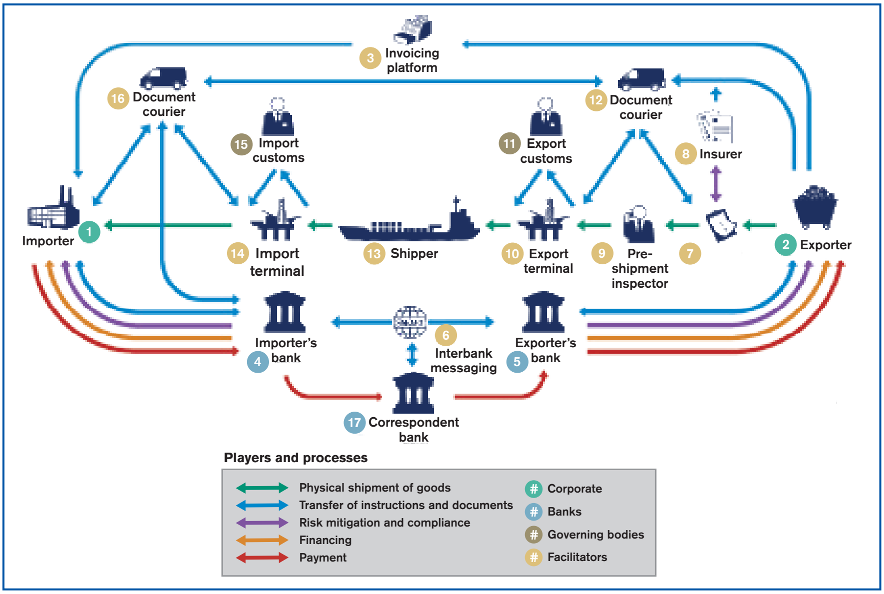
Source: Unicredit Group, cited in UN/CEFACT (forthcoming).

20 documents, creating approximately 5,000 data field interactions (see Figures 6 and 7). Only 1 per cent of these interactions creates value, with 85 per cent to 90 per cent of the transactions consisting of "ignore/transmit to the next party" actions (Boston Consulting Group, 2017).

The system is costly and has led banks and companies like essDocs and Bolero to explore how trade finance processes could be digitalized. Efforts have so far focused on digitalizing payments and information, essentially via scanned PDF documents. They have done little, however, to digitalize the transactions themselves and to mitigate the risks associated with trade (Castell, 2018). The transparent and secure nature of Blockchain has raised hopes and led an increasing number of banks to explore how Blockchain could help automate the process, improve efficiency of transactions and enhance security.

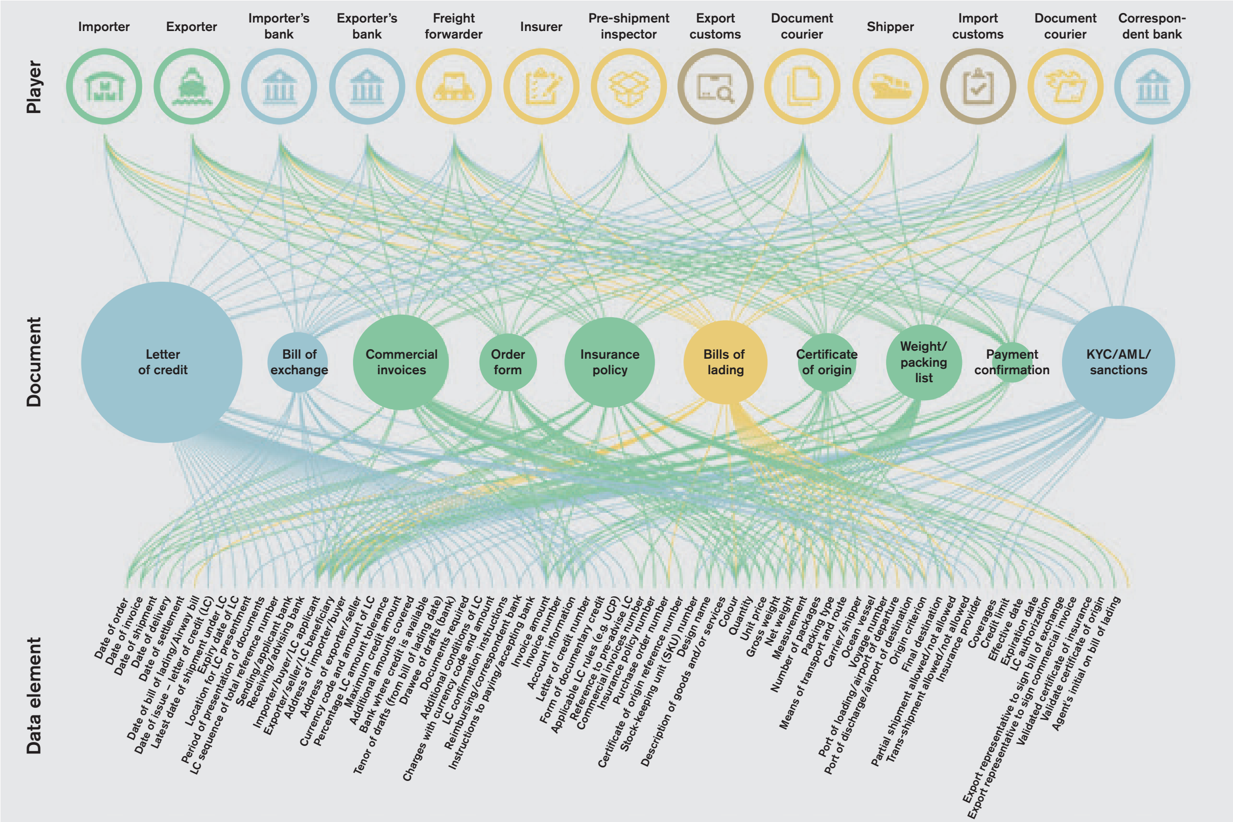
Various proofs of concepts have been developed in the course of the last few years to streamline and automate letters of credit processes, and blockchain applications in this field are now moving towards commercial application. In September 2016, Barclays and fintech startup Wave reported having conducted the first live blockchain-based trade finance deal (Barclays, 2016). The transaction, conducted

Figure 6 **The traditional trade finance process is highly fragmented across multiple entities and processes**



Source: Boston Consulting Group (2017).

Figure 7 Numerous players, documents and data elements are involved in a trade finance transaction

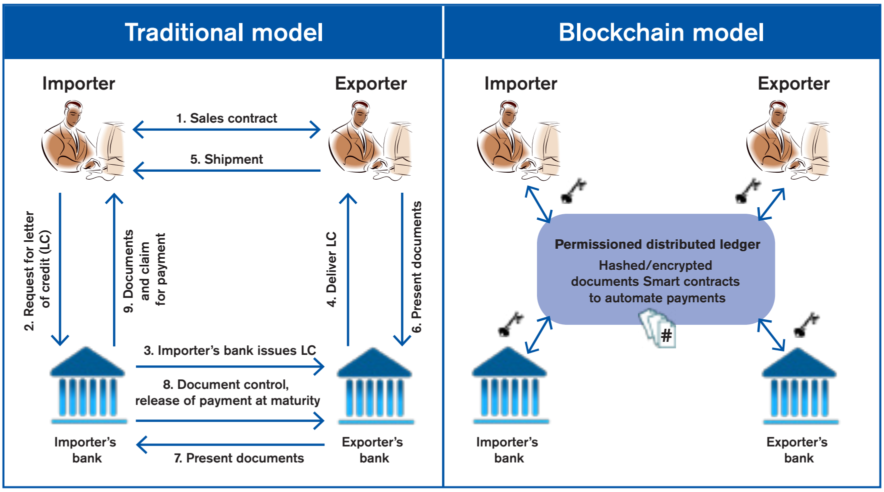


Source: Boston Consulting Group (2017).

through a permissioned ledger, guaranteed the export of almost $100,000 worth of cheese and butter from Irish dairy cooperative Ornua (formerly the Irish Dairy Board) to the Seychelles. According to Barclays, the letter of credit transaction process, which usually takes between seven and 10 days from issuing to approval, could be reduced to less than four hours. The letter of credit itself was issued through the SWIFT (Society for Worldwide Interbank Financial Telecommunication) system and the funds were released in a traditional manner.

In August 2016, Bank of America, HSBC and the Infocomm Development Authority of Singapore (IDA) announced that they had built a blockchain application based on the Hyperledger Fabric to improve the letter of credit transaction process. The application mirrors a traditional letter of credit transaction by sharing information between exporters, importers and their respective banks on a permissioned distributed ledger (see Figure 8). A series of digital smart contracts* allows them to execute the deal automatically (HSBC, 2016). And in May 2018, HSBC completed what it claims is the "world's first commercially viable trade finance transaction" using Blockchain, arguably opening the door to the commercial use of the technology for trade finance operations (Weinland, 2018). The letter of credit transaction for US group Cargill for a shipment of soya beans from Argentina to Malaysia was conducted on the Voltron blockchain platform for letters of credit built by a group of 11 banks on the Corda platform developed by the R3 consortium.

Figure 8 Example of letter of credit process[a]



[a] The specific features of blockchain platforms (e.g. types of payments) depend on the characteristics chosen by participants.

Source: Author

Beyond efforts to leverage the potential of the technology to enhance existing traditional trade finance processes, such as letters of credit, the disruptive nature of the technology is leading some companies to develop new supply chain finance products and models.

While letters of credit remain important, an increasing number of trade transactions take place on open account terms using supply chain financing.[3] In the European Union, for example, letters of credit are, in fact, little used for intra-regional trade. Not without a reason: the cumbersome process involved with letters of credit usually takes longer than the time needed for the goods to arrive at destination. Open account transactions, however, are the highest risk option for the exporter: in an open account transaction, the goods are shipped and delivered before payment is due.[4]

Making open account financing less risky using blockchain technology was the bet made by seven banks in December 2016, with the launch of the Digital Trade Chain Consortium, since then renamed We.trade (Groenfeldt, 2017). We.trade is a blockchain-based "bank-centric platform", built on the Hyperledger Fabric, that counts nine banks and covers 11 EU countries (July 2018 data).[5] Traders register to the platform via their banks. Importers and exporters can then record their transactions on the platform after having agreed the terms of their contract (goods concerned, price, payment term, settlement conditions). A smart contract provides guarantee of payment and automatic settlement when the conditions determined between the parties are met. Payments can either proceed on open account terms or via a Bank Payment Undertaking (BPU), i.e. a bank guarantee of payment. The platform completed its first live operations in July 2018, involving twenty companies and five major banks (Suberg, 2018).

The We.trade initiative is only one among many projects that are blossoming in various corners of the globe. For example, IBM recently partnered with Indian company Mahindra[6] and Chinese conglomerate Sichuan Hejia[7] to develop new permissioned blockchain-based solutions for supply chain financing; and China-based Dianrong, a leader in online marketplace lending, and FnConn (a Foxconn subsidiary) united to launch ChainedFinance in March 2017.[8] Other examples include the partnership between Mizuho Financial Group and Hitachi, the Eximchain project supported by the MIT (Huertas, Liu and Robinson, 2018), and the Marco Polo platform released in September 2018.

All of these platforms leverage blockchain technology and smart contracts to streamline financial flows between buyers, sellers and financiers, and enhance the security, speed, transparency and reliability of supply chain financing. Recent studies demonstrate that Blockchain can, indeed, deliver substantial benefits for all parties involved in supply chain financing transaction, by expediting the processes and lowering the overall costs of financing programmes (Hofmann, Strewe and Bosia, 2017). These initiatives open particularly interesting opportunities for micro, small and medium-sized enterprises (MSMEs), which often struggle to obtain trade financing because of lack of sufficient collateral or poor or non-existent credit history. By giving financiers greater visibility into the supply chain cash flow and the credit history of companies, Blockchain can facilitate KYC processes and ease MSMEs' access to affordable finance.[9]

The use of blockchain technology for trade finance operations has also raised the interest of monetary authorities. In March 2017, the Hong Kong Monetary Authority unveiled a trade finance platform using blockchain technology (Perez, 2017), and the Monetary Authority of Singapore is working with the IBM Center for Blockchain Innovation to develop applications and solutions using Blockchain to improve the efficiency of trade finance processes and transactions (IBM, 2016). In November 2017, they both announced a joint project to develop a global trade connectivity network, a blockchain-based cross-border infrastructure to digitalize trade and trade finance between Hong Kong (China) and Singapore. Over time, the aim is to expand the network to the region and the globe. The platform is expected to go live in early 2019. China's central bank is also spearheading a trade finance platform to provide supply chain finance across the Guangdong, Hong Kong (China) and Macau (China) bay area, with the aim of helping small and medium-sized enterprises access trade finance. The platform entered the testing phase in Shenzhen in September 2018 (Huillet, 2018a).

The hype is real, but some remain sceptical in light of the fever that surrounded the bank payments obligation (BPO) a few years ago. Launched in 2013 by SWIFT, BPOs are conditional payment guarantees given by one bank to another. Unlike letters of credit, which are paper-intensive, BPO uses electronic data-matching to facilitate payments between an importer's bank and an exporter's bank. When it was launched, BPO was praised as a new and revolutionary way to optimize trade finance flows. Although quicker and cheaper than letters of credit, BPOs have only been used on a limited scale. Various reasons have been invoked for this lack of interest: each party to the transaction had to be BPO-enabled, investing in the technology could be costly, and moving to BPO required an overhaul of traditional and well-established processes and a change in culture.

Does Blockchain have better chances to succeed than BPOs? Opinions are split, in particular when it comes to letters of credit. Some observers note, for example, that the most serious source of fraud in letters of credit relates to the issuance of false documents rather than tampering with documents, an issue that Blockchain cannot solve, as the technology cannot prevent false information from being fed into the ledger (Takahashi, 2018). Checking documentation will, therefore, remain necessary.

In addition, payment under a letter of credit is already often done by electronic transfer.

Others, however, note that distributed ledgers offer potential new benefits, including increased cybersecurity, greater transparency, real-time transactions, automatic payments through smart contracts, easy auditability of transactions due to the transparent and immutable nature of the technology, and easy inclusion of additional participants. Blockchain enthusiasts believe that the technology offers the strongest potential solution to digitalize trade finance, even leading some to claim that the BPO will be transformed into a "Blockchain Payment Obligation", in the words of Wassilios Lytras, co-founder of Gatechain, a Swiss startup that develops blockchain-based solutions for trade finance.

However, digitalization of trade finance through Blockchain, if it happens, will not occur overnight. First, the technology is still being tested and important investments are still needed to make it operational on a wider scale. A positive development is that the various stakeholders involved in trade finance transactions are joining forces. Banks, fintech and other players are forming partnerships to jointly investigate the potential of the technology and develop applications best suited to the needs of their clients. For example, as mentioned in Chapter 2, R3 (R3CEV LL) is a technology company that leads a consortium of more than 200 financial institutions and regulators in research and development of Blockchain in the financial system, with its own platform, Corda.[10] In August 2017, a group of banks in the R3 consortium announced the trial of a platform dedicated to letter of credit transactions (Persio, 2016). The platform, called Voltron, entered its second pilot phase in September 2018 and should be made available in 2019. However, R3 senior management acknowledges that widespread adoption will not be achieved for another five to six years (Palfreeman, 2017).

In September 2018, a consortium of 10 R3 banks released another platform, Marco Polo, to deal with open trade finance (Wass, 2018c).

Second, having the technology in place is not enough. Legal frameworks that clarify, for example, the legal status of electronic documents, which rules and resolution process apply when a smart contract is used, and who is liable at each point of the process, will need to be developed. Just as letters of credit are governed by a specific set of rules agreed by the International Chamber of Commerce (the Uniform Customs & Practice for Documentary Credits – UCP 600), blockchain-enabled smart contracts used for letter-of-credit transactions will also need a set of internationally agreed rules, as banks may not be willing to commit before these legal issues are addressed. The current letter of credit system may be hugely costly, but it is efficient in terms of legal protection. Work is underway in fora such as the

International Chamber of Commerce (ICC) and the International Organization for Standardization (ISO), but developing standards may take time (see Section 4.2(c)).

However, the question of liability – i.e. who is liable at each point of the process – does not apply in the same terms in the case of supply chain solutions such as the one developed by We.trade. Indeed, an interesting feature of this new approach is that liability issues are set in an offline contract between the buyer and the seller. Smart contracts are only used to automatize processes and guarantee payment when the agreed conditions are met. They only cover the operational elements of the offline contract.

Beyond the need for legal frameworks, globally agreed standards that ensure, among other things, interoperability will need to be developed in order to allow the technology to start to be used on a wide scale. A key limitation of current bank-centred applications is the fact that they can only process transactions between banks participating in the project. A truly global system would have to connect all banks – a huge endeavour and a technically challenging task – or bridges will have to be built between existing platforms.

Efforts are underway to address legal and interoperability issues and develop common standards, but this is likely to take time (see Section 4.2(c)).

Third, even this may not be enough, as the BPO experience shows. Although the ICC has developed Uniform Rules for BPO (URBPO), companies have not shown a high level of enthusiasm in using BPOs. The success of Blockchain in trade finance will ultimately depend on whether companies see value in this solution. This will depend on the extent to which the benefits that the technology can yield outweigh the costs of adapting current systems. Beyond legal and interoperability issues, this may only be the case if the underlying trade has been digitalized to enable synergies to be built and Blockchain to be used to its full potential – i.e., if the various aspects of an international trade transaction, including customs procedures and logistics, are digitalized. Unlike previous attempts to digitalize trade finance, blockchain-based solutions are driven by a much larger set of stakeholders, including banks, customs authorities, logistics providers, governments and regulatory bodies. This could give Blockchain the impetus needed to succeed in digitalizing trade where other technological innovations have failed; time will tell. In the near future, however, applications are likely to remain limited in scope.

Investments in the technology remain something of a gamble at this stage, but the flurry of activity that surrounds Blockchain and the opportunities that the technology could potentially open make it a gamble that many financial institutions feel it is important to take – not least in order not to be left behind if the legal and operational uncertainties still surrounding Blockchain are addressed. Should this be the case, the trade finance landscape could well look very different in the future. Interestingly, some observers believe that, while Blockchain has been intimately linked to finance since its inception, the technology has a better chance of first leaving its mark in areas like trade facilitation, where coordination of multiple actors remains a real hurdle, or in issues related to traceability (see Section 4.2(a)).

(b) Trade facilitation in action

Over the past few years, trade facilitation has become a key focus of trade policy. Not without reason: inefficient border procedures continue to impose significant costs on businesses – and ultimately on consumers and the economy as a whole. Blockchain is seen by many as an opportunity to facilitate trade procedures and accelerate the digitalization of cross-border trade.

While tariffs accounted for 9 per cent on average in 2013 (WTO, 2015a), a 2015 WTO study found that trade costs can amount to a 134 per cent *ad valorem* tariff on a product in high-income countries and to a 219 per cent tariff in developing countries (WTO, 2015c). In a large part, these costs are the consequence of paperwork and of the number of agencies involved in border procedures, resulting in burdensome customs procedures. Beyond customs, multiple government agencies responsible for health, food, quarantine, safety, and consumer protection traditionally intervene in customs procedures. A survey-based study found that the median number of government agencies directly involved in cross-border transactions is 15, and can reach 30 in some cases (Choi, 2011). The number of actors involved leads to complex and often duplicative administrative procedures. It is therefore critical to simplify paperwork and to streamline and automate procedures, which explains the growing importance attached to trade facilitation measures – i.e. the simplification of import, export and transit procedures – which led to the negotiation of the WTO Trade Facilitation Agreement (TFA).

The TFA, which was adopted at the Ninth Ministerial Conference in Bali in December 2013 and entered into force in February 2017, aims at facilitating the release and clearance of goods, enhancing transparency, and promoting cooperation between customs and other appropriate authorities on trade facilitation and customs compliance issues, including through the use of electronic means to exchange data and documents related to cross-border trade transactions.

Although trade facilitation is a problem for all trading nations, it is particularly important for developing countries. The latter are expected to gain the most from more efficient customs procedures. According to WTO estimates, the full implementation of the TFA could reduce global trade costs by an average of

14.3 per cent, with African countries and least-developed countries (LDCs) forecast to enjoy the biggest average reduction in trade costs. Full implementation could also reduce the average time needed to import by 47 per cent and cut export time by more than 90 per cent (WTO, 2015c). For every dollar of assistance provided to support trade facilitation reform in developing countries, the World Bank estimates that there is a return of up to US$ 70 in economic benefits.[11]

A number of governmental, regional and inter-governmental organizations are actively working on the implementation of paperless trade measures. For example, the United Nations Economic and Social Commission for Asia and the Pacific's (UNESCAP) Framework Arrangement on Facilitation of Cross-Border Paperless Trade in Asia and the Pacific, adopted in June 2016, aims to facilitate cross-border paperless trade among willing ESCAP member states by enabling cross-border mutual recognition of trade-related data and documents in electronic form and providing a dedicated intergovernmental framework to develop legal and technical solutions. The United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT) developed a series of some 40 recommendations (UNECE, 2017) to simplify, standardize and harmonize trade procedures and information flows, some of which are directly related to the use of electronic means and electronic data structure standards for information exchange. UN/CEFACT also develops base semantics to help enable electronic exchange of information. Parties to the International Plant Protection Convention (IPPC), a multilateral agreement deposited with the Food and Agriculture Organization of the United Nations (FAO) that aims to protect plant health by preventing the introduction and spread of plant pests, adopted a standard that describes principles and guidelines for the preparation and issue of electronic phytosanitary certificates. The IPPC, with support from the Standards and Trade Development Facility (STDF), recently launched a Global ePhyto Hub to facilitate exchanges of ePhyto certificates, in particular among developing countries: an exporting national plant protection organization can transfer an ePhyto certificate via a secure system to the hub, which will then transfer it to the importing country's "mailbox".[12]

A growing number of economies are also moving beyond simple customs automation systems, pioneered by ASYCUDA (i.e. Automated System for Customs Data), the computerized customs management system developed by the United Nations Conference on Trade and Development (UNCTAD), towards more integrated and sophisticated platforms: the single window, i.e. a "facility that allows parties involved in trade and transport to lodge standardized information and documents with a single entry point to fulfil all import, export and transit related regulatory requirements."[13] Such initiatives are increasingly integrating electronic certificates, such as the Association of Southeast Asian Nations (ASEAN) Single Window, which has agreed a protocol for the exchange of electronic certificates of origin among some of its member states and is exploring the establishment of an electronic phytosanitary certificate. The importance of putting in place single windows has been highlighted in the WTO TFA.[14]

However much remains to be done. In a recent study, UNESCAP estimates that the global average implementation rate of "paperless trade" measures stands close to only 50 per cent, with more advanced paperless trade measures such as electronic single windows and electronic application and issuance of preferential certificates of origin remaining at a relatively early stage (UNESCAP, 2017). The latter has only been fully or partially implemented by only slightly more than 40 per cent of economies. The implementation of cross-border paperless measures is even lower. Measures such as electronic exchanges of sanitary and phytosanitary certificates have been fully or partially implemented in less than 30 per cent of the surveyed economies, with developed countries doing slightly better on average than developing economies, except Latin America and the Caribbean, which are leading on several fronts.

Blockchain is seen with hope by many actors involved in international trade as a new opportunity to further facilitate and digitalize international trade transactions. Cross-border transactions involve exchanges of data and documents between two main categories of actors: businesses (B) – importers, exporters, banks, and transportation and logistics companies – and government authorities (G). Electronic single windows are increasingly used to facilitate G2G processes at the national level (i.e. exchanges between national government agencies) and B2G processes, but cross-border G2G processes remain complex. Can Blockchain facilitate such processes, improve cross-border G2G interactions for issues such as sanitary and phytosanitary certification, and move closer to truly paperless trade? While the technology presents interesting features to facilitate certain aspects related to border procedures, moving to a truly global paperless blockchain-based system will require more than simply the technology.

(i) Blockchain could facilitate national G2G and certain B2G border procedures

Because it allows information to be exchanged and processed with all those authorized in real time and in a highly secure manner, and processes to be automated through the use of smart contracts, thereby minimizing coordination costs and delays, Blockchain could enhance the efficiency of a number of B2G processes, enhance inter-agency cooperation at the national level and help to administer single windows, where they exist, in a more efficient way. In particular, it could prove useful with regard to the following:

B2G and national inter-agency coordination

The highly secure, decentralized and distributed nature of Blockchain could support and enhance the exchange of information between government agencies at the national level and open new opportunities for them to cooperate more effectively (WCO, 2017). Blockchain is particularly suited to situations that involve multiple actors. In a traditional system, most stakeholders act in silo and in a sequential manner, records (e.g. shipper, export broker, import customs, bank and transportation records) are kept separately, and any party can add to or alter them, making these records vulnerable to fraud; while in a blockchain-based system, all information is shared on a common platform and is nearly impossible to modify. All parties involved act in full transparency and in real time, and all actions can be easily tracked. In cases where multiple authorizations are required to export a product, the exporter would be required to enter the information only once. The data would then be used by the respective agencies connected to the platform to validate the transaction or issue the relevant documents.

A proof of concept developed by IBM to ship flowers from Mombasa, Kenya, to Royal Flora in the Netherlands illustrates well the advantages that the technology can bring.[15] Exporting flowers from the port of Mombasa requires signatures from three different agencies and six documents that describe the origin, chemical treatment, and quality of the goods, and customs duties. The Kenyan farmer, using his mobile, submits a packing list that becomes visible to all participants in the permissioned ledger. This action initiates a smart contract that enforces an export approval workflow among the three agencies that must approve the export. As each agency gives its consent, the status of export is updated in real time, and for all to see. Simultaneously, information about the inspection of the flowers, the sealing of the refrigerated container, the collection by the trucker and the approval from customs is communicated to the port of Mombasa, allowing it to prepare for the shipping of the container. At all times throughout the process, all actions relating to the documents and the goods are captured and shared on the permissioned ledger and are visible to all authorized participants in real time: which documents were submitted, when and by whom; where the flowers are and who is in possession of them; and the next steps.

Certification and licensing

As the Royal Flora example shows, the use of Blockchain can help to streamline the approval workflow of certificates. Sanitary and phytosanitary certificates, certificates of origin and conformity assessment certificates delivered by trusted authorities are commonly required to provide assurance to the importer or the competent authorities in the country of importation that the goods being exported meet certain requirements.

Another feature of the technology that could be of interest when it comes to certification is the fact that blockchain transactions include a reference to previous transactions (a "hash pointer"). In the case of phytosanitary certificates, for example, shipments cannot be split and sent under a single certificate. Exporters wishing to split their shipment need to go back to the agency having issued the certificate and request a replacement certificate. With a blockchain-based system that links transactions to previous ones in a secure and trusted manner, one could imagine that requesting a replacement certificate would no longer be necessary if the goods are sent to the same destination[16] – which would greatly facilitate the life of both traders and certifying agencies – provided, of course, that the regulatory framework can be adjusted to permit this.

Blockchain can also prove interesting to administer import and export licenses more efficiently. Such permits are normally delivered for a set period of time. Storing an import or export licence on the blockchain would save the importer or exporter the trouble of having to keep the permit in a safe place to avoid losing it and would allow customs authorities to easily check the authenticity and validity of the permit. Using fake permits would no longer be possible.[17] The use of a smart contract could even allow the parties to go one step further by automatically rendering an import/export permit invalid upon expiration of its validity period, which could help fight fraud and avoid situations like that faced by the Philippines in 2016, when the Department of Agriculture cancelled and recalled all import permits on meat products to tackle meat import fraud, having found that old permits were being recycled to smuggle imports (Fortune, 2016).

Blockchain applications are also being explored in relation to certificates of origin. After having acquired eCertify and TradeCert, two of the leading electronic certificate of origin (eCO) providers, in May 2018, paperless trade platform provider essDOCS unveiled a new-generation eCO solution, essCert. Some of the new features that essCert will offer include blockchain/distributed ledger technology (DLT) options, enabling chambers of commerce to connect eCO data to blockchain platforms and Internet of Things (IoT) devices to improve origin verification (essDOCS, 2018).

That same month, the Singapore International Chamber of Commerce, which has authority to deliver certificates of origin, and fintech company vCargo Cloud unveiled a permissioned blockchain-platform for eCOs to improve efficiency, minimize the costs of verifying certificates of origin and prevent fraud. The system provides for a hybrid solution when the recipient is not ready to accept digital documents. In such cases, both a digital and a paper copy are issued, and a QR* code that contains the hash* of the digital copy that is on the blockchain is embedded in the paper copy. The QR code can be scanned with a smartphone to verify the eCO. These eCOs can be printed, but allowable prints are restricted to prevent unauthorized duplicates (IT News Africa, 2018).

Kenya, the Republic of Korea and the United Kingdom are working on similar projects, and the Common Market for Eastern and Southern Africa (COMESA) announced in February 2018 a pilot project using Blockchain for its new digital free trade area to connect transacting parties in real time through a blockchain platform. The system will integrate an electronic certificate of origin (Mbogo, 2018).

An important point to note when it comes to certificates of origin is that authentication from chambers of commerce does not attest to the true origin of the product, only to the statement provided to the chambers of commerce by the exporter, leading some to argue that such authentication would, in reality, not be truly necessary. Blockchain would not change this state of affairs. Arguably, the benefits of a blockchain-based system when issuing certificates of origin would be limited to proving that the certificate is authentic – i.e. that it has been delivered by the pertinent authority – and has not been tampered with. However, if blockchain traceability uses become more widely implemented (see Section 4.2(a)), one could imagine a day when certification of origin would rely on blockchain data to be determined directly at the border, without the need for a certifying authority. The announcement by the US Customs and Border Protection in August 2018 that it would launch a live test to track information and help validate that products imported from partners of the North American Free Trade Agreement and the Central American Free Trade Agreement originate where they claim could be a first step in that direction (Baydakova, 2018).

Release and customs clearance of goods

Blockchain applications could enhance the efficiency of customs clearance processes and reduce the need for manual verification. In particular, it could be used to:

- Submit requests for advance rulings.[18] Rulings, once issued, would be securely stored on the blockchain, in a permissioned ledger, and remain accessible at all times by authorized stakeholders, including all customs offices located in the territory, throughout the validity period of the ruling, thereby facilitating the release and clearance process.
- Facilitate pre-arrival processing,[19] i.e. processing prior to the arrival of the goods, and expedited release of goods,[20] as required data can be shared on the ledger in real time.
- Optimize risk assessment.[21] As customs documents are submitted via the system, they would be immediately and automatically analysed and assessed on the basis of pre-determined selectivity criteria encoded in a smart contract. Consignments meeting the selectivity criteria would be automatically flagged.
- The potential of the technology in these various areas still has to be fully explored, but some initiatives are emerging. In May 2018, the Korean Customs Service, for example, announced the development of a blockchain-based customs platform to

facilitate e-commerce customs clearance. The Republic of Korea's customs authority signed a memorandum of understanding with e-commerce companies to test the technology to accelerate customs clearance of e-commerce goods from these companies, share information in real time, generate automated import customs clearance report to authorities, and prevent fraud and smuggling (CCN, 2018).

Temporary admission of goods

Goods imported for a specific purpose and for a limited period of time, such as paintings for an exhibition, are relieved from payment of import duties and other taxes, on the condition that they are re-exported within the specified period without having undergone any change (except normal depreciation).[22] Using Blockchain to track their movements and share information could allow to move away from today's paper intensive process and improve the efficiency of the temporary admission procedure.

A proof-of-concept conducted by the EU Commission's DG TAXUD[23] in cooperation with the International Chamber of Commerce demonstrated that Blockchain could be used to ensure the integrity of temporary admissions carnets (so-called ATA Carnets)[24] and transactions. A pilot will now be launched to test the application (Saadaoui, 2018).

Revenue collection and accuracy of trade data

Smart contracts could be encoded based on applicable legal and regulatory requirements to allow the automatic payment of customs duties according to an "if... then..." formula", e.g. "if" the goods arrive at the customs terminal on the importing side, "then" payment of duties is automatically processed. A digital mechanism for monitoring external events, also known as an oracle*, could be used to trigger smart contract executions when pre-defined conditions are met, thereby replacing self-reporting. For example, an oracle could be programmed to monitor a truck equipped with sensors and trigger payment of duties when the truck crosses the border.

Blockchain applications could also permit intermediaries to collect duties and taxes on behalf of governments and to transfer them automatically to respective authorities using smart contracts – which could prove useful in the case of low-value shipments related, for example, to e-commerce.

Finally, the use of Blockchain to register tariffs imposed on imports could help improve the accuracy of trade data and statistics.

Post-clearance audit[25]

As in the case of risk management, smart contracts could be used to screen documents on the basis of pre-defined criteria to optimize post-clearance audit. In case of doubt, the immutable nature of Blockchain makes it possible to easily track and audit transactions.

Compliance management
Blockchain could make it easier to determine the provenance of products – and thereby to prove compliance with, for example, preferential treatment granted under free trade agreements – and help reduce fraud, inaccuracies and errors (see Section 4.2(a)).

Identity management
Blockchain could facilitate the verification of identities of businesses and individuals, including authorized economic operators (AEOs).[26]

Blockchain's potential to enhance the efficiency of border procedures and B2G transactions at the national level is multifaceted. Various organizations, such as UN/CEFACT, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the World Customs Organization (WCO) are exploring how the technology could be implemented and integrated with existing customs systems and certification processes, and IT companies and government agencies are partnering to investigate the potential of the technology via the development of proofs of concepts and pilot projects. However, while Blockchain can provide the tool to administer border procedures and single windows at a national level in a more efficient, transparent, and secure manner, the real challenge will be to make cross-border G2G processes more efficient.

(ii) The hope for easier cross-border G2G processes

Cross-border electronic B2B transactions are common and have been underpinning economic globalization since the advent of the internet, but electronic cross-border G2G exchanges supporting supply chains are still in their infancy (Stokes, 2017). Blockchain's decentralized nature is seen with hope by many actors in the field as an opportunity to help overcome some of the challenges that make cross-border G2G processes complex or risky.

The technology could prove interesting, for example, to alleviate the risks associated with certain types of cross-border G2G processes, such as the sharing of information related to authorized economic operators. Implementation of AEO mutual recognition agreements (MRAs) hinges on various challenges, including the manual process of sharing sensitive and/or confidential data with low standards of security and integrity, the difficulty to establish the provenance and traceability of the data and to guarantee secure access, the inability to grant AEO benefits in real time, and the inability to react in real time when a suspension occurs, with all the consequences that this may have on the security of the supply chain (Corcuera-Santamaria, 2018). The specific features of the technology could enhance the cross-border management of MRAs by making it possible to automate the process of sharing AEO data among the parties to an MRA in real time and in a secure manner, and by providing a traceable mechanism that guarantees the integrity of data. The potential of the technology to facilitate the implementation of AEO mutual recognition agreements is currently being tested. A pilot project between Mexico and Costa-Rica (called Cadena) was launched in March 2018 with the support of the Inter-American Development Bank to create a common platform for the management of AEOs.

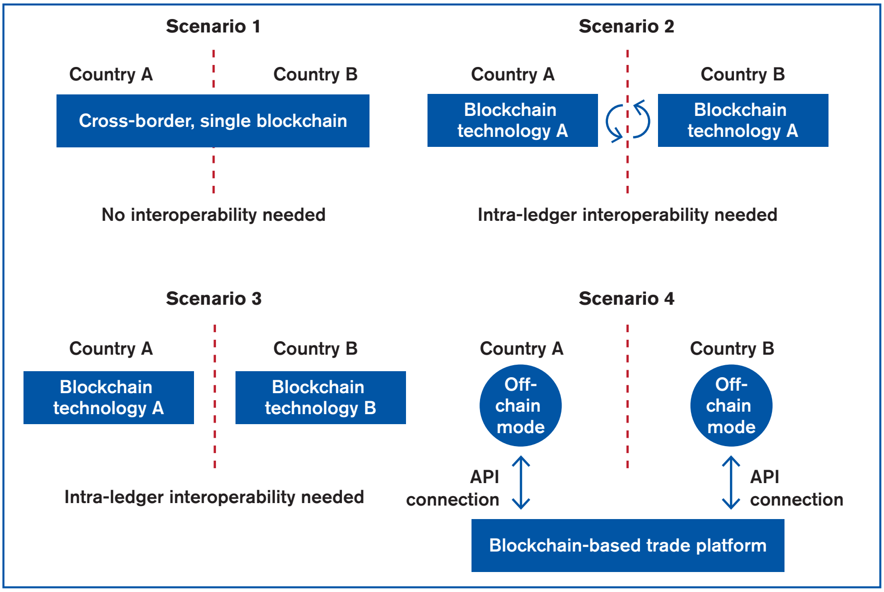
Can the technology facilitate the various dimensions of cross-border G2G interactions involved in customs clearance, in particular G2G exchanges of customs documents and certificates? Challenges related to cross-border G2G processes are, broadly speaking, of three types: technical interoperability, that allows IT systems to talk to each other at a technical level, regulatory issues, and data simplification and standardization. While Blockchain could help with respect to the former – under certain conditions – it can do little when it comes to regulatory issues. In fact, the latter will to a large extent determine Blockchain's ability to truly enhance G2G processes.

(iii) Technical interoperability

The move to digital documents, such as e-phyto certificates, has raised new issues of interoperability. In the paper world, such documents are simply presented in paper copies to the competent authorities. The move to digital documents requires the establishment of *ad hoc* "e-bridges" between competent authorities from the importing and exporting countries, which can be a complex and burdensome process. The creation of hubs, such as the e-phyto hub recently launched by the IPPC, can help manage the routing of connections, but such hubs do not provide a holistic, integrated approach – not to mention that such hubs may raise challenges in terms of administration (e.g. the need to trust a third party), financial implications regarding the management of the hub, and security (e.g. related to the single point of failure).

Can Blockchain facilitate such G2G processes from a technical point of view? The answer is not straightforward. Much depends on the actual technical setting at the national level on both the importing and the exporting sides. The ideal scenario would be one in which importing and exporting government authorities would be part of the same single blockchain. In such a case, no interoperability would be needed. Data could be exchanged directly from one party to another through the platform, based on the rules of the platform (see Figure 9, Scenario 1). Smart contracts could be encoded to share only certain types of data with other governments authorities and other participants in the platform. This scenario, which is the most ambitious one, is being tested by various actors in the field. One such

Figure 9 Cross-border G2G scenarios



Source: Author.

project is the Singapore Customs Declaration initiative. In collaboration with Singapore Customs, IBM developed a blockchain-based customs portal allowing it to send customs declarations from New York to Singapore.[27] A permissioned ledger allows all members of the network to access all customs information in a single place and in real time. Various private sector consortia in the field of transportation and logistics are also looking into the feasibility of developing multi-stakeholder trade platforms (see Section 3.1(c)). Although, in theory, such platforms would be ideal, it is difficult to envisage such a scenario at a global level. This approach is more likely to be limited to some trading lines and some customs authorities, with various platforms running in parallel.

Another scenario would be one in which government authorities on both the importers' and exporters' sides belong to two different platforms built on the same blockchain technology (e.g. Hyperledger Fabric). In such a case, "intra-ledger interoperability" – i.e. interoperability between blockchains platforms built on the same blockchain technology – would be required (see Figure 9, Scenario 2). Such interoperability is the subject of intense research and solutions are emerging. In May 2018, the Enterprise Ethereum Alliance, for example, unveiled an open-source cross-platform standards-based framework for Ethereum-based permissioned blockchains that would allow interoperability between permissioned blockchains built on the Ethereum public blockchain (Higgins, 2018). As in Scenarios 1 and 3 of Figure 9, smart contracts would ensure that only certain types of information can be retrieved by other relevant authorities. Given the multiplicity of blockchain technology-based frameworks emerging, such a scenario is likely to be limited to some cases only.

Scenarios 3 and 4 of Figure 9 seem more likely to become reality in the years to come. In Scenario 3, the government authorities on both sides of the transaction would each belong to a different platform, each being based on its own technology. In such a case, inter-ledger interoperability would be needed. Aware of the stakes at play, the Blockchain community is actively looking into possible solutions. Interoperability tools between Hyperledger and Ethereum, for example, are being developed.[28] Another, more global, approach being discussed would consist in creating an inter-ledger notarization system that would allow authorized parties to verify transactions irrespective of the ledger on which they are created (UN/CEFACT, 2018). Notarization could be performed by a sole entity or by different entities – at the cost, however, of reintroducing some degree of centralization. Many in the community see the development of a notarization system as a critical element of widespread interoperability (see also Section 4.2(a)).

In Scenario 4, either some or all of the government authorities in the importing and exporting countries would remain off-chain and would interact with a given blockchain-based trade platform through APIs (i.e. application programming interfaces, which allow information to be pulled out from one system to another) on a case-by-case basis – provided that the coding used by the smart contracts of the blockchain is compatible with APIs. In this scenario, Blockchain would do nothing to facilitate cross-border G2G interaction, which would continue to proceed as it had prior to the introduction of the new blockchain system. Such a scenario could nevertheless present some value for both government agencies and participants in the blockchain-based trade platform: APIs could allow government agencies to pull relevant information from the platform to accelerate customs clearance and other processes, and participants in the blockchain would be able to pull authorized information from government agencies to facilitate the processes they handle via the platform.

What these various scenarios show is that while Blockchain can, under an integrated system, considerably facilitate technical cross-border G2G interaction, it is unlikely to be a panacea to global G2G interoperability issues. A truly global integrated system is unlikely. A more probable scenario is the coexistence at a global level of various platforms built on different technologies. Unless interoperability issues between such platforms are settled, turning to Blockchain with a view to facilitating technical cross-border G2G interaction, and international trade transactions more generally, is unlikely to make a real difference.

(iv) Regulatory issues

Going paperless requires more than simply the technology and technical interoperability. It requires a conducive regulatory framework that provides for e-authentication methods and the recognition of e-signatures, e-documents and e-transactions; that recognizes the authority of other government entities (both national and foreign) to issue required documentation, such as certificates; and that allows for the sharing of certain types of information between government authorities. This is true at the national level, where many electronic exchanges cannot be sent from one agency to another because the proper framework has not been put in place, but even more so at the international level.

National legislation may have to be comprehensively examined and adjusted to give legal recognition to e-signatures and e-documents. To date, only a limited number of countries have legal provisions for such recognition. Most countries – as well as commercial buyers/importers – continue to request paper versions of documents. Likewise, in many countries, national legislation has to be adjusted to authorize the access and sharing of information with another administration, even at the national level. A first step should be to recognize e-signatures and electronic transactions on a national basis, and subsequently to explore accepting such messages from other countries. Recognizing e-documentation issued by another country's entity requires case-by-case agreements (UNNExT, UNECE, UNESCAP, 2012).

Only a few truly paperless exchange channels exist to date, such as the exchange of health certificates between the Netherlands and China for dairy products and of phytosanitary certificates between the Netherlands and Colombia for flowers.[29] Building such channels is complex and time-consuming, not least because regulatory issues have to be settled product by product.

Moving to Blockchain would still require definition of the regulatory parameters that allow data to be exchanged among competent authorities. The technology may be new, but the same old regulatory hurdles remain. However, the inherent characteristics of Blockchain and the possibility of using smart contracts to limit access to information only to those authorized could potentially facilitate the establishment of such channels by creating a secure and trusted environment for the exchange of data – provided there is political will.

Although Blockchain can help accelerate the digitalization of trade and enhance the efficiency of border procedures, the road to truly paperless trade remains long. High-level political support is needed to drive trade integration and help establish a legal framework conducive to paperless trade. One of the obstacles to greater trade integration may, in fact, be political. Today, only a limited number of single windows around the world are fully integrated. Many are built on interfaces that allow the electronic exchange of information, but not the processing of data.[30] One of the reasons is the reticence of authorities to share data via electronic means with other authorities. Will the higher level of security that Blockchain offers be a game changer? Time will tell.

(v) Data simplification and standardization

In addition, Blockchain will only be able to work at its full potential if data is entered in a format that allows it to be understood in the same way by the various parties involved and easily processed as part of the system. Aligning the semantics (i.e. the meaning of the information exchanged) is crucial. Both UN/CEFACT and the WCO have developed libraries of semantics (see also Section 4.2(b)). Developing standard data sets that cover all data used for information exchange for import, export, transit – and, ideally, for modes of transport and finance – and aligning the processes is also critical.[31] While the IPPC has published a standard format for ePhyto certificates, this is not the case for other documents required for cross-border trade transactions, such as veterinary certificates, for example, which remain bilateral. Blockchain can potentially enhance cross-border trade procedures, but it will not be able to address standardization issues. Implementing a blockchain platform without having rationalized processes and aligned the semantics beforehand would defeat the very purpose of a blockchain-based system. As far as veterinary certificates are concerned, work is underway at the Codex Alimentarius[32] and the World Organisation for Animal Health (OIE) to develop a standard format for veterinary certificates, but it is likely to take time before such a standard is agreed.[33]

Developing single standards is a slow and cumbersome process. A more flexible approach could be to map existing formats and ways of entering the data, and agree on a set of approaches that would allow advanced smart contracts to be codified in order to extract the required data and process it via a blockchain platform. Machine learning and artificial intelligence could be useful tools in this regard. Rather than harmonizing approaches beforehand, with the risk that single agreed standards may rapidly become obsolete, this approach would rely on the "standardization of diversity": the diversity of approaches would be acknowledged and mapped, with the intention of providing a "menu of 'standard' ways" of entering the data. Smart trade requires standardization, but it needs smart and flexible standardization.

Last but not least, efficient cross-border procedures do not only depend on well-coordinated government agencies. They also require the efficient integration of the various aspects of a cross-border trade transaction, from trade finance, to customs formalities and logistics. On this front as well, things are moving rapidly.

(c) Tying it all together: the wager for transportation and logistics companies

Transportation and logistics are the backbone of international trade. The sector constitutes a fertile ground for blockchain implementation due to the high number of actors involved. Not surprisingly, ports, as well as transportation and logistics companies are actively investigating the potential of Blockchain, in combination with the IoT, in the hope of cutting costs and enhancing processes, and for some, with the declared ambition of developing trade platforms that could connect all actors along the supply chain, from shippers to customs authorities and banks, in an attempt to digitalize international trade. The development of such platforms could not only significantly impact the transportation and logistics sector itself; it could profoundly transform international trade in goods.

Potential benefits of this technology for the transportation and logistics sector are arguably wide-ranging and include helping to track ships and trucks, optimizing loading capacity, reducing administrative and coordination costs, increasing transparency in prices, ownership and in the entire transportation chain, accelerating payments through the use of smart contracts, enhancing security and reducing fraud, and simplifying claim settlement by creating an immutable record of freight history. International shipments are usually handled by various companies along the way. Having all relevant shipping information shared with authorized partners in real-time on a secure blockchain that guarantees that any data added has not been tampered with, can significantly improve coordination, accelerate processes and cut costs. One of the key benefits that Blockchain offers when it comes to transportation and logistics is the possibility of enhancing collaboration between the various companies involved, while at the same time allowing them to retain control of sensitive information and of who knows what and when.

These potential benefits are leading an increasing number of companies in the sector to develop blockchain applications. Shipping and logistics company NYK (Nippon Yusen Kabushiki Kaisha), for example, is participating in a consortium to develop a blockchain-based trade-data-sharing platform that aims to improve the logistics of its supply chain. The consortium, formed by NTT Data Corp. of Japan, comprises 14 companies from various sectors involved in international trade, including banking, insurance, integrated logistics, and import and export. Another example is Marine Transport International (MTI), a freight forwarder based in the United Kingdom and the United States, which carried out a successful pilot project based on their public Blockchain Container Streams system. According to MTI, the project demonstrated that the logistics industry would see improved connectivity, efficiency and security thanks to Blockchain (Marine Transport International (MTI), 2017). In the Republic of Korea, Hyundai Merchant Marine Co.

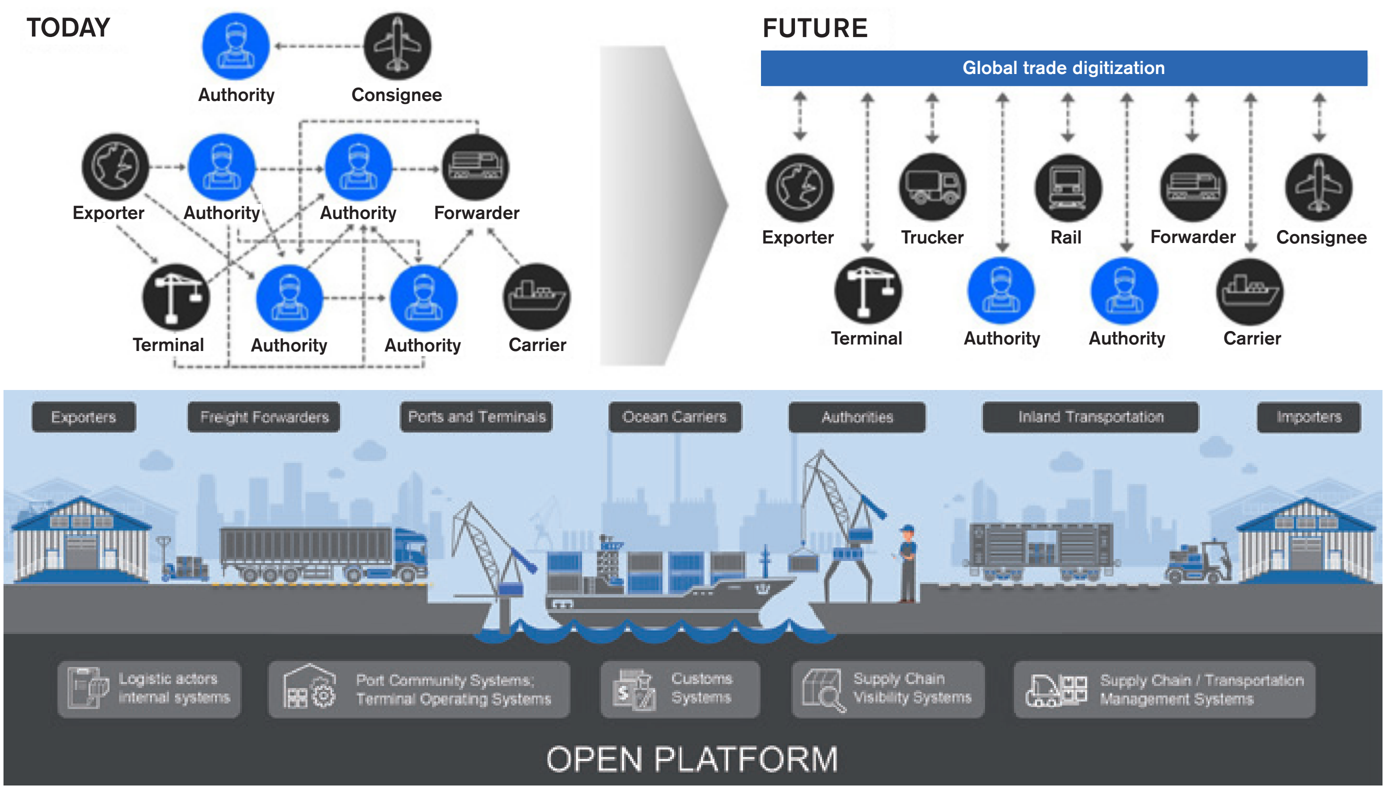
held various trial runs in 2017 using a system developed by Samsung. Other initiatives include Blockfreight,[34] the SAP ocean shipping project[35] and Quasa,[36] an open blockchain platform for cargo transportation companies in Russia and the Commonwealth of Independent States. These are only a few of the projects that are being developed in this field.

The number of smart port projects with a blockchain component is also increasing rapidly. In Europe alone, ports such as Hamburg, Antwerp and Rotterdam are all looking at the potential of Blockchain to help them streamline their activities and improve the sharing of logistical and contractual information between parties.

Initiatives are flourishing in every corner of the globe, leading some observers to note that Blockchain is about to revolutionize the world of transportation and logistics.[37] Some of the projects being developed could, in fact, have an even broader impact. The attempts of certain companies to work with government authorities to develop platforms that would connect all actors along the supply chain could be revolutionary – but are not without challenges.

With 90 per cent of goods traded internationally transported by sea, maritime transportation plays a critical role in global trade. One of the leading players in the sector, Maersk, has been working actively with IBM to develop a Blockchain-based global trade platform, called TradeLens,[38] that aims to connect the various parties involved in international trade – from freight forwarders to government authorities – and to digitalize the supply chain from end to end, with a view to streamlining and facilitating procedures (see Figure 10). The platform was officially launched in August 2018 after having been piloted for several months (Wass, 2018b). A cross-industry advisory board will be established with a view to taking into account the specific needs of the various sectors concerned in designing the platform in an effort to develop an industry-wide platform. The trade document module, called ClearWay, enables importers, exporters, customs brokers, and trusted third parties, such as customs and other government agencies, to collaborate in cross-organizational business processes, and allows for the automation of various business processes such as import and export clearance via smart contracts. The success of the platform will ultimately depend on whether the various actors involved in international trade are willing to sign up. At the time of its launch, more than 20 port and terminal operators across the globe, accounting for more than 230 marine gateways, as well as two other ocean carriers (Pacific International Lines and Hamburg Süd), several freight forwarders and customs brokers, and customs authorities in Australia, the Netherlands, Peru, Saudi Arabia and Singapore, were already participating, or had announced that they would participate, in the platform.[39] This is a promising start. However, no banks are part of the project at this stage, and the TradeLens platform is not the only one of its kind.

Figure 10 Maersk-IBM Global Trade Digitization Project



Source: White, M. (2018).

Other companies, including rivals of Maersk, are looking into similar end-to-end approaches. After having successfully completed a proof of concept in early 2018 to digitalize bills of lading in cooperation with APL Ltd. (which is owned by the world's third largest container line), logistics company Kuehne + Nagel, and Danish customs (The Maritime Executive, 2018), Accenture, for example, is looking at broadening the test to key players on both the importing and the exporting sides, including export customs authorities and banks (see Figure 3).

If these projects succeed, Blockchain could well become the future of trade infrastructure and the biggest disruptor to the shipping industry and to international trade since the invention of the container. However, several remaining challenges must be overcome.

First, global trade platforms can only work at their full potential once all the underlying trade has been digitalized, including trade finance and customs clearance processes, as well as key documents such as bills of lading (i.e. a detailed list of a ship's cargo given by the master of the ship to the person consigning the goods). As discussed in the preceding sections, full digitalization of trade finance and customs procedures is not yet a reality. As for key documents such as bills of lading, projects are underway that explore how Blockchain could be leveraged to digitalize them. Previous attempts to create electronic bills of lading systems, such as SEADOCS, failed and no longer exist, mainly due to the requirement to subscribe to the system. However, because Blockchain allows for transactions to take place on a peer-to-peer basis with no prior subscription required, it opens new perspectives in this area. According to Accenture, the use of Blockchain has led to an 80 per cent reduction in efforts associated with managing data related to the bill of lading.[40] Besides the Accenture proof of concept mentioned above, other projects aimed at digitalizing bills of lading include, for example, an initiative by the International Port Community Systems Association (IPCSA). In addition, in November 2017, fintech startup Wave successfully completed a pilot with ZIM, an Israeli shipping company, and Sparx Logistics of Hong Kong, China to issue and transfer electronic bills of lading using blockchain technology (Logistics and Fintech News, 2017).

The need to digitalize the various operations along the transportation chain means that the development of global trade platforms requires complex and time-consuming integration work. Maersk and IBM acknowledge that the global trade platform they developed will only expand gradually, one trade line at a time.

The multiplicity of projects underway also raises issues of interoperability. Will the various platforms being developed set different standards, at the risk of creating a spaghetti bowl of standards? In the absence of standards that ensure that platforms talk to each other at a technical level, but also at a semantic level (i.e which information to enter in which format), efforts to digitalize international trade will not only remain limited; they may also recreate, at another level, the silos that Blockchain aims to break (see Section 4.2(b)). Cooperation among the various actors within an industry, but also cross-industry and with standard-setting organizations is paramount in order to avoid rebuilding silos and barriers. At the industry level, initiatives are emerging in the trucking industry, with the creation of the Blockchain in Transport Alliance (BiTA),[41] a consortium of manufacturers, trucking companies and logistics companies that aims to develop common standards around blockchain applications in the transportation industry, from speeding up transactions to securing data transfers. BiTA members account for about 85 per cent of all truck-related transactions in the United States and include companies such as UPS, SAP, US Xpress and Bridgestone, to name just a few.

Blockchain holds interesting promises to digitalize international trade and deeply transform transportation and logistics, but it can only succeed if companies work hand-in-hand at the industry and cross-industry levels to set the parameters for the use of Blockchain, which requires a cultural mind shift from competition to collaboration – or "cooperative competition". An open dialogue on standards between all the stakeholders involved in international trade is essential.

Finally, the integration of customs into such platforms raises several regulatory issues. Beyond the difficulties related to cross-border G2G processes (see above), processing customs declarations on the basis of information retrieved from a blockchain-based global trade platform could raise liability issues. Information required for customs clearance usually has to be submitted by a single declarant, who is liable. In a blockchain system, information can be added by various stakeholders making it impossible to pin down a single declarant – unless the regulatory framework is adjusted to clarify liability issues.

As the various initiatives underway in the areas of trade finance, customs procedures, and transportation and logistics show, Blockchain opens new opportunities to move closer to paperless trade, but various technical, regulatory and standardization challenges need to be overcome before Blockchain can truly reform the way goods are traded internationally. However, given the potentially significant impact that the use of blockchain technology could have on cross-border trade operations, such time and effort may be worth the investment. If technical challenges are overcome and the tests that are underway are successful, global trade could, with political will, look radically different in 10 to 15 years.

2. A new generation of services?

Services are a key contributor to economic activity, accounting for over 60 per cent of global production and employment. Over the past two decades, trade in services has become the most dynamic segment of world trade, growing more quickly than trade in goods (WTO, 2015b). The services industry has, like other industries, been affected by the rise of new technologies, in particular the internet. New business models have emerged. The advent of blockchain technology could further reshuffle the deck.

In virtually every services industry, an increasing number of applications is being developed that leverage the technology to provide better, quicker, and cheaper services on a national and transnational basis, challenging established incumbents. Besides trade finance and transportation and logistics, which have been discussed in the preceding section because of the key role they play in international trade in goods, other services of particular interest for international trade include cross-border payments, insurance services, and retail distribution.[42]

(a) Financial services

Blockchain has its origins in finance, and this sector is, for many, one of the most compelling use cases for the technology. Originally developed in the wake of the 2008 global financial crisis as an alternative to centralized financial transactions, Blockchain is the technology underpinning the now famous Bitcoin cryptocurrency.

Blockchain is, however, much more than cryptocurrencies. Its potential applications go well beyond the nebulous world of digital currencies, including in the financial sector. An increasing number of banks, financial companies, stock exchanges[43] and startups is investigating how the blockchain technology can help them improve their operations. Banks are, in fact, some of the largest holders of patents for blockchain technology (20 per cent of total patents), behind blockchain-specific companies but ahead of traditional technology firms such as IBM (Decker and Surrane, 2018). According to McKinsey & Company, the global banking industry is expected to spend US$ 400 million on blockchain-related projects by 2019 (McKinsey & Company, 2017). Proofs of concepts and pilot projects are flourishing, with some 70 per cent of financial organizations already experimenting with the technology, and new business models are emerging that could deeply transform the finance industry.

One of the areas where Blockchain could have a significant impact is cross-border payments, which account for about 40 per cent of global payment transactional revenues (McKinsey & Company, 2016b). Cross-border payment processes have already undergone significant changes over the last decades with the emergence of new players that provide customers and businesses with alternative, enhanced value propositions to process cross-border payments over the internet or via mobile phones. E-payment alternatives such as PayPal, Amazon Payments and AliPay are now widely used. In developing countries, and particularly in Africa, the low level of banking penetration has led mobile service providers to develop mobile banking solutions as an alternative, and complement, to traditional banking. The use of mobile banking, i.e. of mobile phones, to send and receive payments and conduct other banking transactions, has been soaring in recent years and is acquiring a cross-border dimension (WTO, 2016c). M-Pesa, which was launched in Kenya in 2007 by Safaricom, the country's leading mobile service providers, is now used by 70 per cent of the Kenyan population and has spread to 10 countries (Adegoke, 2017).

An increasing number of companies is now turning to Blockchain to further improve cross-border payments. A variety of non-bank actors are developing new business models to make cross-border payments quicker and cheaper, leading well-established institutions to adjust.

(i) The growing non-bank offer

The non-bank offer is diverse and falls into three main categories.

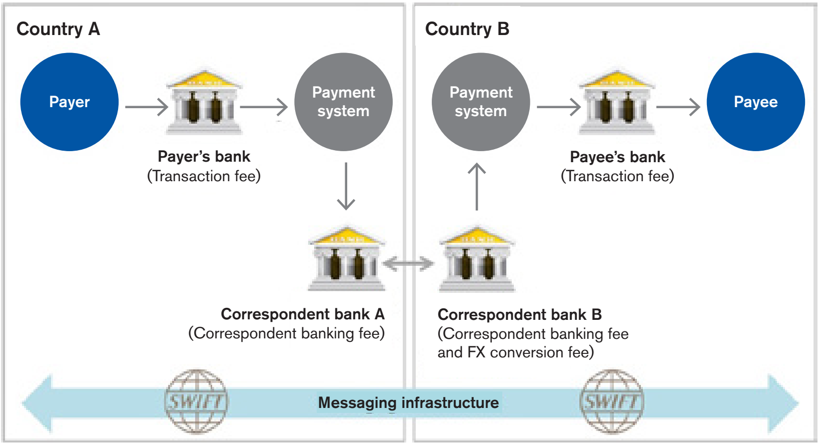
The first category includes companies that offer the possibility to process cryptocurrency payments, such as AliPay, which recently integrated a Bitcoin option for its customers. Numerous startups, many of which are based in developing countries, are proposing crypto-based global payments, such as BitPesa in Kenya, BTCGhana, Bitso in Mexico, BitSpark in Hong Kong, China, OkCoin in China, OkLink/Coinsensure in India, Rebit and Coin.ph in the Philippines, Remit.ug in Uganda, and Abra and Ripple in the United States, and the list goes on. The exploding number of startups offering crypto-based cross-border payments in developing countries would seem to suggest that the use of blockchain technology and cryptocurrencies could have a strong impact on markets that are underserved by traditional financial institutions. Many see in Blockchain a tool to further promote financial inclusion – to "bank the unbanked" – and an opportunity for developing countries to leapfrog traditional technologies (see, for example, International Finance Corporation (IFC) (2017)). Blockchain and cryptocurrency enthusiasts note that the technology enables customers to establish a digital identity easily, making it simpler for unbanked people to acquire access to financial services, and can further drive down the cost of cross-border payments. However, whether the use of cryptocurrencies effectively enables further reduction in the cost of payments compared to mobile banking depends on the cryptocurrency used, as average transaction fees can vary from zero to more than US$ 7 (Ohnesorge, 2018), even without considering the extreme volatility of most cryptocurrencies. Furthermore, cryptocurrency cross-border payments have the disadvantage of requiring an internet connection, while some mobile payment systems only require a regular mobile phone, an important factor in developing countries. Whether, therefore, the use of cryptocurrencies for cross-border payments will really drive down costs, foster financial inclusion and further disrupt the sector is still very much an open question.

The second category consists of companies that leverage the blockchain technology to offer end-users quick, secure and cheap cross-border payment solutions in fiat currencies* via peer-to-peer networks. The startup Circle, for example, provides blockchain-based cross-border payments in fiat currencies with no fee or exchange rate markup. The company, which started in the United States before moving to Europe, recently entered the Chinese market with the aim of connecting Chinese consumers to the rest of the world (Lomas, 2016). Traxpay,[44] for its part, created a blockchain-based platform for businesses in a supply chain to make real-time payments to each other, bypassing banks and traditional trade finance instruments – a sort of PayPal for the B2B world. Whether such companies will manage to establish themselves as key players in the marketplace remains to be seen.

The third category includes companies that leverage the blockchain technology to challenge the low efficiency of the current correspondent banking system. Banks continue to use a complex infrastructure to transfer money abroad, with cross-border payments often routed through a series of counterparties. When cross-border payments need to take place between banks that do not have an established agreement, a correspondent bank must be used as an intermediary (see Figure 11). Since many banks worldwide do not have established banking arrangements with one another, the payer's bank often uses the SWIFT network to search for a correspondent bank that has agreements with the payee's bank or another correspondent bank on the territory of the payee's bank. The payer's bank then sends the transferred funds to the account held at the correspondent bank, which collects a fee and sends the money to the foreign corresponding bank or receiving bank.

Correspondent banking typically involves the two banks establishing reciprocal accounts with each other, usually referred to as "Vostro" or "Nostro" accounts.[45] Such correspondent accounts enable banks to handle cross-border payments requiring foreign currency exchange, such as those that occur when goods are imported from a foreign country.

Figure 11 The Correspondent Banking Model



Source: Barry and Zaccardi (2015).

The involvement of multiple financial institutions increases costs and delays. Correspondent banks typically charge US$ 20 to US$ 60 for their service on top of the prevailing foreign-exchange spread, and while most cross-border payments could in theory be executed in one to two days, a 2015 McKinsey survey revealed that a typical retail cross-border payment takes three to five working days to complete (McKinsey & Company, 2016c).

The low efficiency of the current system has led startups, such as Ripple, to develop alternatives based on Blockchain.[46] Ripple is trying to transform payment systems – which they see as slow, limited in transparency and expensive – through its blockchain-based value exchange platform. The Ripple platform allows financial institutions to exchange, in real time and at little to no cost, currencies, cryptocurrencies, commodities and other tokens of value directly, without relying on traditional intermediaries of the international financial system. The process is bilateral and instant. When a payment order is entered into the platform, liquidity providers linked to the platform compete to provide the best exchange rate. Ripple then automatically chooses the best rate to settle the payment. According to Ripple, the entire process takes three to six seconds.[47]

Ripple has licenses with more than 100 banks and financial institutions and its ambition is to enable cross-border payments to become a truly global activity. The opportunity to circumvent correspondent banks could prove particularly interesting for developing countries, which were confronted with a decline in the number of active correspondent banking relationships in the wake of the 2008 financial crisis due to increasing compliance costs driven largely by more stringent KYC and anti-money-laundering regulatory requirements. The costs of maintaining a basic correspondent relationship have risen from EUR 15,000 to EUR 75,000 per relationship (International Chamber of Commerce (ICC), 2017a), an amount which, for many banks in developing countries, is unsustainable in light of the actual size of the transactions to be handled in those relationships. The regions with the lowest number of active correspondent banking relationships are Latin America, Oceania and Africa (Financial Stability Board (FSB), 2018).

For the moment, however, in spite of the high number of banks that have signed onto the network, it seems that only a limited number of large operations have actually taken place. Banks are still testing the system (Leising and Robinson, 2018).

Other notable institutions such as IBM with its Blockchain World Wire platform and Alibaba affiliate Ant Financial are also working towards similar products.

Another noteworthy initiative is the cross-border blockchain payments service launched in October 2017 by IBM, KlickEx Group – a United Nations-funded Pacific financial services company – and Stellar.org, a non-profit organization that supports an open-source blockchain network for financial services. The service aims to improve efficiency and reduce the cost of making cross-border payments in the Pacific region by enabling the electronic exchange of 12 different currencies across Australia, New Zealand, the Pacific Islands and the United Kingdom. The service, which is already processing live transactions in the Pacific region, is expected to be expanded to other regions of the world (Mearian, 2017).

It is still too early to tell whether these initiatives will succeed on a global scale and deeply modify the way cross-border payments take place. In order to offer valid alternatives to the existing correspondent banking system, blockchain applications for cross-border payments would have to connect all currencies and financial institutions worldwide — "a massive undertaking" as McKinsey & Company notes in a 2016 study (McKinsey & Company, 2016c) if not a utopia. In addition, building a global network for cross-border payments may be technically difficult, if not impossible with the current state of the technology, unless speed and efficiency are compromised. But what is clear is that the emergence of new business models that short-circuit traditional intermediaries is disrupting the financial world, leading financial institutions to adjust.

(ii) *Financial institutions' initiatives*

An array of well-established financial institutions is now investigating the potential of Blockchain (see Figure 12).

In January 2017, SWIFT launched a proof-of-concept application to test whether Blockchain could be used to improve bank reconciliation of their Nostro accounts in real time, lowering costs and operational risk and optimizing their global liquidity. Indeed, under the current system, banks need to monitor the funds in their overseas accounts via debit and credit updates and end-of-day statements. The management and reporting of inter-bank payments represent a significant portion of the cost of cross-border payments. According to SWIFT, on average 34 per cent of the cost of an international transaction is related to Nostro trapped liquidity caused by the absence of real-time data, and 9 per cent is imputable to investigations and exceptions mainly driven by a lack standardization in the end-to-end payment process and by the related Nostro account reconciliation. Banks have identified Nostro account reconciliation as a particular pain point (SWIFT, 2018a).

According to the SWIFT Nostro Proof of Concept final report published in March 2018, Blockchain delivered the expected business functionalities, including real-time handling, transaction status updates, full audit trails, visibility of expected and available balances, and real-time simplified account entries confirmation. However,

Figure 12 **Financial services firms invest early in Blockchain**

Source: CB Insights (2017).

the value of the blockchain solution depends on bank's liquidity management capabilities, level of automation and centralization. While the larger banks usually have their own internal structures in place to manage liquidity reporting – many of them in real time – and may not see the need to integrate a blockchain solution into their existing systems and processes, such a solution could benefit mid-tier banks significantly. SWIFT concludes that rather than a "one size fits all" approach, a hybrid solution, with some components decentralized and others centralized and operated by a neutral third party, would appear to be best suited. The report notes, however, that significant work and investment will be required by all banks to upgrade their back-office applications and migrate to real-time liquidity reporting and processing before the financial industry can adopt Blockchain on a large scale. Blockchain technology will also need to mature and develop further to support a large global infrastructure (SWIFT, 2018a). For the time being, SWIFT would not yet commit (Manders, 2018).

However, the success of the proof of concept has convinced SWIFT to make Blockchain a "strategic priority". The company is already working on new proofs of concept (SWIFT, 2018b), not least to avoid being ultimately outpaced by startups such as Ripple that are leveraging the technology to provide alternatives to SWIFT's financial messaging (Skinner, 2016).

Beyond the question of Nostro account reconciliation, a frenzy of activity is surrounding the use of Blockchain to streamline banks' activities, including cross-border payments.

Various consortia have been formed, the most well-known of which is R3 (R3CEV LLC), which started in 2015 with nine financial companies: Barclays, BBVA, the Commonwealth Bank of Australia, Credit Suisse, Goldman Sachs, J.P. Morgan, the Royal Bank of Scotland, State Street, and UBS. R3 now counts over 200 banks, insurance companies, financial institutions, regulators, trade associations and technology companies as members. The consortium, which created an open-source distributed ledger platform called Corda "designed from the ground up to record, manage and synchronise financial agreements between regulated financial institutions" (Brown, 2016), announced in October 2017 the launch of a cross-border payments platform built on top of the company's Corda technology (Brady, 2017). The platform aims to provide for faster and more efficient execution of cross-border payment transactions.

Several well-established financial institutions recently announced the launch of their own blockchain networks to enhance cross-border payments processes.

In October 2017, Mastercard launched its own blockchain network to address challenges of speed, transparency and costs in cross-border payments in the business-to-business (B2B) space. Mastercard's blockchain is a permissioned ledger that can be accessed via an API, making it possible for users to connect to the blockchain without having to create their own distributed ledger server nodes* (Mastercard, 2017).

In November 2017, Visa rolled out the first pilot phase of its blockchain-based B2B payment service, B2B Connect, first announced last year (De, 2017). The platform aims to ease cross-border payments by facilitating direct payments between institutions, cutting out traditional intermediaries. The United States-based Commerce Bank, the Republic of Korea's Shinhan Bank, UnionBank of the Philippines and the United Overseas Bank, based in Singapore, are collaborating with Visa on the project.

That same month, J.P. Morgan launched the blockchain-based Interbank Information Network (IIN), in collaboration with the Royal Bank of Canada and Australia and New Zealand Banking Group Limited. IIN leverages blockchain technology to "minimize friction in the global payments process" by allowing faster payments in fewer steps and more securely (J.P. Morgan, 2017).

With its promise of greater efficiency, faster settlements at lower costs, lower risk of fraud, auditable traceability and rising pressure from digital innovators, Blockchain is seen by many financial institutions as a "must investigate" technology. Savings generated by the use of the technology could be potentially significant. According to Santander *et al.*, (2015), Blockchain could reduce banks' infrastructure costs attributable to cross-border payments, securities trading and regulatory compliance by US$15-20 billion per annum by 2022.

Will Blockchain become the future of cross-border payments? Time will tell. The technology is still maturing and people are still investigating its full potential. Regulatory uncertainties and lack of interoperability of current platforms remain a challenge (see Section 4.2). Adoption is, therefore, likely to be gradual. Well-established financial institutions are more likely to focus first on internal operations to improve efficiency and reduce organizational complexity and back-office costs – not least because, today, some top-tier banks make significant profits on cross-border transactions and may not be keen to embrace a technology that could cut out one of their key revenue streams.

But one thing is certain: Blockchain is disrupting the sector and pushing well-established financial institutions to adjust. If the newly developed applications are conclusive and issues of interoperability are solved, making it possible to connect different payment platforms, Blockchain could well become the future of financial services infrastructure; nevertheless, a complete overhaul and decentralization of the financial landscape is unlikely. Ironically, the technology is now being championed by those that Satoshi Nakamoto, the "father" of blockchain technology, wanted to make superfluous, as a way to improve their own operations. In the end, Blockchain may well make these well-established financial institutions stronger.

(b) Insurance

The financial services world is not the only services sector that is being disrupted by this technology. Blockchain is starting to make its mark on insurance as well. All of the larger consulting companies, including McKinsey & Company, Ernst & Young, Deloitte, PricewaterhouseCoopers and KMPG, recently published studies on the potential of Blockchain in the insurance sector,[48] and insurance companies such as Axa, Generali, Allianz, Aegon, Munich Re, Swiss Re and Zurich, to name just a few, are investing in the technology.

The potential of Blockchain for insurance is multifaceted. The use of Blockchain and smart contracts could help reduce administrative procedures and costs through automated verification of policy holder identity and contract validity, and automated handling of claims. When a claim is submitted, the network could help ensure that it is valid and that no multiple claims have been submitted for the same incident, thereby reducing fraud – which is estimated at 5 to 10 per cent of all claims (McKinsey & Company, 2016a). Smart contracts could allow automatic payments to be triggered when certain conditions specified in the smart contract are met. Blockchain could simplify administrative procedures, increase trust and transparency, speed up the resolution of claims, and help the insurance industry handle transactions in a way that is not only more secure but also accountable to its customers.

The application of Blockchain is also being tested in the field of multinational insurance policies. In June 2017, AIG, IBM and Standard Chartered Bank announced that they had successfully piloted the first multinational, smart-contract-based insurance policy using Blockchain (IBM, 2017). The UK insurance master policy and three local policies in Kenya, Singapore and the United States were converted into one smart contract to provide a shared view of policy data and documentation in real time and automate procedures, increasing transparency, trust and efficiency in the management of the process. The companies announced that the use of Blockchain allowed full visibility into coverage and premium payment at the local and master levels, as well as automated notifications to network participants following payment transfers, and that the process of developing the multinational policy, which can take months, was cut down to a few days.

Of particular interest for international trade is the potential impact that the technology can have for the marine insurance sector. With 90 per cent of international trade taking place by sea, marine insurance plays a critical role in international trade. To manage the diversity of the risks to which their freight is exposed – from cargo damages to delays due to congested ports – shippers buy insurance from multiple brokers and underwriters. This US$ 30 billion industry still relies heavily on paper and little has been done until now to optimize costs and processes. A recent proof-of-concept for marine insurance developed by Maersk, Microsoft, Ernst & Young and several insurance companies could reshuffle the deck. The Insurwave blockchain platform they designed, which is built on Microsoft's Azure cloud-based technology, allows all parties – including shipping companies, brokers, insurers and other suppliers – to access the same ledger, which is updated in real time and can be used for marine insurance contracts (Kelly, 2017). The platform aims to accelerate billing and payment processes and to provide greater transparency, in particular on claim history, to better inform pricing decisions, while ensuring greater security of data and transactions. The consortium started testing the system in April 2017 and built about a dozen use cases. The new maritime insurance system began commercial operation in January 2018. The system will first be used for a limited number of ships and journeys before being deployed more widely, possibly even to other categories of insurance, such as car insurance (Ralph, 2017).

As with financial services, the use of Blockchain could profoundly transform the insurance industry, including in its multinational dimension. Applications are now moving from proofs of concept into implementation. The coming years will tell whether Blockchain is a real game-changer.

(c) Retail distribution/e-commerce[49]

Retail distribution has undergone a radical transformation in the course of the last 10 to 20 years. The rise of the internet has profoundly changed consumers' behaviours, with a growing number of them shopping online. Market research company eMarketer estimates that retail e-commerce sales rose over 23 per cent in 2017 to reach almost US$ 2.3 trillion. Around 10 per cent of retail sales occur online, a number which is expected to surpass 16 per cent by 2021 with total e-commerce sales almost hitting US$ 4.5 trillion (eMarketer, 2017). The digitalization of retail distribution has also given rise to new business models and the emergence of powerful e-commerce platforms like Amazon and Alibaba.

The use of Blockchain for e-commerce sales could impact the current e-commerce landscape in several ways.

First, Blockchain could offer customers safer and quicker solutions, which could help to increase customer numbers and boost e-commerce sales. Traditional e-commerce platforms often lack transparency. A blockchain-based e-commerce system makes it possible to easily track records of previous transactions, and smart contracts can facilitate transactions by enabling automatic payment transfers. Blockchain's immutable nature can also help prevent fraud by making it easier to track counterfeit goods and fraudulent behaviour. The transparent nature of Blockchain and the potential that this technology offers to fight fraud and counterfeit goods is what has prompted e-commerce giant Alibaba to invest heavily in Blockchain (see Section 4.1(a)).

Second, Blockchain can be used to implement a peer-to-peer marketplace that operates without the need for a central actor. New players are emerging that use Blockchain to offer customers direct access to sellers without having to go through a centralized platform like Amazon. OpenBazaar, for example, is a free online peer-to-peer marketplace launched in November 2017, on which one can sell and buy goods without having to sign up for an account. There is no listing or platform fee applied. A smart contract locks in the funds once the payment is made and releases them when the buyer receives and verifies the item.[50] Such initiatives remain, for the time being, very limited in scope. Whether such platforms will offer real benefits compared to existing ones and manage to become key actors remains to be seen.

Blockchain is just starting to enter the e-commerce world. It may not revolutionize it, but by increasing security, trust and transparency, and possibly facilitating payments, including cross-border payments (see Section 3.2(a)), it could give e-commerce a further boost and may affect existing business models.

Blockchain is entering the services world at high speed, with both well-established companies and startups turning to Blockchain to provide enhanced services in areas as diverse as supply chain finance, cross-border payments, insurance, transportation and logistics, and even e-commerce. A significant shake-up of power relationships within a sector is, however, unlikely. If a "revolution" does occur, it is more likely to be internal: the intrinsic characteristics of Blockchain and the possibility to automate transactions through smart contracts make it an attractive tool for companies to cut costs and streamline processes. If the initiatives underway prove conclusive, Blockchain could well become the future "infrastructure" of the services industry. Because of its automation capabilities, Blockchain could be to the services sector what robots have been to manufacturing.

3. Strengthening intellectual property rights

Intellectual property (IP) is an increasingly important part of international trade. Many products, from new medicines and pharmaceutical products to high tech goods such as smartphones, involve large investments in research and design. In fact, most of the value of such products lies in the amount of innovation, ideas and knowledge involved. Music recordings, films, books, computer software are creative products that are bought and sold for the ideas they contain rather than for the support on medium through which they are traded.

Protecting IP has become a key preoccupation of businesses, creators and innovators. Over the last decades, a comprehensive set of rules has been developed at the national and multilateral levels to provide adequate protection of IP and ensure the fair remuneration of creators and innovators. The WTO Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), which came into force on 1 January 1995, provides a general framework of minimum standards for the protection and enforcement of IP rights applicable to all WTO members. It includes disciplines on copyright and related rights (i.e. the rights of performers, producers of sound recordings and broadcasting organizations); trademarks; geographical indications; industrial designs; patents; the layout designs of integrated circuits; and undisclosed information, including trade secrets and test data. The World Intellectual Property Organization (WIPO) administers no less than 26 treaties that cover the whole range of IP rights. The principle WIPO treaties on copyright, patents, trademarks, and industrial designs are integrated by reference into the TRIPS Agreement. An increasing number of free trade agreements also contain provisions on IP.

The rules exist, but administration and enforcement remain, in many cases, a challenge. As copyright does not require registration and is available upon the creation of an original work, determining the right owner can be difficult and sometimes impossible. As a consequence, authors and performers often struggle to be paid for their creation, and when they do, a large part of their revenue is often captured by intermediaries, such as labels or record companies, performance rights organizations and streaming digital service providers like Spotify, in the case of music. This situation has caught WTO members' attention. Brazil, in a submission to the WTO General Council in December 2016, called for "a decision on the management of copyright towards fair payment for authors and performers" in which WTO members would "stress the importance of transparency in the remuneration of copyright and related rights in the digital environment" (WTO, 2016a).

In a follow-up submission circulated in September 2018, Brazil and Argentina note that "information technology could and should facilitate access to real-time data on the use and remuneration of right holders" (WTO, 2018).

Copyright piracy and trade in counterfeit products are also of particular concern. According to the OECD and the European Union Intellectual Property Office (EUIPO), the value of imports of counterfeit and pirated goods is worth close to US$ 500 billion a year – around 2.5 per cent of global imports – with French, Italian and US brands hit the hardest (OECD-EUIPO, 2016), and the WHO estimates that 10 to 30 per cent of medicines on sale in developing countries could be counterfeit, causing 700,000 deaths a year globally (World Health Organization, 2016).

One specificity of IP rights is that they are territorial by nature. They are granted, protected and enforced separately in different jurisdictions around the world. Rights granted in one jurisdiction are only protected and enforceable in that jurisdiction. For example, use of a patent in a jurisdiction other than the one where the patent has been granted would not necessarily be considered infringement.

Can Blockchain help to address these challenges of administration, enforcement and territoriality? The use of Blockchain in the area of IP is still relatively new, but it could open interesting opportunities. A rapidly growing ecosystem of companies is looking at how blockchain technology can be used to improve the administration and enforcement of IP rights across multiple jurisdictions. Blockchain applications are numerous and could affect both the governance of IP rights and the IP industry. Blockchain for registered and unregistered rights could arguably be used to provide proof of creation, ownership, and first use; to register IP rights; to administer and manage IP rights, including payments; and to enforce IP rights and fight counterfeits. However, while applications of blockchain technology can help alleviate some of the challenges that rights-holders face, the technology will not solve all issues.

(a) Proof of existence and ownership

Proving ownership of literary or artistic works, trademarks, patents or designs is essential if one is to claim IP protection. Yet, as already noted, determining ownership can be a challenging task, in particular in the case of copyright.

(i) Copyright

Literary or artistic works, such as drawings, paintings and literary, musical, cinematographic and photographic works, are protected the moment they have been "fixed in some material form".[51] No registration is required. However, in jurisdictions where authors and performers do not have adequate means to catalogue their works, ownership can be hard to prove.

Using Blockchain could be particularly interesting to prove ownership of digital literary and artistic works. Blockchain could provide authors and performers of such works with an immutable, secure and time-stamped* proof of ownership. Digital works created directly on applications using the technology could be "registered" instantaneously, upon creation.

Potential advantages of using the technology to record copyright are multifaceted: records added to the blockchain cannot be duplicated, manipulated or faked; they are permanent; and information stored can easily be tracked, making it easier to enforce IP rights. Some companies such as Binded (former Blockai), Ascribe, Blocknotary, Copyrobo and KodakOne are already offering authors and performers the possibility to record their digital work on blockchain applications, and services providing proof of existence for any type of work, including copyright, have flourished in recent years.[52] Binded,[53] for example, helps artists claim their copyrights and protect them by allowing them to place their original digital art and photos on Binded's copyright platform. The company creates a timestamp in the blockchain and delivers a copyright certificate as proof of authenticity. Although such companies still have a limited user base for the moment, they offer an interesting pathway for artists and creators wishing to prove ownership of their digital works.

In the case of non-digital works, however, Blockchain can only provide proof of existence, not ownership. Blockchain cannot guarantee the trustworthiness of information entered onto the ledger. It can only guarantee that "on-ledger" information has not been tampered with. Blockchain registration cannot, therefore, solve issues related to unlawful acquisition of creative works. Blockchain registration cannot guarantee that the person who registers the work is the original creator of the work. It only proves that at the time the data was added to the ledger, the work existed – proof of existence – and was in possession of the person who registered it. A physical verification system will still be required. In the case of non-digital works, original works cannot be stored on the blockchain; only the cryptographic* digest of the work can. As hashing* creates a fingerprint that is unique to the work it is related to, it is a guarantee of authenticity, but not a guarantee of ownership.

(ii) Trademarks

For trademarks, ownership rights are acquired by the party that uses or registers a particular sign first (e.g. a word, logo, phrase or design) with a central authority. Proof of first use or registration is therefore key.

In those jurisdictions where proof of first use is required, Blockchain could be used to create a time-stamped cryptographic record of a trademark that could then serve as proof of first use. In those jurisdictions requiring registration, the central authorities responsible for trademark registration could choose to take advantage of the immutable and transparent nature of blockchain technology to enhance registration and management of IP rights.

Although some IP offices, such as EUIPO, are allegedly looking into using Blockchain to record and enforce IP rights (Mertens, 2018b), the migration of government agencies to a blockchain-based system will not happen overnight. In the meantime, startups are stepping in, at the risk of creating confusion and potential conflicts between two different types of registration (Monteleone, 2018). In the United States, the startup Cognate,[54] for example, is using Blockchain to issue "chain marks" – in lieu of trademarks. Companies can upload proof of trademark use and other information about their mark. After review of the documentation, the company registers the mark as a "chain mark". The process is quick and fast: it only takes one day and costs approximately US$ 40, while registration to government agencies such as the United States Patent and Trademark Office (USTPO) or EUIPO can take up to 12 months, with much higher fees (Mertens, 2018b).

Such initiatives raise the question of the legal status of trademarks' "registration" through permissioned blockchain-based platforms in case of litigation. Such registration could be useful to prove first use, but will these "chain marks" be enforceable in courts, in the same way that trademarks are? Will they offer the same level of protection as traditional trademarks?[55] Should existing rules be adjusted to take account of these new developments? These issues will need to be considered; the disruptive potential of blockchain technology is likely to keep IP lawyers and regulators busy in the years to come.

(iii) Patents

Blockchain could also facilitate patent registration. A patent is a legal right granted by a national or regional patent office for a certain period of time – at least 20 years – to an inventor who has created something new, which involves an inventive step and that can be industrially applied. Patent applications are handled at the national or regional level by some 200 patent offices, some of which are already investigating the potential of Blockchain to help them streamline their activities (Mertens, 2018a). Beyond the institutional use of Blockchain by official agencies, inventors could use the technology to record a hash* of the patent description on the blockchain, which could then be used as the first step in the patent application process (Boucher, 2017).

Private sector companies are already stepping in to provide solutions to this effect. Bernstein Technologies, a Munich-based company, for example, allows firms to create a digital trail of records of their innovation processes using blockchain technology. Inventions, designs, and proofs of use are registered on the blockchain and a blockchain certificate proves the ownership, existence and integrity of any IP asset.[56] Registered information remains private thanks to cryptography.

While these could be valuable efficiency improvements, Blockchain will not alter the way patents are granted. More than the actual registration of patents, it is the management and enforcement of patent rights – and of IP rights in general – that Blockchain has the potential to transform.

(b) Simplified management and enforcement of IP rights

Beyond proof of creation, use, ownership and registration, blockchain technology offers particularly interesting opportunities to administer, control the use of, and enforce IP rights.

This is particularly important for copyright, the management of which can be complex. Not only can ownership be hard to prove, but keeping track of who is using the work is equally difficult, and third parties wishing to use a work sometimes find it challenging to know who to approach to obtain a license. Once creations have been uploaded to the internet, it becomes extremely difficult for authors and performers to track, and be paid for, use of their work.

(i) Easier monitoring and licensing

The use of Blockchain could make it easier for IP rights-holders to monitor and track the distribution of registered and unregistered intellectual property. Blockchain platforms such as Binded and Ascribe, for example, enable authors, once an online work is registered, to search through a whole set of sources in order to check who is using their work.

Blockchain could also facilitate licensing with individual parties and the assignment of rights via software, and one could imagine a system in which transactions involving the licensing and assignment of IP rights are entered on a blockchain in order to keep an immutable record of such transactions and help track their use.

The startup Ascribe, for example, offers the possibility of transferring, consigning or loaning digital creations via its blockchain-based platform, as well as of monitoring their use. In the case of trademarks, records entered on the blockchain could then be proof of use of the trademark. Another example is KodakOne, a blockchain platform that allows photographers and agencies to store their image assets and associated metadata and track ownership, rights and license transactions regardless of where those images are used and by whom.[57]

(ii) Smart IP rights

One of the most interesting features of the technology is the possibility to use smart contracts that self-execute upon fulfilment of certain conditions. Smart contracts built onto a blockchain could prove particularly useful to ensure the automatic, flexible and fair payment of rights-holders.

In the music industry, for example, where monitoring the use of creative works is a particularly acute problem, one could imagine that a songwriter could post a song onto the blockchain with a smart contract that would specify the contact details of the rights-holder(s) and the conditions applicable to the use of the work. This would make it easier for third parties to contact the rights-holder(s) to obtain a license to use the work, and for the songwriter and other rights-holders to obtain payment for the use of his/her creations. Licenses granted through smart contracts would be self-executing upon use of the work. Payments of royalties would be automatically executed and amounts of royalties charged could be made flexible and adjusted based on usage (frequent users, for example, could be charged less than one-time users).

Such arrangements already exist; for example, the singer Imogen Heap, a best-selling UK recording artist and founder of Mycelia, a research and development hub for music makers, launched in 2017 a pilot project with the Featured Artists Coalition (FAC) and Digital Catapult involving blockchain technology. The pilot project, which covered two Imogen Heap's songs at the time of writing, enables users to purchase licenses to download, stream and mix the songs via smart contracts. Payments are sent automatically to all rights-holders upon use of the songs. Building on the experience of the pilot project, Mycelia is now developing a Creative Passport to allow interested music-makers to use the technology to automatize and personalize the management of their IP rights. The objective of the Mycelia Creative Passport project is to create a "fair, sustainable, and vibrant music industry ecosystem" in which all those involved, from musicians to distributors, are paid fairly for their work.[58] Blockchain "could help musicians make money again", as Imogen Heap notes (Heap, 2017).

Can the use of Blockchain lead to a complete decentralization of copyright management and threaten well-established intermediaries such as labels and record companies, performance rights organizations and digital streaming services such as Spotify? Nothing is less certain. These intermediaries play an important marketing and management role that a distributed ledger cannot fulfil at the moment. In addition, they are likely to resist and counter any attempt to marginalize them.

In fact, aware of the stakes at play, three of the world's biggest licensing and royalties collection companies – ASCAP (United States), SACEM (France) and PRS for Music (United Kingdom) – joined forces in April 2017 to develop a prototype of metadata recording and management using the IBM blockchain to make it easier to determine ownership and speed up licensing and royalty payments (Smirke, 2017). That same month, music streaming company Spotify acquired Mediachain Labs,[59] a startup that develops blockchain solutions to solve problems of attribution of rights. With this acquisition, Spotify hopes to better connect artists and other rights-holders with the tracks hosted on Spotify's service and help solve music's attribution problems (Higgins, 2017b). These developments would seem to suggest that the industry is likely to remain consolidated, and that we are more likely to witness a reorganization than a revolution.

Blockchain could also be an interesting tool to manage "fractional ownership", i.e. rights owned by various holders, a situation that has become relatively standard nowadays, in particular in the musical industry, as seen earlier, and for patented innovations. In the case of patents, in many cases, innovation is no longer developed in-house. Collaboration between various individuals and entities has become the norm, or close to it, making the management of patent rights a more complex endeavour. Blockchain could help to register and track who has contributed what and who will obtain future shares of revenue, and to ensure the automatic remuneration of the various rights-holders.

This also holds true for traditional knowledge. The current system of patent protection was developed "in the age of industrialization in the West and developed subsequently in line with the perceived needs of technologically advanced societies", as WIPO notes on its website.[60] Indigenous people and local communities in developing countries have, for several decades, argued that their traditional knowledge, i.e. the living body of knowledge that is developed, sustained and passed on from generation to generation within a community and that often forms part of its cultural or spiritual identity, such as traditional medicines, should be granted effective protection, and that authorities in third-party countries should ensure that patent applicants have had authorized access from national authorities to the genetic resources and related traditional knowledge before granting a patent. In India, where traditional knowledge plays a key role, a searchable database of traditional medicine – not blockchain-based – has been established and can be used as evidence of prior art by patent examiners when assessing patent applications. The global, immutable and transparent nature of Blockchain, combined with the possibility to use smart contracts to automate payments, could help such communities to monetize the value of their knowledge more reliably and to keep track of its use.

As these examples demonstrate, Blockchain can make it easier to control and track the distribution of registered and unregistered intellectual property, simplify the licensing and assignments of rights, help to manage rights, accelerate and optimize payments of fees, and ensure the fair compensation of rights-holders; and it enables these actions on a global scale.

(iii) Towards "global IP chains"?

We live in a globalized economy, but there is no such thing as a global patent, trademark or copyright: IP rights remain territorial. In this context, managing IP rights can be a particularly complex endeavour. The combined use of Blockchain and smart contracts could, in this respect, open new opportunities. Smart contracts could facilitate the management of IP rights on a global scale, thereby contributing to the emergence of "global IP chains".

In the area of copyright, for example, the complexity of licensing copyright in a trans-border environment, in which copyright laws are largely national, led to the development of open-source[61] and creative commons[62] projects. Contracting a qualified legal counsel in order to take into account the diversity of existing laws for cross-border licensing agreements is often too costly for the average rights-holder. Open-source and creative commons projects have found a way around this problem by making work freely available online and allowing anyone to use or improve upon it without the obligation to pay any financial compensation, provided that the creator of the work is acknowledged. Under this approach, works do have a global reach, but their creators do not get paid.

The use of smart contracts in conjunction with a blockchain could resolve the dilemma of open-source/creative commons licenses by making it possible to overcome the territorial nature of copyright while, at the same time, allowing fair and automatic payment of licensing fees to the creator(s) of the work (Savelyev, 2017). Similar approaches could be envisaged for other types of IP rights.

A number of people have also speculated that Blockchain could give rise to global registries of IP rights, which would enhance the visibility and transparency of "IP chains" on a global scale. Information on IP rights remains scattered. The current patent system consists of some 200 independent national and regional offices. The same is true for trademarks and copyright. Various attempts have been made to create global registries in the area of copyright, but they have all failed. In 2008, the European Union attempted to create a Global Repertoire Database, but the project was discontinued after collection societies and publishers refused to support it. Other projects, such as the International Music Registry, backed by WIPO, have had the same fate.

Can the decentralized nature of Blockchain open new perspectives in this regard? One could imagine the creation of IP-specific global registries linking all national registries and relevant stakeholders. Information added to a blockchain-based IP registry would be accessible to everyone, but only national authorities or other relevant stakeholders would be able to write on the blockchain.

While this is theoretically possible, such initiatives may face the same hurdles as previous attempts in the area of copyright. They would require the engagement and political will of all those involved, as well as a considerable amount of coordination. While this is not impossible, it will not be an easy endeavour, and is compounded by the technical limitations that still affect the technology itself. The push may come from the private sector; several startups are already working on such initiatives. For example, the startup IPwe[63] aspires to create a blockchain-based Global Patent Registry, and several startups formed the consortium Concensum to develop a Global Copyright Register.[64]

Whether these initiatives, which are still in their infancy, will succeed in bringing greater transparency to the IP rights landscape remains to be seen, but they have the merit of putting the question of global transparency of IP rights on the table. It also remains to be seen whether national jurisdictions will be willing to recognize IP rights entered in a blockchain as valid.

One thing is certain: the disruptive nature of Blockchain, the opportunities that the technology opens, as well as its potential legal implications, deserve the attention of regulators and legislators.

(iv) Fighting piracy and counterfeiting

In April 2018, the French museum Terrus dedicated to painter Etienne Terrus, a close friend of painter Henri Matisse, discovered that more than half of its collection was fake (France24, 2018). Counterfeit products are legion and affect all areas of intellectual property – artistic and creative works, inventions and brands alike. Blockchain offers interesting opportunities when it comes to fighting piracy and counterfeiting, as Blockchain's immutable and transparent nature makes it easy to check the origins of products. Hashes of digitizable IP works, such as books, on blockchain can serve as a proof of existence and origin, while the concomitant use of Blockchain and smart contracts can allow IP rights-holders to control and track the rightful use of their IP rights, as mentioned above.

For physical objects, scannable QR* codes attached to a work or product can give access to the history of the work or product and serve to prove authenticity. A myriad of startups is developing solutions to track and identify products such as pharmaceuticals, electronics, and luxury and fashion items, and to ensure that consumers or producers receive an authentic product. Everledger for diamonds, Blockpharma for pharmaceutical products, as well as Blockverify, VeChain and Chronicled for protection against counterfeiting of a range of products, are some of the companies active in this field. Fashion brand Babyghost, for example, partnered with VeChain, a startup that focuses on protecting brands, trademarks and products, to incorporate in each garment a VeChain chip embedded with a public key stored on the blockchain. By scanning the QR code on the label with their smartphone, consumers can access the story of the garment, including information about the designer and the design, and verify the authenticity of the product (see also Section 4.1(a) and Campbell, 2016). In most of these cases, the potential of Blockchain is realized thanks to the use of other technologies and innovations, in particular the IoT.

One can easily imagine the opportunities that blockchains open for fighting counterfeiting in international trade. The TRIPS Agreement gives WTO members the possibility to authorize customs officials to act upon their own initiative, *ex officio*, to suspend the release of goods for which there is evidence that IP rights are being infringed.[65] A key problem is the lack of expertise of most customs officials in detecting counterfeit goods.

The use of the technology to trace the provenance of products, from factory to end-users, could be a precious tool to demonstrate *prima facie* evidence of infringement. A brand owner using blockchain technology to record the history of its products could, for example, inform customs and enforcement agencies that its products include a crypto-embedded tag linked to the blockchain that proves its origin. The absence of a tag or an incorrect tag would then make it easy for enforcement officers to detect counterfeits (Burstall and Clark, 2017). The stakes are high, not only in areas such as pharmaceuticals and luxury products, but also in the car and aeronautics industries, where, as in the health sector, counterfeits can be very dangerous.

However, there is growing concern that Blockchain could make the enforcement of IP rights for digital goods, in particular copyright, nearly impossible. While data on a blockchain cannot be easily altered, nothing can prevent a malicious user from submitting a pirated version of the work to the blockchain – and there is no obligation for the infringer to attach any kind of identifying data to the upload. The decentralized and anonymous nature of public blockchains makes it extremely difficult, if not impossible, to identify those buying and selling unauthorized copies of digital goods and to pin liability to them (Vogel, 2015; Gabison, 2016).

Although the technology presents interesting features, by making it easier to control and track the distribution of (un)registered IP and to fight piracy and counterfeiting, by simplifying the licensing and assignments of rights and making it possible to manage IP rights on a global scale, and by accelerating and optimizing payments of fees to ensure fair compensation of rights-holders, its full practical and legal implications still have to be thoroughly assessed. The sooner regulators and legislators start looking into these, the better.

4. Enhancing government procurement processes

To carry out their functions, government agencies often need to purchase goods and services using public resources. Such purchases are commonly referred to as government procurement or public procurement. Government procurement is a key aspect of international trade. It constitutes an important market, accounting for 10-15 per cent of the gross domestic product (GDP) of an economy on average, and global government procurement is worth about US$ 9.5 trillion per year.[66]

Given the economic importance of public procurement markets, savings that can be achieved from more transparent and efficient processes can have a significant impact on a country's economy – not least to help curb corruption and fraud which are estimated to 20-25 per cent of procurement budgets in a sector like construction and close to 60 per cent of foreign bribery cases prosecuted under the OECD Anti-Bribery Convention (OECD, 2016). A 2004 study by the European Commission showed that a 10 per cent saving in public procurement would turn the budget deficits of some EU member states into surpluses, and no eurozone member state would run a public sector deficit that broke the 3 per cent limit (European Commission, 2004).

The need for more transparency and efficiency has prompted government agencies around the world, often with the support of multilateral organizations such as the World Bank and the Asian Development Bank (ADB), to leverage information technology to enhance transparency, reduce costs, and better manage and monitor government procurement processes. Following Canada and its e-government MERX initiative, which went live in 1991, e-Government procurement (e-GP) systems – i.e., electronic systems designed to handle some or all steps of the government procurement process – have been developed and launched across the world. The use of e-GP is now widespread, and systems are becoming increasingly sophisticated (Asian Development Bank, 2013).

Although the degree of sophistication varies from one system to another, functionalities typically provided include: supplier/buyer registers; information services (access to government procurement-related information such as news and publications); e-bidding systems, which facilitate the transmission of electronic bidding documents and allow sellers to submit their bids; e-auctions and e-reverse auctions (i.e. price competitions carried out online in a dynamic manner); e-purchasing tools (for low-value and high-volume transactions); catalogue-based ordering systems; purchasing cards; and an e-payments and e-receipt systems (Asian Development Bank, 2013).

In parallel, new regulatory frameworks have been developed that allow procuring entities to take advantage of electronic means, such as the 2011 UNCITRAL Model Law on Public Procurement and the revised WTO Agreement on Government Procurement (GPA).[67]

The revised GPA, which entered into force in April 2014, recognizes the importance of using, and encouraging the use of, electronic means. The GPA explicitly states that procuring entities can accept tenders by electronic means – thereby opening potential avenues for the use of blockchain technology – but that the relevant IT systems and software must be "generally available and interoperable with other generally available information technology systems and software"[68] – which in the current state of the technology remains a challenge (see Section 4.2(a)). A second interesting feature of the GPA is the inclusion of an explicit reference to corruption in its preamble: parties to the GPA are required to conduct their procurement activities in a "transparent and impartial manner" and in a way that "avoid[s] conflicts of interest and prevents corrupt practices" – a first in a WTO agreement.[69]

Can Blockchain be leveraged to further improve government procurement processes? Can it add anything to already sophisticated e-GP systems? Various key features of the technology make it an interesting tool to use in public procurement, but it is essential to weigh up the trade-offs carefully.

First, Blockchain provides for a highly secure electronic environment, in which data are time-stamped and stored in a near immutable way. One of the most important elements of e-GP is security. Commercial quotes submitted by bidders need to be stored in a safe and secure manner, and because tendering forms the basis for a legal contract, all data need to be kept secured, complete and auditable. The question of data security and fraud, although probably less common than in a paper-based environment, is reported as one of the deterrents to e-GP (Asian Development Bank, 2013).

Second, Blockchain enables the automation of government procurement procedures via the use of smart contracts, thereby ensuring efficiency, neutrality and fairness of processes. Smart contracts, i.e. self-executing contracts stored on the blockchain, can help to improve both the tendering process itself and the management of awarded contracts. Indeed, not only is it near impossible for any party to manipulate the data stored, but no-one can bypass the smart contract and its permissioning logic. The automation of submissions, reviews and payments, and the near impossibility of manipulating data can help to prevent fraud involving actors within the process and reduce costs, and allow for a fair, efficient and impartial process, as required under the GPA.

How would a blockchain-based tender process run? A government agency – the procuring entity – would publish a notice of intended procurement. Interested suppliers would submit their bid via the blockchain application used by the agency within the required timeframe (a permissioned ledger). Bids would be hashed and encrypted* upon submission. Upon closure of the submission period, all bids would be analysed and assessed by the smart contract on the basis of the encoded criteria, and a winning bid would be identified. Once the winner was identified, authorized signers could examine the documents submitted by the winning supplier and validate them. The winning bid would be formally announced, and unsuccessful suppliers would be automatically informed.

Once the contract has been awarded, a smart contract could set the terms of delivery, fulfilment of the contract, and payment. Work could be verified by authorized signers and goods supplied under the contract automatically recorded onto the blockchain using blockchain-based logistics. When the terms specified in the smart contract are met, payment would be automatically made to the supplier.

Third, using Blockchain to run tender processes can be particularly interesting to help fulfil another requirement of the revised GPA, namely electronic traceability. The revised GPA mandates parties using electronic means to ensure appropriate traceability of the conduct of covered procurement processes for at least three years.[70] This provision is meant to ensure the availability of data during a certain period of time in case of litigation. Given the immutable nature of Blockchain, using a distributed ledger to conduct procurement processes *de facto* ensures that all data will remain accessible to authorized users automatically and indefinitely.

Various countries are currently investigating the potential of Blockchain for government procurement. The US General Services Administration, for example, is working with specialized companies (Sapient Consulting and United Solutions) to develop a proof of concept to speed up the fast-lane review process for IT contracts through automation and bring it down to “single digits in terms of days” (Friedman, 2017). Japan is currently testing a blockchain-based system for processing government tenders to improve the efficiency of public procurement processes. The system would connect the various government offices involved in a tender to facilitate the sharing of data (Tian, 2017). Mexico recently launched an initiative to deploy Blockchain within the public sector, including for tender processes.[71] The United Arab Emirates wants blockchain technology to power its entire government by 2020, which would make Dubai the first “city built on blockchain” (Lohade, 2017).

While Blockchain potentially holds interesting promises to enhance government procurement processes, manage public contracts, and fight fraud, it remains to be seen whether these proofs of concept are conclusive and whether the use of Blockchain can bring e-GP to a more secure and automated level at a cost that justifies the transition to a blockchain-based system. The use of smart contracts in government procurement processes will also require the clarification of liability issues (see Section 4.2(c)), and interoperability issues will need to be addressed before parties to the WTO GPA can put in place such systems.

As the various examples presented in this chapter show, Blockchain offers interesting opportunities to improve the efficiency of international trade transactions that involve multiple actors in various areas covered by the WTO, including trade finance, border procedures, transportation and logistics, financial services, insurance, retail distribution, IP and government procurement, while providing for a secure environment. It can enhance transparency, ease tracking of transactions, and speed up processes, including through the use of smart contracts, which allow for the automation of transactions. It is therefore seen by many as the most promising technology to digitalize trade.

The number of trade-related blockchain applications – developed by established companies and startups, often working hand-in-hand in a collaborative manner within consortia in what could be deemed a “cooperative competition” setting, as well as by government authorities – has boomed in recent years. Not without a reason: the technology can only work at its full potential if the various dimensions of international trade, from trade finance, to customs operations and logistics, are digitalized and if common approaches and standards are developed. Smart trade requires more than just the technology. It requires standardization and a conducive regulatory environment, which calls for a holistic, cooperative approach that breaks down existing silos.

While Blockchain presents interesting features, it is not a panacea for all problems and it is essential that the costs and benefits are carefully weighed up. For the time being, investment in the technology is something of a gamble, but it is a gamble that many companies feel important to take given the stakes at play.

Endnotes

1. An open account transaction is a sale where the goods are shipped and delivered before payment is due.

2. Letters of credit are a guarantee of payment issued by the bank of the buyer on its behalf to the seller. The letter of credit is a written commitment that the goods will be paid once delivered, provided the obligations attached to the letter of credit (i.e. delivery conditions and submission of documents such as bill of ladings, which list and detail the goods being shipped) are met. The letter of credit is a guarantee that the bank will cover the outstanding amount, should the buyer be unable to pay.

3. The annual "Rethinking Trade & Finance" report from the International Chamber of Commerce's (ICC) Banking Commission reports on "the long-anticipated disappearance of the documentary letter of credit". Nearly 80 per cent of those surveyed expect little or no growth, or even decline in the use of traditional trade finance in the coming years. See International Chamber of Commerce (ICC) (2017a).

4. See the UNECE *Trade Facilitation Implementation Guide* for more information: http://tfig.unece.org/contents/open-accounts.htm.

5. Participating banks include: Banco Santander, Deutsche Bank, HSBC, KBC, Natixis, Nordea, Rabobank, Société Générale and Unicredit.

6. See https://www.ibm.com/blogs/blockchain/2017/03/disrupting-supply-chain-financing-mahindra/

7. See https://www.hyperledger.org/news/2017/04/11/4-11-17-coinspeaker-ibm-and-sichuan-hejia-launched-a-blockchain-platform-for-pharmaceutical-procurement

8. See https://www.dianrong.com/en/news/desktop/58d0ea009578922900e60d02.html

9. Some blockchain projects focus specifically on streamlining KYC processes, such as the shared KYC platform developed by IBM in cooperation with Deutsche Bank, HSBC, Mitsubishi UFJ Financial Group (MUFG) and the Treasuries of Cargill. See http://fintechnews.sg/14420/blockchain/ibm-completes-poc-blockchain-based-shared-kyc-deutsche-bank-hsbc-mufg-cargill-ibm-treasuries/

10. See https://www.r3.com/

11. See https://www.wto.org/english/news_e/brief_tradefa_e.htm

12. FAO/IPPC e-Phyto Factsheet #7. Available at: https://www.ippc.int/static/media/files/publication/en/2017/11/IPPC_ePhyto_Factsheet7_e_W.pdf

13. UNECE Recommendation 33.

14. Article 10.4 of the Agreement.

15. See https://www.youtube.com/watch?v=tdhpYQCWnCw&feature=youtu.be

16. If the goods are sent to a different destination, requirements may differ and a new certificate may be required.

17. In December 2017, the National Food Authority (NFA) of the Philippines issued a warning against individuals or entities using fake or fabricated rice import permits following a report that some unscrupulous individuals or parties were selling spurious permits allegedly issued by the NFA under the 2017 minimum access volume private sector rice import scheme. See http://www.nfa.gov.ph/35-news/1053-nfa-warns-against-fake-rice-import-permits. Accessed on 20 June 2018.

18. Advance rulings are binding decisions by customs authorities. Such decisions can be requested by importers or exporters with regard to the classification, origin or customs value of the goods intended for importation or exportation. Advance rulings are binding throughout the customs territory and are valid for a specific period of time. Advance rulings facilitate the release and clearance process, as they guarantee that certain key assessments have already been made. Article 3 of the TFA lays down specific disciplines on advance rulings.

19. Article 7.1 of the TFA provides that "each Member shall adopt or maintain procedures allowing for the submission of import documentation and other required information, including manifests, in order to begin processing prior to the arrival of goods with a view to expediting the release of goods upon arrival". The same article encourages the lodging of documents in electronic format for pre-arrival processing of such documents, opening the door to the use of technologies such as Blockchain to process customs documents (paragraph 1.2 of Article 7).

20. Article 7.8 of the TFA requires WTO members to "adopt or maintain procedures allowing for the expedited release of at least those goods entered through air cargo facilities to persons who apply for such treatment, while maintaining customs control".

21. Article 7.4 of the TFA requires WTO members to "base risk management on an assessment of risk through appropriate selectivity criteria" so as to "avoid arbitrary or unjustifiable discrimination, or a disguised restriction on international trade". Selectivity criteria "may include, *inter alia*, the Harmonized System code, nature and description of the goods, country of origin, country from which the goods were shipped, value of the goods, compliance record of traders, and type of means of transport".

22. See the 1990 WCO Convention on Temporary Admission (http://www.wcoomd.org/en/about-us/legal-instruments/~/media/2D53E23AA1A64EF68B9AC708C6281DC8.ashx).

23. DG TAXUD is the department of the European Union Commission responsible for EU policies on taxation and customs.

24. An ATA Carnet is an international customs document used in 87 countries that permits duty-free temporary admission of most goods for up to one year normally.

25. Article 7.5 of the TFA provides that "each Member shall select a person or a consignment for post-clearance audit in a risk-based manner, which may include appropriate selectivity criteria".

26. An authorized operator – or authorized economic operator – is defined by the World Customs Organization (WCO) as a party involved in the international movement of goods, in whatever function, that has been approved by, or on behalf of, a national customs administration, as complying with WCO or equivalent supply chain security standards. Criteria to qualify as an authorized operator shall be specified in a WCO members' law, regulations and procedures. Authorized operators include manufacturers, importers, exporters, brokers, carriers, consolidators, intermediaries, ports, airports, terminal operators, integrated operators, warehouses and distributors. Article 7.7 of the TFA includes specific provisions regarding the accreditation of authorized operators.

27. See https://www.youtube.com/watch?v=LeKapqAQimk

28. Hyperledger Burrow (https://www.hyperledger.org/projects/hyperledger-burrow) and Hyperledger Sawtooth (https://sawtooth.hyperledger.org/docs/core/releases/1.0/introduction.html).

29. Interview with the Dutch customs. The Dutch customs are working on the establishment of further paperless bilateral channels.

30. There are three basic models of single windows:

- Those organized around a single authority that receives information (either on paper or electronically), disseminates this information to all relevant governmental authorities, and coordinates controls to prevent undue hindrance in the logistical chain. This is the model used in Sweden.
- Single automated systems for the collection and dissemination of information that integrates the electronic collection, use, and dissemination (and storage) of data related to trade that crosses the border – like in the United States. Such single windows can either be integrated (i.e. data is processed through the system) or based on interfaces (i.e. data is sent to the agency for processing), or a mix of the two.
- Automated information transaction systems, through which a trader can submit electronic trade declarations to the various authorities for processing and approval in a single application. This is the most advanced model of single windows. Such a model is used in Singapore.

See UNECE "Recommendation and Guidelines on establishing a Single Window". Available at: https://www.unece.org/fileadmin/DAM/cefact/recommendations/rec33/rec33_trd352e.pdf

31. See UN/CEFACT recommendation 34 on "Data simplification and standardization for international trade", December 2010. Available at: http://tfig.unece.org/contents/recommendation-34.htm

32. As per http://www.fao.org/fao-who-codexalimentarius/home/en/ the "Codex Alimentarius, or 'Food Code' is a collection of standards, guidelines and codes of practice adopted by the Codex Alimentarius Commission. The Commission, also known as CAC, is the central part of the Joint FAO/WHO Food Standards Programme and was established by FAO and WHO to protect consumer health and promote fair practices in food trade".

33. In October 2017, the Standards and Trade Development Facility (STDF), a global partnership that helps developing countries to gain and maintain access to markets by tackling sanitary and phytosanitary gaps, approved funding for a feasibility study that will look at options for e-certification in the veterinary area. The study will be implemented by the OIE, in close collaboration with the FAO, World Bank Group, WCO and other organizations.

34. See https://blockfreight.com/

35. See https://events.sap.com/teched/en/session/36839

36. See https://www.quasa.io/src/assets/pdf/wp_en.pdf

37. See, for example, https://www.bloomberg.com/news/articles/2018-04-18/drowning-in-a-sea-of-paper-world-s-biggest-ships-seek-a-way-out and https://www.supplychaindigital.com/technology/blockchain-technology-set-revolutionise-logistics-industry

38. See https://www.tradelens.com

39. See IBM Press Release: http://newsroom.ibm.com/2018-08-09-Maersk-and-IBM-Introduce-TradeLens-Blockchain-Shipping-Solution

40. Author's interview with Accenture in 2018.

41. See https://bita.studio/

42. This list does not pretend to be exhaustive. The choice was made to focus on the sectors where cross-border transactions are likely to be affected the most. Other services industries, such as the health sector and travel-related services, have started to investigate the use of Blockchain to reduce costs, simplify procedures, enhance coordination between various stakeholders, enhance efficiency of booking/appointment systems, etc.

43. Nasdaq's private Linq blockchain network, for example, enables private companies to issue and trade shares – see Nasdaq (2015).

44. See https://www.traxpay.com/

45. Vostro and Nostro accounts refer to the same thing from a different perspective. If Bank A has an account with Bank B in Bank B's home currency, this account is a Nostro account for Bank A (i.e. for Bank A, "Nostro" refers to "our" account with Bank B) and a Vostro (or "your") account for Bank B.

46. Ripple is a distributed ledger system, but not a blockchain *per se*.

47. See https://ripple.com/

48. See, for example, Deloitte (2016), Ernst & Young (2017), KPMG (2017), McKinsey & Company (2016a), and PricewaterhouseCoopers (2016).

49. At the WTO, e-commerce is "understood to mean the production, distribution, marketing, sale or delivery of goods and services by electronic means" (WTO official document number WT/L/274). Work on e-commerce at the WTO therefore goes beyond the services dimension of e-commerce. Issues related to trade in goods, intellectual property and development are also part of the WTO work programme on e-commerce. This section focuses exclusively on retail distribution and the services dimension of e-commerce.

50. See https://www.openbazaar.org/

51. Article 2 of the Berne Convention (http://www.wipo.int/treaties/en/text.jsp?file_id=283698).

52. See for example https://poex.io/about, https://proofofexistence.com/about, and https://www.microsoft.com/en-us/store/p/proof-of-existence/9nblggh4z1t2

53. See https://binded.com

54. See https://cognate.com/

55. Ibid.

56. See https://www.bernstein.io/

57. See https://kodakone.com/index.php?id=1

58. See http://myceliaformusic.org

59. See http://www.mediachain.io/

60. See http://www.wipo.int/pressroom/en/briefs/tk_ip.html

61. Open source software is computer software, the source code of which is released under a license in which the copyright-holder grants users the rights to study, modify, enhance and distribute the software to anyone and for any purpose. Open source entails the free availability of source code and distribution.

62. The Creative Commons (CC) project enables rights-holders to legally share their knowledge and creativity in a more equitable, accessible and flexible manner. Creative Commons licenses enable the free distribution of an otherwise copyrighted work. A Creative Commons license is used when an author wants to give people the right to use, share and build upon a work that they have created. These licenses are often seen as the "open-source equivalent" for non-code works. For more information, see https://creativecommons.org

63. See https://ipwe.com/ipwe-registry

64. See https://concensum.org/en/e-services

65. Article 58 of the TRIPS Agreement.

66. See https://www.open-contracting.org/why-open-contracting/

67. Government procurement practices are not covered by the multilateral rules of the WTO, but by a plurilateral agreement which currently includes 47 members (including the European Union and its 28 member states – 2018 data). In fact, government procurement is explicitly exempted from the main disciplines of both the General Agreement on Tariffs and Trade (GATT — see Article III: 8a) and the General Agreement on Trade in Services (GATS — see Article XIII:1).

68. Article IV.3.a of the revised GPA.

69. The exact language of the Preamble reads: "Recognizing the importance of transparent measures regarding government procurement, of carrying out procurements in a transparent and impartial manner and of avoiding conflicts of interest and corrupt practices, in accordance with applicable international instruments, such as the United Nations Convention Against Corruption;" (https://www.wto.org/english/docs_e/legal_e/rev-gpr-94_01_e.htm).

70. Article XVI.1(b) of the revised GPA.

71. See https://www.unece.org/fileadmin/DAM/cefact/cf_forums/2017_Rome/PPTs/BlockChain/PM_05_Yolanda_Martinez_Mancilla_Mexico_Blockchain_HACKMX.pdf, slides 23-24.

4 A world of opportunities... and challenges

Research published by the European Parliament in 2017 claimed that Blockchain could “change our lives” (Boucher, 2017). What the various blockchain applications that are being developed in areas as diverse as trade finance, trade facilitation, trade in services, intellectual property and government procurement show is that Blockchain has the potential to impact both the traders and the government agencies involved in international trade significantly. Opportunities are multifaceted, but will only be realized if several key challenges are addressed.

1. Multifaceted opportunities

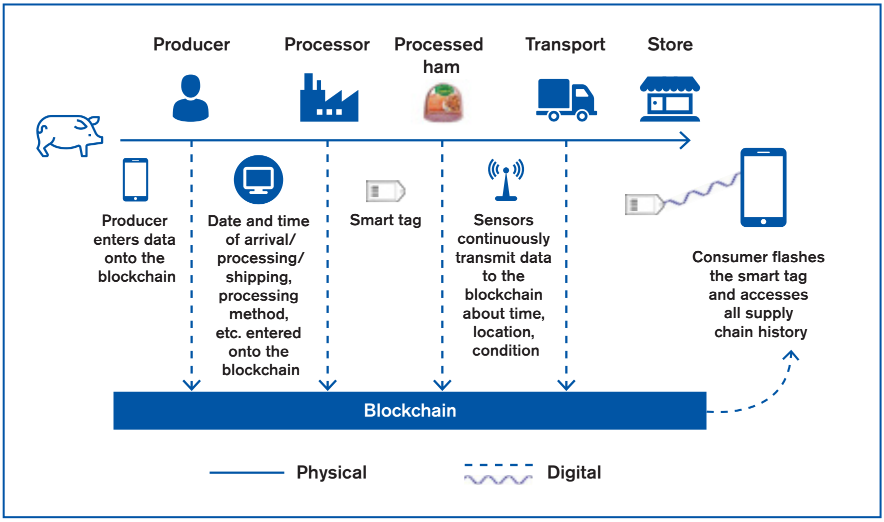
(a) Enhancing trust and transparency in value chains

One of the most obvious uses for Blockchain is data monitoring. Blockchain, in combination with IoT, provides new ways to track the journey of products. It is a powerful tool to promote transparency and traceability of supply chains (see Figure 13), help fight counterfeits and build consumers’ trust.

Unlike current labelling systems that can be manipulated, Blockchain provides a highly secure system to prove the origin and authenticity of products. The number of startups and companies turning to Blockchain to help track products and fight counterfeits has been skyrocketing.

The company Agridigital, for example, is using Blockchain to help agricultural businesses solve supply chain inefficiencies and risks, and track the provenance of the agricultural products they use.[1] Other companies are leveraging the technology to offer supply chain transparency and anti-counterfeiting solutions to businesses, such as Blockverify, which helps firms fight counterfeiting in pharmaceuticals, luxury items, diamonds and electronics, and Everledger, which enables companies to record and track the movement of diamonds from mine to store.

Figure 13 Illustration of an end-to-end traceability process



Source: Author.

Various initiatives aim to enhance transparency with a view to building consumers' trust. For example, Provenance, a UK-based startup specialized in blockchain traceability, is working with Coop, the largest UK consumer cooperative, to track the journey of fresh products from source to supermarket in real time to increase consumers' trust in food retail. At each point of the journey, data on the product, supplier, location, as well as on the environmental and social impact of each business, are collected and added to the blockchain, creating a digital history of the product that is accessible to all, from the farm to the consumers.[2] French multinational retailer Carrefour is also introducing blockchain technology to enhance the traceability of its animal product lines and guarantee consumers as much transparency as possible.[3] Another Provenance project, in the fashion industry, tracked sustainable alpaca fleece from shearing in the farm through to spinning, knitting and finishing in fashion retailer Martine Jarlgaard's London studio, enabling customers to check the authenticity of the materials used, the processes and the people behind the products.[4]

Following the various scandals that have shaken the food industry in recent years, major food and retail companies are turning to Blockchain to enhance the transparency of the food supply chain, but also to enable them to quickly track tainted products and help restore trust in the quality of the food we eat.

Source: Provenance.

For example, in October 2016, US company Walmart teamed up with IBM and Tsinghua University in Beijing to track the movement of pork in China via a blockchain. The blockchain documents how the meat has flowed from producers to processors, distributors, grocers, and, finally, consumers. The origins and batch number of the product, the information on the plant and on processing methods, the expiration dates and details on retailing steps are all documented on the blockchain, making it possible to track potential contamination sources rapidly and to guarantee the origin of the products. According to Walmart, the use of blockchain has helped to reduce the time required to track tainted products from days to seconds, enabling more precise and rapid recalls, with a view to preserving consumer trust in the food industry (Higgins, 2017c). Walmart simultaneously ran a similar trial on mangoes.

The encouraging results of Walmart's pork and mango trials led other large food companies such as Unilever, Nestlé and Kroger to partner with IBM to explore how blockchain technology could be applied to their supply chains to improve the traceability of their products and help them cut down the time it takes to identify sources of contamination (Hackett, 2017). In June 2018, Walmart, Nestlé SA, and eight other companies formed a consortium powered by the IBM Food Trust blockchain platform that will leverage blockchain technology to track food across the globe (Giles, 2018). The Food Trust platform will connect growers, processors, wholesalers, distributors, manufacturers, retailers and other stakeholders through a permissioned ledger to enhance visibility and accountability along the supply chain and provide participants with a record of food origin details, processing data, and shipping details – among other elements. Traceability through Blockchain is, in fact, already happening. Walmart is using it on a day-to-day basis to track products over 25 product lines, from dairy products to processed foods and meat. As of August

2018, Walmart had tracked over 4 million food packages over a period of approximately one year.[5]

In March 2017, the Chinese e-commerce firm Alibaba announced a partnership with PricewaterhouseCoopers to help solve China's food safety issues (Millward, 2017). Alibaba is testing uses of Blockchain to track food products through the supply chain.

In some value chains, traceability can be a sanitary requirement, for example to ensure that foods are free of diseases such as bovine spongiform encephalopathy. Implementing such traceability systems is costly, in particular for developing countries with many small farms. Blockchain could offer an interesting alternative to existing and complex systems and make market access easier for exporters from developing countries.

Beyond issues of quality, blockchain technology is also used by companies to track ethical claims and fair-trading practices. In 2016, Provenance piloted a project in Indonesia, the world's largest producer of tuna, to provide proof of sustainably sourced and slavery-free products.[6] Local fishermen sent text messages to register their catch on the blockchain. The identification was passed on to a supplier, and every transaction that occurred along the supply chain was recorded. Information on the origin of the product and the supply chain journey could be accessed and verified by end-buyers and -consumers using their smartphones. This pilot project demonstrated how Blockchain can be used to track responsibly caught fish and prove social claims, and make fish supply chains more transparent. Another Provenance project tracked coconuts from Southeast Asia to Europe, to provide shoppers with blockchain-verified proof of fair pay to the farmers that grew the coconuts.[7] The traceability of products via Blockchain could open new opportunities for producers from developing countries, as it could make it easier for them to prove the quality of their products and to negotiate fair prices.

Traceability of products along the supply chain to assert origin, quality, and ethical and social claims, and to track tainted products is undeniably one of the most promising uses of blockchain technology. In a widely shared quote, Franck Yiannas, Vice President of Food Safety for Walmart, noted that Blockchain is the "equivalent of FedEx tracking for food" (Giles, 2018).

However, while the use of Blockchain can enhance transparency and help trace products along the supply chain, it can only guarantee that information on the blockchain has not been tampered with. Third parties may still be required to check off-chain processes and confirm that they meet the asserted claims. Ethical and social claims via a blockchain, for example, are only as good as the offline verification processes that guarantees that relevant ethical and social requirements have been met off-chain. Establishing a credible link between offline events and their online record is therefore crucial. In one of the first studies on the economic impact of Blockchain, Catalini and Gans (2017) note that, while it can be relatively easy and cheap to verify transactions of goods whose offline attributes are easy to capture and expensive to alter or fake (e.g. diamonds), in many cases, maintaining a robust link between offline events and distributed ledgers is still expensive, and may require not only one or more trusted intermediaries, but often also multiple parties within the same ecosystem to agree on rules for secure data entry and sharing. Connecting physical goods and events to a blockchain often requires enabling technologies like IoT. This connection can also represent a vulnerability, as physical items and IoT sensors can be tampered with (Carson *et al.*, 2018).

(b) Reduction in trade costs

Studying the economic impact of Blockchain, Catalini and Gans (2017) identify two key costs affected by the technology: verification costs (i.e. the ability to verify the attributes of a transaction cheaply) and networking costs (the ability to bootstrap and operate a marketplace without the need for a traditional intermediary).

The examples presented in the previous chapter confirm the potentially significant impact that Blockchain can have on verification costs, as the transparent and immutable nature of the technology, combined with the possibility to automate processes using smart contracts*, could reduce verification costs to virtually nothing. Information added to the blockchain can be automatically screened on the basis of conditions defined in a smart contract (e.g. to process applications and documents for customs processes or government procurement tenders); information can be easily tracked and audited; and the immutable nature of the technology facilitates the verification of individuals' identity and of the financial records of companies.

As for the impact of blockchain technology on networking costs, it is best evidenced by the emergence of peer-to-peer marketplaces such as OpenBazaar or Hijro, in which the business model consists in leveraging the opportunities opened by Blockchain to cut out traditional intermediaries to lower costs.

The previous chapter also shows that the technology could have a much wider impact on costs. Because of its decentralized, highly secure and immutable nature, and the possibility if offers of automating processes and payments, Blockchain could reduce a variety of other trade costs, in particular processing, coordination, transportation, logistics, financial intermediation and exchange rate costs. Its decentralized nature enables multiple entities to coordinate actions in real time and in a fully transparent and secure manner, thereby enhancing efficiency.

Although it is difficult to assess the overall impact that the deployment of blockchain technology could have on trade costs, it could be significant. As seen in Section 3.1(b), the use of blockchain technology could help with the implementation of the WTO TFA, which aims at easing customs procedures. The WTO has estimated that the average trade cost reduction for all merchandise exports resulting from full implementation of the TFA could amount to 14.3 per cent, with an average decrease of 18 per cent for manufactured goods and 10.4 per cent for agricultural products (WTO, 2015c).

A look at some estimates in the financial sector and the shipping industry can give a further idea of the potential impact of this technology on trade costs.

In a recent study, Accenture and operations benchmarking specialist McLagan estimate that that the deployment of blockchain technology in investment banks could bring 30 per cent of savings by establishing more efficient processes and improving transparency and compliance (Accenture, 2017). Likewise, the use of blockchain technology for trade-related processes, including import and export procedures, and procedures to obtain licenses and certificates, could generate considerable savings, with benefits split among the agencies involved – because less time and fewer resources would be required to administer requests – and traders – who would gain time and save money as a result.

Significant savings can also be expected in the shipping industry, a sector that transports around 90 per cent of goods traded internationally.[8] IBM calculated that moving a container of avocados from Mombasa to Rotterdam costs approximately US$ 2,000, of which US$ 300 were associated with paperwork. According to IBM, digitalization of the process could save up to 15 per cent of the cost of international maritime transport, and going entirely digital could save shipping carriers about US$ 38 billion per year (Allison, 2017b). While digitalization can be achieved through other means than blockchain, the specific features of the technology make it a particularly interesting tool to advance digitalization efforts, as the various examples mentioned in Section 3.1 demonstrate.

McKinsey & Company estimates that Blockchain’s strategic short-term value is, in fact, mainly in reducing costs before creating transformative business models. Based on a quantification of the monetary impact of more than 90 use cases, McKinsey & Company finds that approximately 70 per cent of the value at stake in the short term is in cost reduction (Carson *et al.*, 2018).

Further research is needed to try and quantify the potential impact of Blockchain on the various types of costs that affect international trade transactions. Preliminary indications at hand tend to point to a notable impact, with the World Economic Forum estimating in a recent study conducted in collaboration with Bain & Company that the removal of barriers due to Blockchain could result in more than US$ 1 trillion of new trade in the next decade (WEF, 2018). However, careful consideration needs to be given to the costs of transiting to and maintaining a blockchain-based system. Establishing a blockchain platform is a complex endeavour that requires complicated integration processes. In fact, a large part of the cost reductions to be derived from a blockchain may not be linked to the technology itself, but rather to the integration and streamlining work that is necessary to move to a blockchain system.

The reductions in trade costs that the use of blockchain technology could potentially permit open particularly interesting opportunities for micro, small and medium-sized enterprises (MSMEs), which face proportionally higher fixed costs than bigger companies, in particular when they are small producers from developing countries.

(c) Opportunities for MSMEs and small producers from developing countries

MSMEs are key economic actors. They account for more than 90 per cent of companies worldwide and for two-thirds of total employment in developing and developed countries alike. Yet their participation in international trade is low, with exports accounting for 7.6 per cent of manufacturing sales in developing countries, compared to 14.1 per cent for large manufacturing enterprises. The numbers are slightly higher in developed countries, with MSMEs accounting for 34 per cent of exports on average (WTO, 2016c).

Surveys of firms conducted by various governmental and international organizations[9] point to various factors to explain MSMEs' limited participation in world trade: high tariffs; multiple non-tariff measures; lack of transparency and cumbersome customs procedures; difficulties in accessing trade-related information; difficult access to distribution networks; a lack of skills and technology; logistics and infrastructure costs; and insufficient access to trade finance. These difficulties are common to all MSMEs, from both developed and developing countries, but they tend to impact small firms and small producers from developing countries particularly heavily.

As shown in Chapter 3, blockchain technology can help to address several of these challenges and can be a powerful tool in facilitating the participation of MSMEs in international trade.

MSMEs, for example, face greater difficulties than bigger firms in accessing trade finance. More than half of their trade finance requests are rejected, against 7 per cent for multinational companies (WTO, 2016b), and surveys have shown that about 60 per cent of companies whose requests have been rejected fail to execute transactions (Asian Development Bank, 2017). Anecdotal evidence suggests that banks are reluctant to spend money and efforts to conduct KYC, especially for potential clients unlikely to generate much profit. The often low profitability of MSMEs' transactions, combined with the lack of clear financial and other records – which makes it difficult to evaluate their creditworthiness using traditional methods – make banks unwilling to extend credit guarantees to them (Asian Development Bank, 2017).

Blockchain could help small firms and producers access finance at three levels.

First, the immutable nature of Blockchain could make it easier to track transactions and assess the creditworthiness of companies and individuals – a key hurdle for MSMEs and small producers. Going one step further, in December 2017 six international companies and banks and four fintech startups announced a project using the technology to gather information on price, quality and sustainability of the rice production process of 10,000 Malawian rice farmers to help them access financing on preferential terms based on the evidence supported by the blockchain (CISL, 2017).

Second, MSMEs often have neither the resources nor the ability to deal with complex procedures. Facilitating procedures using Blockchain to address the financing gap of MSMEs – and, of course, help open new revenue streams for the banks – was at the core of an initiative launched in 2017 by several banks. The We.trade platform, which can be accessed from any connected device, aims to streamline trade finance processes for participating companies, in particular small ones, including managing, tracking and securing domestic and international trade transactions. The platform completed its first live operations in July 2018 (see also Section 3.1(a) and Suberg, 2018). Other trade finance platforms, such that recently launched across the Guangdong, Hong Kong (China) and Macau (China) bay area with the backing of China's central bank, specifically target MSMEs.

Third, by allowing companies and individuals around the globe to make transactions on a direct, peer-to-peer basis, without the need to go through banks, blockchain technology opens up the possibility for small firms and small producers to participate in international trade without the need to secure traditional trade finance. One such example is the FastTrackTrade platform,[10] which leverages the technology to build a digital trade network of MSMEs to facilitate commercial transactions between buyers and sellers and give participating companies direct access to the trade finance services of various fintech companies, thereby bypassing banks. Another example is the supply chain finance platform launched by IBM in cooperation with a technology research laboratory in Kenya and Twiga Foods, a business-to-business logistics platform that helps farmers distribute bananas, tomatoes, onions and potatoes to 2,600 kiosks across Kenya and that uses machine-learning algorithms and blockchain technology to extend microloans to small businesses via mobile phones. Having piloted the platform with 220 small food retailers across Kenya over an eight-week period, the trial saw customers increase their order size by 30 per cent. The platform is expected to be rolled out across Africa by the end of 2018 (Wass, 2018a). Blockchain enthusiasts see in Blockchain an opportunity to promote financial inclusiveness in countries with large unbanked populations (International Finance Corporation, 2017).

As noted in Section 3.1, Blockchain could potentially improve the efficiency of export procedures and help to administer single windows in a more effective way, by allowing all authorized parties to interact in real time and in a fully transparent and secure manner; by reducing the volume of communications among parties, given that every transaction is time-stamped* and recorded on the blockchain in a near immutable way and is visible to all concerned; by improving the traceability of transactions; and by making it possible to automate certain processes via the use of smart contracts. If deployed appropriately at a cost that justifies the benefits, Blockchain could contribute to the implementation of the TFA and make participation in international trade easier for MSMEs. The ICC estimates that the TFA could increase MSMEs' exports by up to 80 per cent in some developing economies (International Chamber of Commerce, 2017b).

Blockchain could not only make it easier for MSMEs to interact with customs authorities, but also with consumers and businesses along the supply chain, by reducing transaction costs, thereby enabling MSMEs to grow their exports. As a recent report by the European Parliament noted, MSMEs could be one the greatest beneficiaries of Blockchain (European Parliament, 2018).

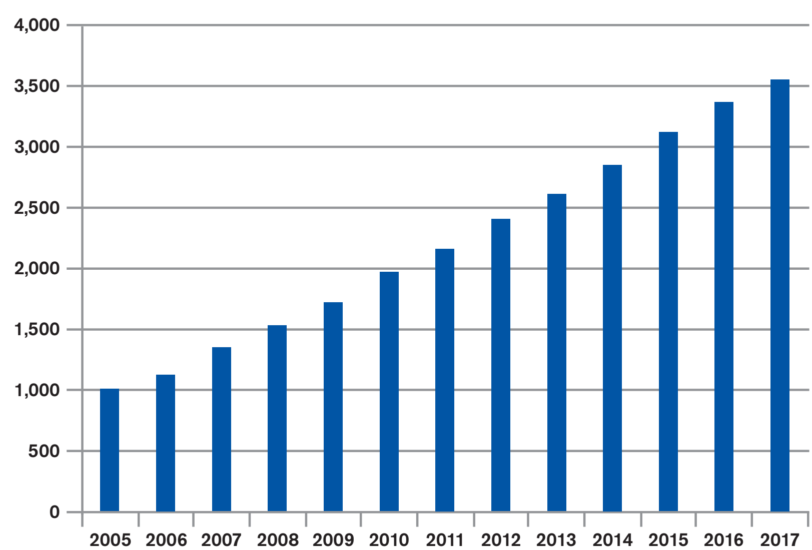
Blockchain offers opportunities to track the origins of products more easily (see Section 4.1(a)), and this may also help small producers from developing countries to prove the quality of their products and to negotiate fair prices. In fact, Oxfam announced in August 2018 that it had started a pilot using the technology to help Cambodia's rice farmers receive a better price for their crops. Small farmers often lack power and information for negotiating with middlemen, traders and companies on price and other conditions. The BlocRice application aims at enhancing transparency and traceability along the supply chain to empower Cambodian rice farmers in their price negotiations and in finding buyers.[11] In the same spirit, Blockchain could help small producers to defend their traditional knowledge and IP rights.

E-procurement is also widely advocated as an effective tool to encourage the participation of MSMEs in public procurement tenders. Blockchain technology could improve the efficiency of tender processes and reduce costs for smaller suppliers to participate in government procurement markets.

In short, Blockchain has the potential to empower individuals and companies around the globe to make transactions more efficiently, economically and quickly. It could lower barriers to entry into international trade for small companies and producers, and could be a powerful force for their inclusion, provided that they have the technical knowledge required to participate in the technology – or the resources to use a service provider – and that they have adequate internet access.

While significant progress has been made in connecting an increasing number of people to the internet (see Figure 14), more remains to be done to close the digital gap between advanced and less developed economies. Disparities remain significant both in terms of access and bandwidth. Close to 80 per cent of Europeans use the internet, compared to less than 20 per cent of Africans (see Figure 15), and the digital gap between Organisation for Economic Co-operation and Development (OECD) countries and least-developed countries (LDCs) has been growing sharply since the beginning of the millennium, with a slight improvement since 2013 (see Figures 16 and 17). There is a long way yet to go before the United Nations' Sustainable Development Goal 9c, which calls on the international community to "significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020" is implemented.[12]

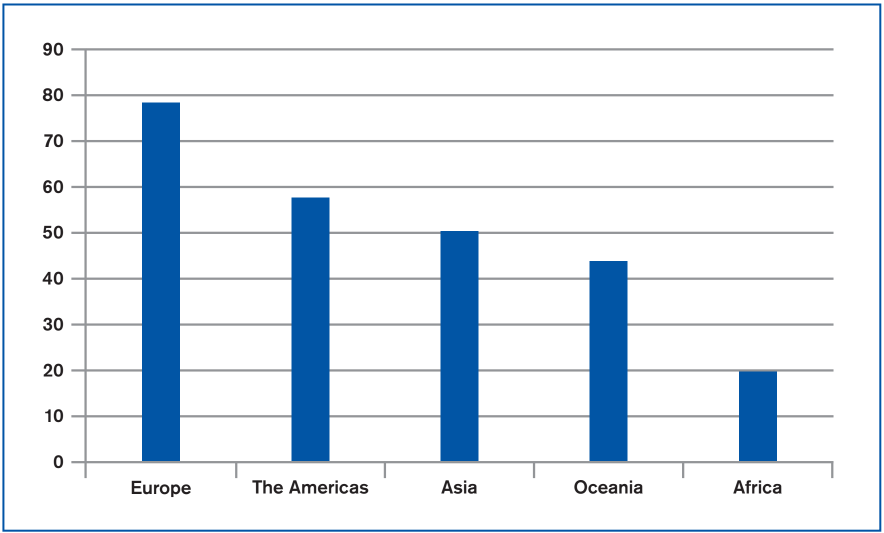
Figure 14 **Number of people using the internet, in millions, 2005-17**[a]



Source: ITU/ICT indicators.

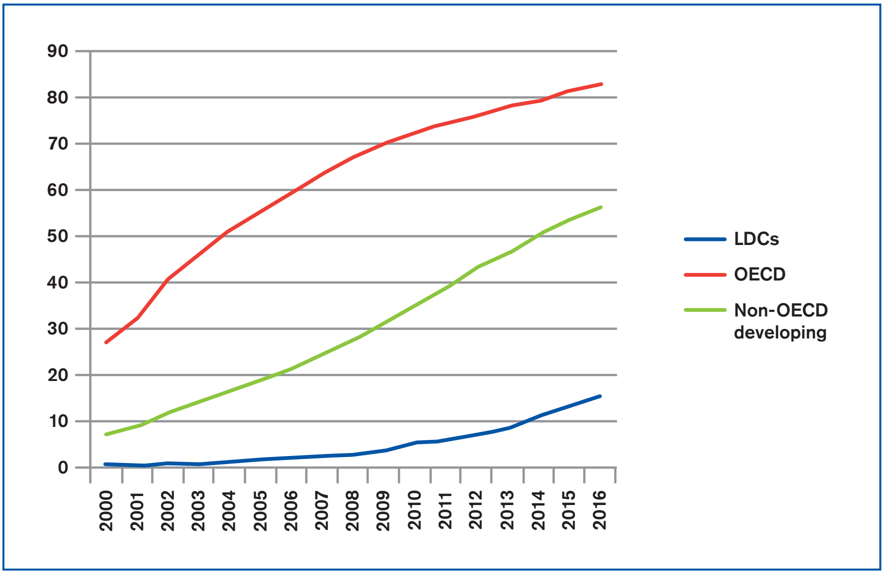
[a] estimates

Figure 15 Internet users (percentage of population) in 2015



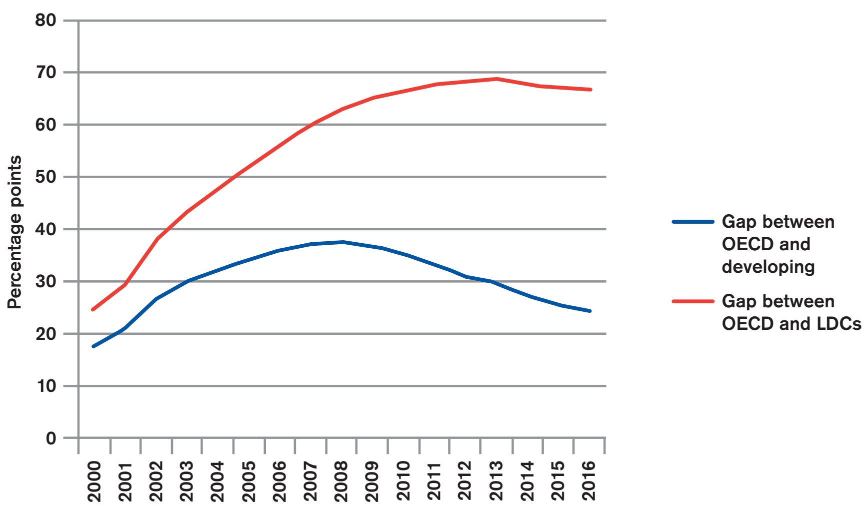
Source: Author's calculation based on ITU/ICT indicators.

Figure 16 Internet users (per 100 inhabitants)



Source: Author's calculations based on ITU/ICT Indicators.

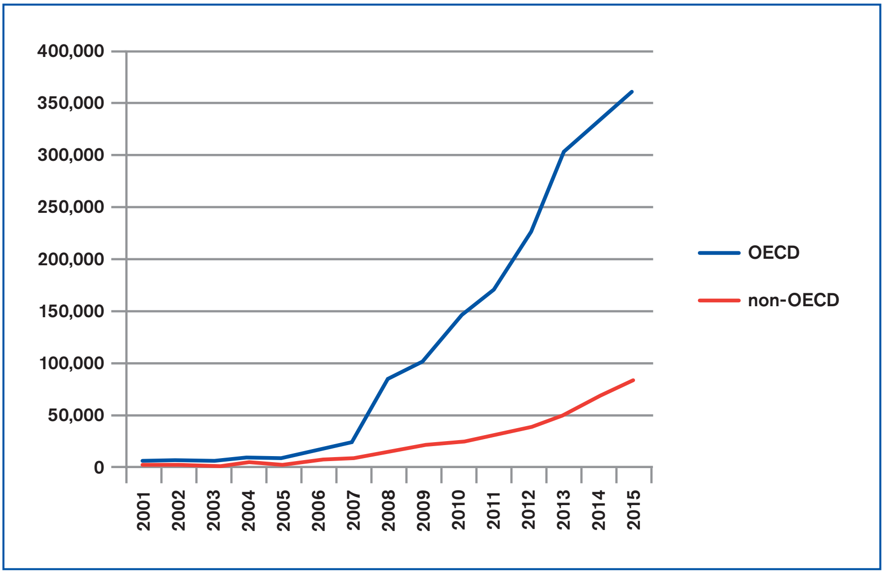
Figure 17 Gap in internet use (per 100 inhabitants)



Source: Author's calculations based on ITU/ICT Indicators.

More worrisome is the growing bandwidth gap (see Figure 18). Not only do fewer people in developing countries, in particular LDCs, have access to the internet, but they also have access to less powerful telecommunications installations and a limited bandwidth speed. Worldwide disparities in terms of the distribution of installed telecommunication bandwidth are large and significant: in 2014, just three countries (China, Japan, the United States) hosted 50 per cent of the globally installed bandwidth potential (Hilbert, 2016). This concentration is not new – historically 70–75 per cent of the global telecommunication capacity has been in the hands of 10 countries – but if nothing is done in the years to come to address this "double gap", in terms of access to the internet and bandwidth capacity, inequality will continue to grow and the deployment of technologies like Blockchain may exacerbate disparities by *de facto* cutting out those that do not have the technical capacity to participate in them. Instead of benefiting from the opportunities opened by the technology, small firms and producers, in particular those from developing countries and LDCs, would be left further and further behind. The risk is not negligible. Indeed, the evidence already shows that MSMEs are lagging behind in adopting digital technologies (Organisation for Economic Co-operation and Development, 2017).

Figure 18 International internet bandwidth per internet user (in bit/second)



Source: Author's calculations based on ITU/ICT Indicators.

Although Blockchain can lower barriers to entry and facilitate the participation of MSMEs and small producers in international trade, some sectors may benefit more than others. The emergence of new business models based on or articulated around blockchain platforms could shake entire sectors, forcing existing companies, including small ones to adjust or risk being left behind. The fear of losing ground to competitors may explain the number of companies, in particular in the services sector – financial, insurance, logistics, distribution, etc. – that are rushing to investigate the potential of Blockchain.

Barriers to entry are, however, not likely to fall for everyone. While simple "users" of blockchain platforms are likely to benefit from lower barriers to entry, companies that compete directly with "platform insiders", i.e. with companies that are the "keepers" of a permissioned platform (such as participating banks in the case of platform run by banks), will likely face higher barriers. The level of investment needed to become one of the "keepers" of a permissioned platform could cut out latecomers and make it harder for new entrants to expand in a given market. While MSMEs are likely to benefit as users, they may find it more difficult to be "platform insiders". Some observers note that, while Blockchain could enhance competition by facilitating entry, it could also lead to greater collusion, and it cannot be ruled out that a single blockchain could become dominant due to network effects, leading to a reduction in the level of competition and higher barriers to entry, which could affect MSMEs disproportionally (Cong, 2018).

Although the technology can facilitate the participation of MSMEs and small producers in international trade, like any innovation, it also carries with it the risk of disrupting some sectors and categories of workers. Opportunities and benefits may not be shared equally.

2. Success is not a given

Blockchain opens interesting opportunities in terms of cost reductions, efficiency, traceability, and security, but a number of challenges have to be overcome before the technology can be used widely.

(a) Technological challenges

(i) The scalability challenge: can Blockchain be deployed widely?

While some observers believe that blockchain technology has the potential to make fundamental changes to the ways in which our societies operate (Boucher, 2017), many also point to the limited scalability of blockchains due to the predetermined size of blocks and energy consumption issues. This is particularly true for public blockchains, but less so for consortium and private blockchains, which do not face the same limitations.

Scalability is probably one of the biggest challenges faced by public blockchains, and it has become an active area of discussion within the Blockchain community. For example, although Bitcoin has a theoretical limit of 4,000 transactions per second, the Bitcoin network processes about 7 transactions per second on average[13] and Ethereum about two times that of Bitcoin.[14] In comparison, mainstream payment processors like Visa can process 2,000 transactions per second on average, with peaks at 56,000 transactions per second (Croman *et al.*, 2016). With the number of blockchain transactions increasing at an exponential rate – daily transactions on the Ethereum network, for example, increased by 500 per cent between early 2016 and early 2017 (Croman *et al.*, 2016) – public blockchains are growing increasingly more congested, leading to further delays in the validation of transactions.

The rapid growth in the number of transactions has led the cryptocurrency community to ponder over possible solutions to address the scalability issue. A decision was recently made to double the size of the blocks on the Bitcoin blockchain from 1 MB to 2 MB and to implement a new technology – known as a segregated witness (SegWit) – to make the amount of data that needs to be verified in each block smaller, thereby accelerating the validation of the blocks (Marshall, 2017). Other proposed solutions, applicable to other blockchains like Ethereum, include, for example, the possibility to conduct some interactions off the blockchain (via the creation of so-called "state channels"), partition the blockchain data into various "shards"* (i.e. over several network segments), and make off-chain computations.[15] Other projects compromise by limiting the number of nodes* needed to validate a transaction at the cost of introducing some centralization. However, none of these solutions on their own can solve the scalability issue of public blockchains, and a combination of approaches will probably be required.

An important point to note, however, is that consortium permissioned blockchains, which are widely used in applications related to international trade, do not face the same limitations. They can use computationally less expensive protocols to verify transactions and are, therefore, more easily scalable. The Hyperledger Fabric, for example, which is a distributed operation system for permissioned blockchains, can process 3,500 transactions per second for certain workloads (Androulaki *et al.,* 2018). Because permissioned blockchains have control over every node in the network, they can ensure that every node is a computer with high bandwidth internet access and high compute power, and that additional compute power is added when needed to ensure that the network does not get congested. It is critical, however, that agencies or businesses turning to Blockchain keep these scalability needs in mind to ensure that their blockchain systems retain their original efficiency and relevance over time.

Finally, it is worth noting that the scalability challenges apply to some distributed ledgers technologies more than others. The vast majority of news articles and studies focus on the Bitcoin blockchain. However, other distributed ledger technologies that do not process transactions in blocks can process a much higher number of transactions (see Table 2). The technology is still maturing and new variants are being developed that provide for greater scalability. Hashgraph, for example, which was launched in 2017, uses a new consensus* algorithm that arguably allows it to process transactions 50,000 times faster than Bitcoin, limited only by bandwidth – i.e. more than 250,000 transactions per second – leading some observers to note that Blockchain has already become obsolete and that the future of distributed ledgers is Hashgraph.[16] It remains to be seen, however, whether Hashgraph or another DLT variant succeed in quickly processing a high level of transactions on a large scale.

(ii) The energy debate: a "permissionless issue", above all

One of the most heated controversies surrounding Blockchain relates to its level of energy consumption. As environmental concerns are at the forefront of the international agenda, some observers note that the greater use of distributed ledger technology could pose a serious challenge to the goal of reducing carbon emissions.

Indeed, the process of validating blocks can, for some blockchains, be computationally intensive and require a high level of energy – which has a direct bearing on the scalability potential of the corresponding blockchain. This is particularly true of Bitcoin transactions. O'Dwyer and Malone (2014) show that in 2014 the Bitcoin blockchain consumed approximately as much electricity as Ireland, i.e. an estimated 3 GW.

These numbers clearly raise questions of sustainability, and even more so in view of the still limited deployment of the technology. While there are good reasons to keep a close eye on the evolution of the energy footprint of blockchain platforms, one cannot generalize based on the numbers mentioned above. Indeed, blockchain platforms are based on different types of algorithms that consume various levels of energy (see Table 2). Bitcoin, for example, is far more energy-intensive than the public blockchain Ethereum – 163 kilowatt-hours (KWh) per transaction versus 49 KWh (Coppock, 2017). In fact, most of the energy debate stems from the high level of consumption of the Bitcoin blockchain. Permissioned blockchains, however, use much lighter consensus mechanisms, which are significantly less energy-intensive. In addition, more energy-efficient algorithms are being developed, such as IOTA or more recently Hashgraph, a new type of distributed ledger that is allegedly 50,000 faster than Bitcoin and that drastically reduces the computational power and level of energy required to validate transactions.

Proponents of Blockchain also note that, moving beyond Bitcoin, blockchain technology can help to increase energy efficiency. The use of smart contracts could allow utility companies to operate their grids more efficiently through a better balance of supply and demand in real time (T'Serclaes, 2017). The deployment of blockchain technology could, on this basis, reshape utility and consumption models and lead to greater energy efficiency.

New technologies and new processes, once developed, are not set in stone. Their characteristics and use evolve over time. The technologies and processes that succeed are those that manage to adjust to meet the constraints of their time and thereby become sustainable. This also holds for blockchain technology: it is only if more energy-efficient algorithms are successfully developed that one can envisage its widespread adoption.

Table 2 Average transaction fees, transaction time, transaction capacity and energy efficiency of the ten biggest crypto-currencies

Cryptocurrency	Average transaction fee in US$	Average transaction time	Transaction capacity per second	Energy efficiency	Additional features
1. Bitcoin	7.32	9-10 minutes	7	Low (PoW blockchain)	
2. Ethereum	0.22	14 seconds	20	Low (PoW blockchain)	Supports smart contracts
3. Bitcoin Cash	0.32	9-10 minutes	50	Low (PoW blockchain)	
4. Ripple	0.0000024 (+ IOU fee)	3.5 seconds	1,000	High (Voting-style algorithm)	Enables IOU transactions in any currency
5. Litecoin	0.15	2 minutes	56	Low (PoW blockchain)	
6. Dash	0.30	2-3 minutes	(4,000)	Low (PoW blockchain)	
7. NEO	None (+ variable fee)	A few seconds	1,000	High (PoI blockchain)	Supports smart contracts
8. IOTA	None	No data available	500-800	Rather high (PoW Tangle)	Especially suited for IOT devices
9. Monero	2.43	2 minutes	1,700	Low (PoW blockchain)	Advanced privacy features
10. NEM	0.21	30 seconds	(3,000)	High (PoI blockchain)	Integrated reputation system

Note: This table is based on data from 20 November 2017. It represents a snapshot and may be subject to significant changes within short time spans. Furthermore, the accuracy of the data on transaction times and capacities varies and is in some instances only based on estimates. It should, however, give the reader a feeling for the rough dimensions of the speeds and capacities of the listed crypto currencies. [PoW = Proof of Work; PoI = Proof of Importance.]

Source: Ohnesorge (2018).

(iii) Security: how secure and for how long?

Although blockchains are highly resilient compared to traditional databases due to their decentralized and distributed nature and the use of cryptographic techniques, they are not completely immune from traditional security challenges. The fact that data are distributed among participating nodes makes disaster recovery much easier: should a node be compromised, blockchain data can be recovered from other participating nodes. The absence of a single point of failure (meaning that there is no central entity to hack) makes it difficult to compromise the entire network. However, a 51 per cent attack, in which the majority of nodes is compromised, remains possible in theory, particularly in the case of permissioned blockchains, which count a much more limited number of nodes than public ones – although relatively difficult in practice. Vitalik Buterin's release of a new consensus algorithm in August 2018, that would require an attacker who wants to control the network to control 99 per cent of the nodes of the blockchain instead of just 51 per cent, could change the playing field (Buterin, 2018) and make attacks even more difficult to conduct. The highest vulnerability comes, in fact, from smart contracts, as the 2016 DAO* attack demonstrated, and from user interfaces (mobiles, laptops, etc.).

Another important point to bear in mind is that Blockchain's resilience relies on encryption* and algorithms, whose strength is based on computing power. Advances in technology, in particular quantum computing, could, in the long term, represent a threat to blockchain technologies. For the time being, current experimental quantum computers do not have sufficient computing power to break cryptographic algorithms. However, the community of cryptographers is getting ready. "Post-quantum" algorithms that would be resistant to quantum computing are being actively researched.

These challenges are significant, but the technology is still maturing and technological solutions are being investigated and developed.

(b) Interoperability challenges

The advent of Blockchain raises issues of interoperability both at a technical level (how various technical interfaces talk to each other) and at a semantic level (how information exchanged is understood by the various parties involved). Such challenges are not peculiar to Blockchain, but, as with other digital technologies, failing to address them would negate many of the benefits that Blockchain could bring.

(i) The digital island problem

An important challenge is that of the interoperability of the different existing blockchains, a problem made more acute by the search for alternatives to develop applications that meet the specific needs of various industries and that often follow different algorithmic approaches. Many platforms are being built that "do not talk to each other". For example, IBM's pilots use Hyperledger Fabric, while Microsoft's blockchain offer is built on the Ethereum blockchain. As for the R3CEV consortium, it has developed its own DLT Corda platform. The startup Provenance uses the Ethereum blockchain, while other companies which offer blockchain-based solutions to track products and enhance supply chain transparency, such as Everledger, are built on Hyperledger Fabric. While each of these projects is, individually, of interest, the lack of interoperability of the platforms on which they have been built limits the use and scalability of both the technology and the projects. *Ad hoc* bridges between two specific platforms can, of course, be built, but such tailor-made solutions cannot easily be scaled up.

Interoperability issues matter particularly for international trade, as a single international trade consignment can touch various ledgers, from finance to logistics, customs, and provenance.

The development of interoperability solutions[17] is therefore critical to avoid conflicts between disparate approaches and ensure that blockchain networks talk to each other, thereby allowing the technology to be used to its full potential. The Blockchain community is well aware of the stakes at play and is actively researching technical solutions.

While the idea of different blockchains interacting with one another still seemed a distant possibility just a year or two ago, concrete solutions are now starting to emerge. At the intra-ledger level, the Enterprise Ethereum Alliance, for example, unveiled in May 2018 an open-source cross-platform standards-based framework for Ethereum-based permissioned blockchains that would allow interoperability between permissioned blockchains built on the Ethereum public blockchain (Higgins, 2018).

Although significant, this new development will not solve the issue of interoperability between ledgers built on different platforms, but on this front too matters are moving forward. Active work is being carried out under the Hyperledger project to develop various inter-ledger interoperability solutions, including Hyperledger Sawtooth and Hyperledger Burrow, which can execute Ethereum smart contracts code,[18] and Hyperledger Quilt, which proposes interoperability between ledger systems by implementing a payments protocol to transfer value across systems.[19] And in May 2018, two startups, Clearmatics and Axoni, demonstrated how a financial derivative could be originated on one enterprise blockchain and settled on another. Interoperability is now emerging as a key design goal of distributed ledger technology (Allison, 2017a).

In addition, in November 2017, companies behind three blockchain platforms – Aion, ICON and Wanchain – announced the creation of a new advocacy group, the Blockchain Interoperability Alliance, aimed at developing globally accepted standards to promote greater connectivity and interoperability between the disparate blockchain networks (Higgins, 2017a). Ethereum co-founder Joe Lubin, Bitcoin scientist Adam Back, Hyperledger executive director Brian Behlendorf, and Richard Gendal Brown of distributed ledger consortium R3 are working collectively to explore approaches to make networks interoperable, either through the development of "interledgers" capable of facilitating interoperability, or through an identity solution that allows users to own their own profiles (Del Castillo, 2017).

The multiplicity of platforms also has more practical consequences, in particular when it comes to international trade, as an international shipment can touch a dozen different ledgers. For parties involved in such transactions, hosting a dozen nodes would be highly impractical. One specific approach being discussed within the Blockchain community consists of creating an inter-ledger notarization system to allow authorized parties to verify transactions, irrespective of which ledger they are created on (UN/CEFACT, 2018). Inter-ledger notarization could be performed by a sole entity or different entities – at the cost, however, of reintroducing some degree of centralization.

(ii) Data standardization

Beyond the purely technical interoperability aspects at the level of interfaces, equally important challenges lie in aligning the semantics (i.e. the meaning of the information being exchanged), developing standard datasets that cover all data used for information exchange for import, export, transit, transportation and finance, and aligning processes. Customs, logistics companies and traders, for example, often do not use the same semantics and view data differently. Is the "port of unlading" the same as the "place of discharge"? Should "product identification" mean the national nomenclature code (used by customs), the "said to contain" (used by transport companies), or the global product classification code (used by traders)? This aspect has been the focus of active work in recent years in order to ensure that the various parties involved understand the same data in the same way. UN/CEFACT and the WCO have both been working on data models to develop a universal language for cross-border data exchange. UN/CEFACT, for example, proposes its Core Components Library[20] and associated reference data models as base building blocks for blockchains to achieve better data interoperability, and has developed a recommendation on data simplification and standardization (Recommendation No. 34), while the WCO has developed its own data model.[21] These challenges, which are linked to the digitalization of trade, predate the advent of Blockchain. However, the development of blockchain use cases that span various stages of international trade, from trade finance to customs procedures, transportation and logistics renders the need for a multi-stakeholder approach on these issues even more critical.

Other international organizations are looking into technical and semantics interoperability issues. In June 2017, the ICC Banking Commission launched a working group composed of industry leaders from banking, fintech and corporate companies to establish a set of minimum standards to which fintech companies can adhere to help address the "digital island problem" (International Chamber of Commerce, 2017c). Work is also underway at the International Telecommunications Union (ITU) and the International Organization for Standardization (ISO). The ITU Telecommunication Standardization Sector established a Focus Group on Application of Distributed Ledger Technology in May 2017. The group will, among other things, develop a standardization roadmap for interoperable DLT-based services, taking into consideration the activities underway in the ITU and in other standards-developing organizations, forums and groups.[22] As for the ISO, it created a committee in 2016 (committee ISO/TC 307) to develop standards to "stimulate greater interoperability, speedier acceptance and enhanced innovation in [the] use and application" of blockchain technology. This committee, which counted 35 participating countries and 13 observers in July 2018, held its inaugural meeting in Sydney, Australia, in May 2017. Several working groups have been established to discuss issues related to use cases, governance, interoperability, security, privacy, identity and smart contracts, and to develop standards (Naden, 2017). Ten ISO standards are currently under development.

The stakes are high. Indeed, the development of incompatible systems would not only run counter to the whole purpose of blockchain technology, which aims at greater integration of processes in a transparent and dynamic manner, but it could also prove counterproductive because it would lock processes into technical silos, and failing to align the semantics would negate the benefits that Blockchain could bring. Addressing interoperability issues both at a technical and a semantic and data level is therefore crucial.

(c) Legal issues

The wide-scale deployment of Blockchain requires more than technology. It requires frameworks that not only ensure the interoperability of networks, but also clarify the legal status of blockchain transactions, and regulate responsibilities and the way data can be accessed and used. Without this regulatory layer, blockchain technology could well be confined to pilot projects.

Legal issues raised by the use of Blockchain are of two types: general issues such as the legal status of blockchain transactions and questions of jurisdiction; and specific issues linked to the use of Blockchain for particular cases. For some customs matters, for example, an authorization delivered by a particular entity may be required to automate certain processes through smart contracts. These specific issues depend on the nature of the blockchain application being developed and are not addressed in this section, but they need to be kept in mind by authorities and companies looking into blockchain uses.

(i) Legal validity of blockchain transactions

The legal status of blockchain transactions and smart contracts remains uncertain, not to mention that of financial instruments issued on a blockchain.[23] Blockchain transactions open classification issues (Werbach, 2018). How are activities that are legitimate, but that are not structured according to the legal requirements of the non-blockchain world, to be classified?[24] Does information stored on a blockchain representing ownership or the existence of an asset prove real ownership or the real existence of that asset? To what extent would a court recognize Blockchain as an immutable, tamper-proof source of truth (Cermeno, 2016)? Are smart contracts legal contracts? Are bonds and derivatives issued on a blockchain legally valid?

Some initiatives have been taken at the international level to try and clarify the legal status of such transactions and processes. On 13 July 2017, the UNCITRAL adopted the eagerly awaited Model Law on Electronic Transferable Records (United Nations Information Service, 2017). The Model Law enables the use of electronic transferable records and sets out the conditions that must be met if an electronic record is to be treated as a transferable document, i.e. a document that entitles the holder to claim fulfilment of the obligation indicated in the document – such as in the case of bills of lading, bills of exchange, promissory notes and warehouse receipts. The principle of neutrality embodied in the Model Law allows the use of all methods and technologies, including distributed ledgers, to be accommodated.

The adoption of the UNCITRAL Model Law on Electronic Transferable Records is an important development which, if transposed into national legislation, can open the way to the legal use of blockchain technology for international trade transactions. The Model Law usefully complements the UNCITRAL principles that guide electronic commerce. Pursuant to the principle of technology neutrality embodied in the Model Law on Electronic Commerce (1996, revised in 1998), the Model Law on Electronic Signatures (2001) and the Convention on the Use of Electronic Communications in International Contracts (2005), a data message stored on a blockchain is deemed to meet the paper-based requirements of writing and a signature, provided that it satisfies the respective conditions (Takahashi, 2017). The Model Law does not, however, cover cryptocurrencies. Separate legislation will be required to set out the conditions under which blockchain-based tokens representing securities (cryptosecurities) can be treated as securities.

UNCITRAL model laws, while important in terms of legislative guidance, do not, as such, have any legal bearing. They are only blueprints that countries can use as a basis to develop their own legislation.

Various governments are now working on legislation to recognize the legal validity of blockchain signatures, smart contracts and financial instruments issued on the blockchain. In 2017, at least eight US states worked on bills accepting or promoting the use of Bitcoin and blockchain technology, and a few have already passed these into law (Parker, 2017). A draft regulation legalizing blockchain signatures and smart contracts was introduced in early 2018 in Florida. Other examples include Malta – which passed bills into law in July 2018 to regulate distributed ledger technologies and virtual financial assets, with the goal of promoting Malta as a "blockchain island" (Alexandre, 2018) – and France, which has taken various initiatives to recognize financial instruments issued on blockchains. In 2016, France introduced legislative changes to recognize certain mini-bonds issued on blockchains, and in December 2017, it passed a new order to allow for the registration and the transfer of financial securities through distributed ledger technology.[25] Another interesting development is the ruling by China's Supreme Court, in September 2018, that evidence authenticated with Blockchain is binding in legal disputes (Huillet, 2018b).

Various proposals that are of direct relevance to Blockchain have also been submitted to the WTO in the context of the WTO Joint Statement on Electronic Commerce. They concern issues such as electronic authentication, the recognition of electronic documents and e-signatures, the establishment of a framework for electronic contracting, encryption, cybersecurity, e-payments and the protection of personal information.[26] As noted earlier, while Blockchain can help to digitalize trade, the move to paperless trade requires a conducive regulatory framework that recognizes the validity of e-signatures, e-documents and e-transactions, and that sets the legal parameters for the electronic exchange of data between relevant stakeholders, in particular government authorities (see Section 3.1(b)).

Some observers note, however, that, as the technology is still maturing, it may be too early to regulate it. They see a risk that early regulation could limit its further development and potential, and could fail to adequately regulate its use (R3 and Norton Rose Fulbright, 2017; Orcutt, 2018). This may be true at an experimental stage. Nevertheless, once the technology is ready for real-life implementation, clarifying the legal status of blockchain transactions will become essential, and regulation takes time to develop. Furthermore, timing is only one aspect of the problem. More important are issues of coordination and content. Because blockchain applications are decentralized and distributed, they often span several jurisdictions.

Lack of coordination and of common understanding on how best to regulate blockchain technology at an international level could well result in a spaghetti bowl of regulations that could ultimately be more harmful than the lack of regulation itself. The decentralized and potentially global nature of Blockchain requires a global approach to regulation, and hence appropriate governance frameworks (see Section 4.2(d)).

(ii) What applicable law and liability framework?

Both permissionless and permissioned blockchains raise issues of applicable jurisdiction, although in slightly different terms. Blockchains, whether permissionless or permissioned, can span several jurisdictions, which poses the question of which national law applies in the event of a dispute or fraud.

Potentially, one could argue that every transaction could fall under the jurisdiction of the location of each participant in the network. However, in the case of public blockchains, nodes can be located anywhere in the world, and the anonymous nature of the platform makes it extremely difficult, if not almost impossible, to identify the processing entity and to pinpoint the place where the contentious transaction is located. The problem is less acute in the case of permissioned blockchains, as participants are known, but the issue of the applicable jurisdiction remains key in the event of blockchains crossing several jurisdictional boundaries.

Likewise, the use of Blockchain raises issues related to the liability framework applicable to blockchain transactions should something go wrong, and the resolution mechanism in case of conflict, technical problems or unintentional action. In the absence of a central entity administering the platform, who is responsible for the functioning of distributed ledgers and the information contained therein in the event of a dispute or unintentional action having adverse consequences? And if a smart contract fails to work as expected, which party is liable?

Do these regulatory hurdles risk impeding the deployment of the technology on a large scale? In the context of permissioned blockchains, many issues related to jurisdiction and liability allow for a technical workaround. Depending on the actual case and the position of the stakeholder, one solution could be to have a “real”, conventional contract that would govern the parties’ relationship, covering both what the blockchain is supposed to do (e.g. allowing damages to be claimed in the case of a wrongful code in a smart contract), as well as formal legal aspects like jurisdiction or applicable law. This contract, which would be legally binding, would be stored on the blockchain, thereby ensuring that the latest version would be available and immutable, unless changes were agreed upon by the stakeholders (using the time-stamping function of the blockchain to check on latest version) (Deloitte, 2018). However, developing industry-specific rules that determine who has liability at each stage of a particular process may be needed in certain cases – e.g. in the case of letters of credit (see also Section 3.1(a)). In the case of permissionless blockchains, issues of jurisdiction and liability remain wide open.

Beyond the regulatory uncertainty surrounding the use of distributed ledgers, the deployment of Blockchain on a large scale could also be hindered by various standards and requirements imposed by national regulatory authorities, including data localization requirements and barriers to cross-border data flows.

(iii) Data localization and data privacy issues

The last few years have witnessed an intense debate over issues related to data localization, restrictions on cross-border data transfers and data privacy, with a growing number of countries adopting measures that impose requirements or restrictions on data flows.

According to the Information Technology and Innovation Foundation (ITIF), as of May 2017, 34 countries had enacted or proposed data localization requirements (Cory, 2017). Data localization requirements can take various forms. Data localization can be explicitly required by law or can be the result of a series of restrictions that make it *de facto* impossible to transfer data, such as local storage requirements, local processing of the data, or government approval to transfer data. Some countries prohibit all data transfers, while others target specific sectors or services. As for barriers to cross-border data flows, they typically involve restrictions on the transfer of personal data to jurisdictions deemed to provide a lower level of data protection, as well as limitations on information that governments consider "sensitive" (Cory, 2017).

Governments' motivations for putting in place such policies, which are increasingly raising concerns among the business community, which is wary of the implications for business activities, are diverse. Pursued objectives typically include addressing potential cybersecurity threats, promoting the local economy, ensuring access to data for the purposes of law enforcement, and protecting citizen's privacy.

To what extent are blockchain transactions likely to be affected by such policies?

As distributed ledgers, blockchain platforms are *de facto* relatively immune to data localization policies. Indeed, local storage requirements and local processing of data, which constitute the backbone of most data localization policies, are automatically met: one of the key principles of the blockchain technology is that all participants in the network have a local copy of the transactions and that every fully participating node must process every transaction. Each time a transaction is added to a blockchain, the digital ledger is updated on all of the nodes simultaneously. Therefore, the goal of ensuring that data is stored and processed locally is automatically met. Requirements that take the form of government approval to transfer data would, however, have an impact on the ability of potential participants in the countries concerned to participate in blockchain consortia that bring together actors from various jurisdictions.

As for data privacy issues, Blockchain is often presented as an opportunity or catalyst for greater personal data protection and new forms of identity management. The use of various cryptographic tools gives users control over their personal data, allowing them to manage and share their personal data only with trusted parties.[27]

One must here distinguish between public and consortium/private blockchains. A specific feature of public blockchains, such as Bitcoin, which is often emphasized, is the fact that they allow transactions between parties without any party having to disclose their identity to any other party or to the public. While today, we mostly do not control who processes our personal data and how, public blockchains make it possible for the data subject to remain anonymous or to use a pseudonym and to control how their data is used. However, whereas it is true that no personal information, such as names, addresses or telephone numbers, is captured in the corresponding transaction data entries of the blockchain, one study showed that it is nevertheless possible to trace the IP address and thereby to de-anonymize clients – although the problem is not inherent to the technology and could be addressed by fixing the technical design of the blockchain (Biryukov *et al.*, 2014).

While public blockchains enable the users themselves to implement the principle of "privacy by design" (Biryukov *et al.*, 2014) at an individual level, consortium/private blockchains provide for this principle at the platform level: privacy levels are determined by the management of the platform. In such platforms, participants are known and identified, but permissions to read and write some of the data added to the platform can be restricted to certain participants in order to protect confidentiality (see Section 2.3). What is clear is that entities using a blockchain-based platform have to ensure that the technical design of the platform meets the requirements of the relevant regulatory framework(s), including data protection laws.

The deployment of the technology could, however, be limited by the rights granted to individuals under national data protection regulations. Much has been said, for example, about the possible incompatibility between the European General Data Protection Regulation (GDPR), which entered into force on 25 May 2018, and Blockchain, leading some to ponder whether the GDPR might not ultimately "block blockchain" (Toth, 2018).

Indeed, two key provisions of the GDPR seem *a priori* incompatible with Blockchain, namely the "right to rectification" and the "right to be forgotten" – i.e. the right to rectify or obtain the erasure of personal data (Articles 16 and 17 of the GDPR). The immutable nature of blockchains makes it very difficult to update, erase, change or correct data. Some in the community argue that a possible solution is to keep personal data off the chain, with only its evidence (cryptographic hash*) exposed to the chain, thereby maintaining the integrity of the transaction while making it possible to erase the transaction itself (Deloitte, 2017; IBM, 2018). The deletion of the data stored externally would mean that the hash stored on the blockchain would point to a location which has been deleted. Others note, however, that hashed data qualifies as personal data under EU law (Finck, 2017).

It has also been argued that, while blockchains and the GDPR seem incompatible at a conceptual level, both pursue the same goal of giving individuals more control over their personal data, but through different mechanisms. Consideration could be given to whether the GDPR's underlying objectives could be achieved through means other than those originally envisaged (Finck, 2017). Interestingly, Blockchain's built-in tracking and auditability functions could help organizations comply more easily with another GDPR provision, regarding internal record-keeping requirements. While the GDPR has *a priori* no direct relevance to international trade, as most information contained in trade documents relates to companies, not individuals, it could have an impact on trade in specific situations, when the contact details of a person at a firm need to be given (e.g. for exports of dangerous goods). Ultimately, the need to find a compromise between ensuring legal protection of personal data and encouraging innovation is one issue that regulators may have to address, and that highlights the need for proper governance fora to be established.

(iv) Closing the gap between the world of law and the world of code

Although the relationship between the world of law and the world of code has evolved significantly following the advent of digital technologies, with the digitalization of law and the emergence of the "code is law" concept popularized by Lawrence Lessig (Lessig, 1999) (i.e. the notion that code sets the terms by which the behaviour of internet users is regulated), law remains difficult for machines to read but easy for humans to apprehend. Conversely, the codes used to programme machines and smart contracts are particularly obscure and complex for humans.

Closing the gap between the two, while not a precondition for the deployment of Blockchain, could be a powerful enabler for the use of smart contracts. Legislation and contracts are often written for a paper-based world, in a way that makes them difficult to use in digital contracts. A new approach to regulation is emerging that advocates the "codification of law" (De Filippi and Hassan, 2018). Various organizations and startups are investigating how law could be codified and made machine-readable to facilitate the transposition of contractual obligations into digital contract code. New Zealand recently carried out a project to explore how laws could be rewritten and laid out programmatically so that they can be analysed by a machine (Darabi, 2018), and several startups, such as Monax[28] and ContraxSuite,[29] are offering "legal engineering" services to help codify contractual obligations and make them machine-readable, in order to ease the writing of smart contracts.

While the move from "code is law" to "law is code" (i.e. law defined as a code) could allow for significant gains in efficiency and transparency and facilitate the use of smart contracts, the difficulty in transposing the flexibility of legal rules into a formalized language that can be interpreted and used by machines may also lead to greater rigidity in the implementation of rules (De Filippi and Hassan, 2018). Finding the right balance between greater efficiency through machine-readability and flexibility is essential.

(v) Legal identification of companies

When a transaction occurs, being able to properly identify counterparties is indispensable. Legal identification becomes more important, but also more challenging, in a world in which many trade and financial transactions are international and span a number of jurisdictions that may not apply the same standards, especially when transactions can take place in nanoseconds, like in the financial sector. The need for a consistent approach was highlighted by the 2008 financial crisis, which unveiled fundamental problems in existing systems for the identification of entities, leading the G20 to call for the creation of a global legal entity identifier (LEI)[30] – i.e. a global framework for the legal identification of the economic actors involved in financial transactions.[31]

While not a prerequisite for the implementation of blockchain applications, the existence of a global LEI would greatly facilitate the processing of blockchain-based transactions and allow the technology to be used in a more efficient way. Current efforts to design a global system are welcome, but greater international coordination may be required to avoid the development of differing systems. Indeed, the global LEI covers legal entities involved in financial transactions. In parallel, discussions are taking place at the WCO to develop a global trader identification number for traders. Ensuring consistency between these two approaches, or joining efforts to develop a common system, would bring clear benefits to entities involved in international trade transactions and would support the deployment of technologies such as Blockchain that have the potential to significantly improve trade processes. Conversely, the use of Blockchain could prove of interest in supporting efforts to develop global entity identification systems.

(d) Governance issues

While Blockchain is a promising technology, its large-scale deployment can only be realized if technical, interoperability and legal issues are addressed in a coordinated manner at the appropriate technical and political levels. Yet, for the moment, the world of Blockchain and cryptocurrencies is "the Wild West". A carefully thought-through governance system[32] that addresses standardization and legal and policy issues, while providing the flexibility to allow the technology to thrive, is needed.

For many, the multi-stakeholder approach that governs the internet provides an interesting model of governance. Internet governance relies on a series of "global governance networks" that bring together companies, civil society organizations, software developers, academics and governments. These networks, which operate by consensus, are of seven types (Tapscott and Tapscott, 2017):

1. Standards networks, which are non-state, non-profit organizations in charge of developing technical specifications and standards, such as the Internet Engineering Task Force (IETF), an open standards organization that develops and promotes voluntary internet standards.
2. Knowledge networks that conduct research and propose new ideas to help solve global problems, such as the Internet Research Task Force (IRTF).
3. Delivery networks, such as the International Corporation for Assigned Names and Numbers (ICANN), which is a public-private partnership that delivers internet domain names and is dedicated to preserving the operational stability of the internet.
4. Policy networks that inform the policy debate and support policy development, such as the Internet & Jurisdiction Policy Network, which facilitates transnational cooperation on cybersecurity, human rights, and other legal and economic policies.
5. Advocacy networks that seek to influence the agenda or policies of governments, corporations and other institutions, such as the Industrial Internet Consortium, which is a group of researchers, companies and public agencies that support the adoption of internet applications across various industries to accelerate the IoT.
6. Watchdog networks.
7. Networked institutions, such as the Internet Society, which defines itself as a "global cause-driven" organization dedicated to ensuring that the internet remains "open, globally connected and secure".[33] The Internet Society is governed by a board of trustees that includes representatives from business, academia and the not-for-profit sector. The Internet Governance Forum (IGF) is another networked institution whose establishment was formally announced by the United Nations Secretary-General in July 2006. The IGF is a forum for multi-stakeholder

dialogue on public policy issues related to internet governance, such as the internet's sustainability, robustness, security, stability and development.

Some groups and networks focused on Blockchain are starting to emerge, such as the Blockchain Research Institute[34] and the Blockchain Interoperability Alliance, an advocacy group that aims to develop globally accepted standards that would promote greater connectivity and interoperability between the disparate blockchain networks (Higgins, 2017a). Various international organizations are also putting in place committees and working groups to look into the technology, including the ICC, ISO, the ITU, UN/CEFACT and the WCO. In March 2017, the IMF launched a High Level Advisory Group on Fintech, composed of senior bank executives, blockchain companies, regulators and academics, to study the economic and regulatory implications of blockchain technology (IMF, 2017), and an ISO committee was created in 2016 to develop standards to "stimulate greater interoperability, speedier acceptance and enhanced innovation in [the] use and application" of blockchain technology. More recently, in February 2018, the European Commission announced the launch of an EU Blockchain Observatory and Forum. The EU Blockchain Observatory and Forum will be an open forum for blockchain technologists, innovators, citizens, industry stakeholders, public authorities, regulators and supervisors, to discuss and develop new ideas and directions. It will collect information, monitor and analyse trends, explore the socioeconomic potential of blockchains and how best to address challenges (European Commission, 2018).

However, a comprehensive ecosystem that brings together companies, civil society organizations, software developers, academics, governments and inter-governmental organizations in various settings to look into standardization and legal and policy issues is still missing. A lack of coordination at a supra-level between the various stakeholders could stifle the deployment of the technology.

It is worth considering whether there would be value in initiating a discussion on the practical and legal implications of Blockchain in relevant international organizations such as the WTO to help shed light on the potential benefits of the technology, as well as on its limitations and on the challenges that may arise if it becomes more widely deployed. As the various examples presented in this publication show, the private sector is advancing at full speed. Given the potentially significant impact that the technology could have on international trade transactions, it is important that regulators start thinking about ways to support the deployment of the technology.

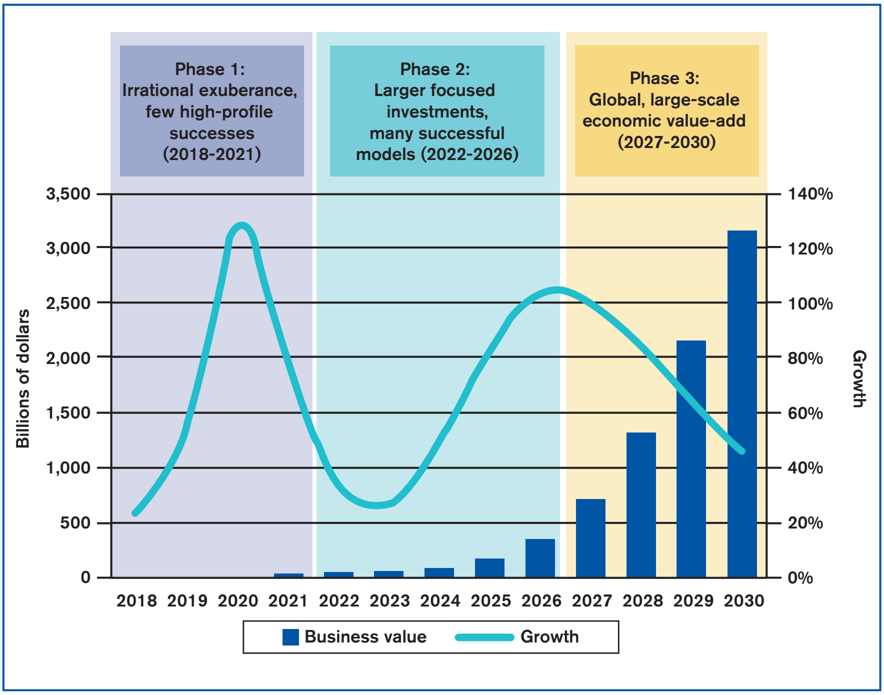
As this chapter showed, the potential benefits of Blockchain for international trade are multifaceted. Because it makes it easier to track products along the supply chain, Blockchain can help enhance trust and transparency in value chains. It can significantly reduce a number of trade costs, and open new opportunities for

MSMEs, in particular small producers from developing countries, to join global markets.

However, various challenges need to be addressed before the technology can be deployed widely and have a transformative impact, including scalability, interoperability and regulatory issues.

The challenges to overcome are up to the opportunities that the technology opens. Where the technology will eventually lead us is difficult to assess for the moment. We are, as Gartner (2018) notes, in a phase of "irrational exuberance, few high-profile successes" (see Figure 19). A few more years and many more proofs of concepts and pilot projects will probably be necessary before successful models emerge, and before the real potential of the technology and its tangible impact on international trade can be fully assessed. But given the transformational impact that the technology could have on global trade, understanding the practical and legal implications of Blockchain on international trade and striving to develop collective solutions to current challenges is key.

Figure 19 Blockchain Business Value Forecast



Source: Figure 3: Blockchain Business Value Forecast Highlights Three Phases of Development, in Gartner (2018).

Endnotes

1. See https://www.agridigital.io/

2. See https://www.provenance.org/case-studies/co-op

3. See http://www.carrefour.com/news/4-new-food-quality-commitments

4. See https://www.provenance.org/case-studies/martine-jarlgaard

5. Discussion with Walmart officials.

6. See https://www.provenance.org/tracking-tuna-on-the-blockchain

7. See https://www.provenance.org/case-studies/fairfood

8. See http://www.ics-shipping.org/shipping-facts/shipping-and-world-trade

9. National and international organizations having conducted surveys of firms focused on MSMEs include those undertaken by the International Trade Centre (ITC), the US International Trade Commission (USITC), the European Commission, the World Bank, the OECD and the WTO. For a recent synthesis of barriers faced by MSMEs, see WTO (2016c).

10. See https://www.fasttracktrade.co

11. See https://cambodia.oxfam.org/what-we-do-resilience/blockchain-livelihoods-organic-cambodian-rice-blocrice-project

12. See https://sustainabledevelopment.un.org/sdg9

13. See https://blockchain.info/de/charts/transactions-per-second?timespan=1year

14. See https://etherscan.io/chart/tx. Ethereum's block limit is accounted for differently than through pure block size – as is the case for Bitcoin. Each Ethereum transaction is assigned a fixed amount of "gas". "Gas" is the execution fee for every operation made on Ethereum. Its price is expressed in ether and is decided by the miners. Each Ethereum block has a "gas limit". The block gas limit is determined by algorithm and vote by miners, and differs from block to block. The "gas limit" for each block determines how many transactions fit the block. In theory, both Bitcoin and Ethereum have a transaction capacity over 1,000 transactions per second.

15. For a detailed and relatively non-technical presentation of proposed solutions, see https://hackernoon.com/blockchains-dont-scale-not-today-at-least-but-there-s-hope-2cb43946551a

16. See, for example, "Future of Blockchain: Will Hashgraph make Blockchain obsolete?", *TechStartup blog*, 14 March 2018. Available at: https://techstartups.com/2018/03/14/future-of-blockchain-will-hashgraph-make-blockchain-obsolete/ Accessed on 8 May 2018.

17. For a technical note on chain interoperability solutions, see Buterin (2016).

18. See https://sawtooth.hyperledger.org/docs/core/releases/1.0/introduction.html and https://www.hyperledger.org/projects/hyperledger-burrow

19. See https://www.hyperledger.org/projects/quilt. The Hyperledger Quilt project was developed to implement the inter-ledger payment standard developed by the World Wide Web Consortium (W3C).

20. See https://www.unece.org/?id=3133

21. See http://www.wcoomd.org/en/topics/facilitation/instrument-and-tools/tools/data-model.aspx

22. See https://www.itu.int/en/ITU-T/focusgroups/dlt/Pages/default.aspx

23. This study focuses on blockchain use cases, not on cryptocurrencies. One should note, however, that the legal status of cryptocurrencies also varies considerably from country to country. While some countries have explicitly allowed the use of Bitcoin, others have restricted or banned it. In a recent paper assessing the differences in cryptocurrency legality across national jurisdictions, Chohan (2017) notes that whilst most countries do not make the use of cryptocurrencies illegal, the exact status of cryptocurrencies remains undefined or changing in many of them. This diversity of legislative response "signals on one hand the perplexity of authorities as to the full possibilities of cryptocurrencies, and on the other hand a realization of the inadequate oversight and governance role those authorities would have in the disintermediated nature of cryptocurrency transactions" Chohan (2017). The decentralized nature of Blockchain makes authorities at best perplexed, and often worried, about their role and relevance in the process.

24. In 2015, for example, FinCEN, the financial crimes enforcement office of the United States, opened a civil law enforcement action against Ripple, accusing the startup of having failed to register as a regulated money services business. Cited in Werbach (2018).

25. See https://www.legifrance.gouv.fr/eli/ordonnance/2017/12/8/2017-1674/jo/texte

26. The Joint Initiative on E-commerce was launched on the margins of the eleventh WTO Ministerial Conference (MC11) in December 2017 by ministers representing 71 WTO members. In the statement, signatories agreed to initiate exploratory work together towards future WTO negotiations on trade-related aspects of electronic commerce. See in particular the proposals submitted by Brazil (WTO official document number JOB/GC/176), the European Union (WTO official document number JOB/GC/188), Japan (WTO official document numbers JOB/GC/177 and 180), New Zealand (WTO official document number JOB/GC/175), the Russian Federation (WTO official document number JOB/GC/181), Singapore (WTO official document number JOB/GC/179) and the United States (JOB/GC/178) (as of mid-April 2018).

27. See Sullivan and Burger (2017). For an overview, see also https://blockchainhub.net/blog/blog/decentralized-identity-blockchain/

28. See https://monax.io

29. See https://contraxsuite.com

30. For a presentation of the global legal entity identifier, see https://www.gleif.org/en/about-lei/introducing-the-legal-entity-identifier-lei

31. "We support the creation of a global legal entity identifier (LEI) which uniquely identifies parties to financial transactions. We call on the FSB to take the lead in helping coordinate work among the regulatory community to prepare recommendations for the appropriate governance framework, representing the public interest, for such a global LEI by our next Summit." Declaration of the 2011 G20 Cannes Summit, http://www.g20.utoronto.ca/2011/2011-cannes-declaration-111104-en.html

32. Some developers prefer the word “stewardship” because they feel that the term “governance” conveys the impression that something is going wrong and needs to be fixed.

33. See https://www.internetsociety.org/

34. See https://www.blockchainresearchinstitute.org/

5 Conclusion

The world as we know it has been shaped by technological innovations. A new technology, Blockchain – a distributed ledger technology – has been greeted by many with enthusiasm and excitement as the next big game-changer. Blockchain, which allows digital records and information to be shared in a secure, transparent and immutable manner without relying on a single trusted third party, offers interesting promises. It could empower individuals and companies around the globe to make transactions more efficiently, economically and quickly, while retaining a high level of security. It could have a significant impact on the way trade operations are conducted, from financial to physical cross-border trade transactions, reducing processing, verification, tracking, coordination and transport costs by streamlining and digitalizing processes that involve multiple stakeholders and have, until now, remained highly dependent on paper. It could reduce fraud, improve the administration of IP rights, enhance traceability and trust in value chains, and open new opportunities for small companies.

Previous technological innovations – from steam to electricity, and more recently the internet – have had profound impacts on the organization of production and communication. Blockchain has the potential to impact transactions. It could be to transactions what the internet was to communication. Sometimes called the "internet of value", Blockchain is above all the "internet of transactions". By breaking the various silos that currently exist between the many parties involved in cross-border trade transactions, Blockchain could bring trade globalization to another level.

However, Blockchain is not suited to all situations, nor is it a panacea for all problems. The technology works best in circumstances where multiple parties are involved in transactions that require trust and transparency. While pertinent in many situations, the use of Blockchain may create barriers if it is used for transactions that do not require high levels of reliability. In addition, setting up a blockchain requires significant investment and coordination efforts, as well as substantial changes to existing systems and culture. It is critical to weigh up the trade-offs carefully.

More importantly, the technology is still maturing, and many challenges, including technical, interoperability and legal issues, need to be addressed before the technology can be used to its full potential. In particular, technical solutions need to be developed to address the “digital island problem” and ensure that blockchains can speak to each other, and rules need to be drafted to clarify applicable laws and regulate responsibilities. Without this regulatory layer, Blockchain will likely be confined to proofs of concept and pilot projects.

Where the blockchain adventure will ultimately lead us is difficult to project. Are we likely to witness a complete overhaul of our economies because of distributed ledgers in the near to medium term? Probably not. A hybrid approach, in which distributed ledgers complement existing systems, is more likely. The technology itself is still evolving and could look somewhat different in a few years. New “superior” distributed ledger technologies are already emerging that are quicker, more secure and less energy-intensive than the original blockchain. Whether the future of distributed ledger technology is Blockchain as originally developed, or another higher performing distributed ledger technology, one thing is clear: the technology is worth investigating, and if this technology is to be given the opportunity to realize its full potential, collective solutions that address key existing challenges, while providing the flexibility necessary for the technology to thrive, are needed.

Given the potential of Blockchain, companies, civil society organizations, software developers, academics, governments and intergovernmental organizations should work hand-in-hand to assess the practical and legal implications of the technology and to develop collective solutions to existing challenges. This is particularly true when it comes to international trade. Blockchain could make international trade smarter, but smart trade requires smart standardization – and smart standardization can only happen through cooperation. If we succeed in creating an ecosystem conducive to the wider development of Blockchain, international trade could well look radically different in 10 to 15 years.

Annex – Blockchain for tech fans

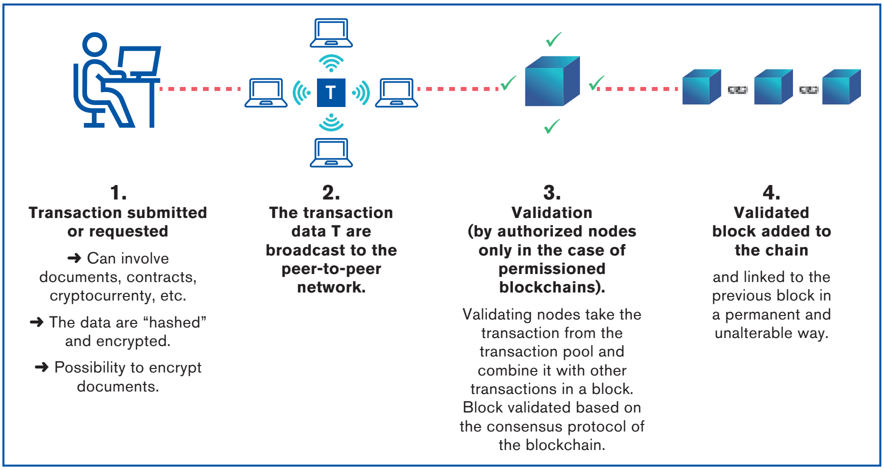
How does Blockchain work?

Blockchain is only one type of distributed ledger technology (DLT). The technology is evolving rapidly and new models of transaction flow are being developed to enhance speed and security and to lower energy consumption, which are moving away from the concept of "blocks", and even from both the concepts of "block" and "chain". "New kids not on the blocks" include IOTA, Ripple and Hashgraph. Although these new models are not blockchains *per se*, the term "blockchain" is commonly used to refer to distributed ledger technology in general and to the phenomenon surrounding it. Figure A.1 illustrates the typical steps involved in blockchain transactions. While this section distinguishes between Blockchain and other distributed ledger technologies in order to explain the various steps involved and clarify the concepts, the rest of this publication uses the term "blockchain" to refer more generally to DLT.

Step 1:

The sender submits or requests a transaction. A blockchain/DLT transaction can involve any type of asset – digital (e.g. cryptocurrency, digital painting), tangible (e.g. a transfer of property or funds, or an exchange of documents such as a customs

Figure A.1 **Typical steps involved in a blockchain transaction**



Source: Author.

declaration or certificates of origin), or intangible (e.g. provision of a service) – which is exchanged between participants in the network. It can involve documents, contracts, cryptocurrencies or any other type of asset.

When a transaction is submitted, various processes take place to guarantee the security of the transaction:

- First, the sender generates a key pair, including a public key and a private key. These keys are mathematically related. The public key is made available to the receiver.
- The sender then hashes* the data to be sent, i.e. converts it into a new digital string of a predefined and fixed length using a mathematical function – a hash. Hashing ensures data integrity and prevents forgery.[1] The resulting hash value is encrypted* using the sender's private key. The encrypted hash forms the digital signature* of the data, i.e. the digital fingerprint of an electronic record. It guarantees that the message was created and sent by the claimed sender and was not altered in transit. The sender cannot deny having sent the message.
- The sender then transmits the digital signature together with the plaintext data to participants in the peer-to-peer network – the receivers.

If the sender does not wish other participants in the network to see the message itself, i.e. the plaintext data contained in the documents submitted, (s)he can choose to encrypt the message.

Step 2:

Once the digital signature has been generated and the message has been hashed and encrypted, they are transmitted to participants in the peer-to-peer network – the receivers, also called nodes* – and added to an unvalidated transaction pool.

Step 3: Validation

The validation process differs depending on the type of DLT and the consensus protocol specific to the blockchain or DLT.

Receivers – in the case of permissioned blockchains, authorized nodes – validate the transaction using the sender's public key to decrypt the transaction. A successful decryption confirms that the transaction originates from the claimed sender. The receiver can then verify the integrity of the data by comparing the decrypted hash value sent by the sender with the hash value that (s)he computed when applying the same hash algorithm on the plain data transmitted by the sender. If both hash values coincide, the receiver has the guarantee that the data were not altered in transit. The transaction can then thus be validated.

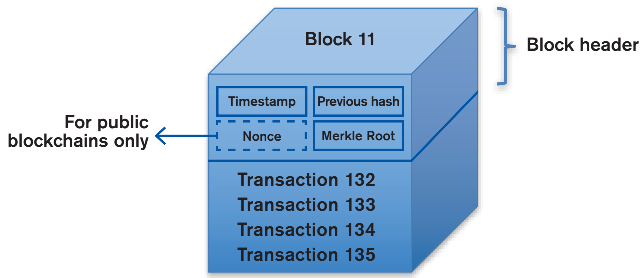
The chain is then updated via the "consensus protocol". Consensus protocols ensure a common, unambiguous ordering of transactions and blocks, and guarantee the integrity and consistency of the blockchain across geographically distributed nodes (see below for a presentation of the most frequently used consensus protocols).

In the case of blockchain technology, validated transactions are first combined with other transactions to create a block that is then validated[2] based on the consensus protocol of the blockchain. If validated, the new block is linked to the chain as the "true state of the ledger". Each block contains several transactions (see Figure A.2). A block is composed of a block header and of records of transactions. The block header contains the following elements:

- The block number.
- The current time-stamp* that captures the date and time to ensure a record of the chronological sequence.
- The hash of the previous block – also referred to as a hash pointer – to link the blocks together.
- The hash of what is called the "Merkle Root"*, which allows easy comparison and verification of large data sets of transactions without the need to include the complete set of data of every transaction in the block header, thereby making the size of blocks more manageable.

In addition, for public blockchains such as Bitcoin, the block header includes the "nonce"* – i.e. a random sequence of numbers that the miners* have to find in order to validate the block and the difficulty target associated with it.

Figure A.2 Composition of a block



Source: Author.

Step 4:

Once a block is validated or, in the case of DLTs that do not combine transactions in blocks, once the transaction has been validated, it is time-stamped and linked to the preceding blocks/transactions with a "hash pointer" – a hash of the previous block/transaction – thereby forming a linear chronological chain of blocks/transactions.

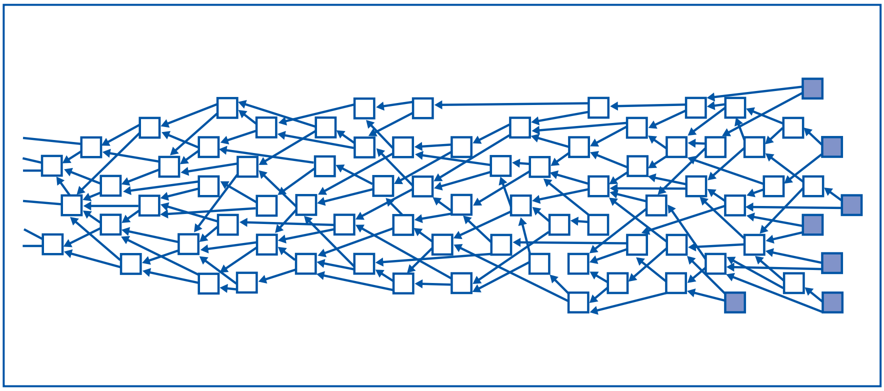
The transactions are then confirmed and the block/transaction cannot be altered or removed – thus, the block/transaction is immutable. Each time a block/transaction is added to the chain, the digital ledger is updated on all the participating nodes. The systematic update of the ledger on all the nodes is an efficient way to ensure that there are no divergent versions of the ledger in the participating nodes.

Other distributed ledger technologies follow a different process. In IOTA, for example, transactions are not grouped into blocks and each transaction is linked to two previous transactions as part of the validation process to form a "Tangle" (see Figure A.3).

What makes Blockchain so different?

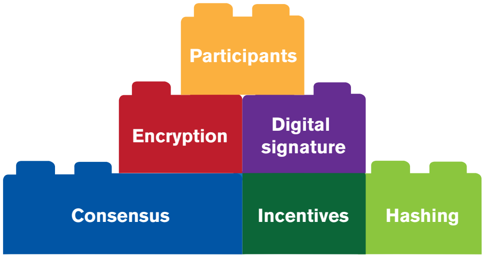
While the various techniques described above – digital signatures, hashing, encryption, Merkle trees – have been the mainstay of information security for several decades, their resistance to malicious attacks has constantly been challenged, leading to a neverending cat-and-mouse game between hackers and cybersecurity specialists to develop and crack codes. Improvements were made, with no major breakthroughs until the creation of blockchain technology.

Figure A.3 **The Tangle**



Source: IOTA.[3]

Figure A.4 Blockchain's "building blocks"



Source: Author.

The main breakthrough feature of Blockchain was that it dovetailed the properties of all these technologies and introduced minor, meticulously thought through alterations in the protocols to deliver a higher level of security. Like Lego blocks, different bricks can be taken out of the bag and put together in different ways to create distinctive features (see Figure A.4) (see Lewis, 2015).

Blockchain's immutability – the fact that records cannot easily be changed or deleted after validation – is achieved by leveraging the various properties of hash algorithms and hash pointers. However, instead of just containing the address of the previous block (as in classical protocols), hash pointers in the blockchain contain the hash of the data inside the previous block. As a result, unlike traditional distributed databases, a change in data in one block will cause all the previous blocks to change. This one small tweak is at the heart of Blockchain's immutability. It is what makes Blockchain extremely reliable.

In addition, Blockchain replaces trusted time-stamping with a distributed and tamper-proof alternative. When a block is validated and added to the chain, time-stamping provides a secure proof of the exact time at which those data were added and existed.

Some commonly used consensus protocols

Proof of Work (PoW – Bitcoin)

This consensus protocol is used by Bitcoin and several other public cryptocurrency platforms. Proof of Work requires that the participants that validate blocks – in other words the validators, also called "miners" – show that they have invested significant computing power to solve a hard cryptographic puzzle (a mathematical problem based on the consensus rule). This process is called "mining"*. Miners compete with each other to validate a block and add it to the blockchain. They do this by churning out enough random guesses on their computer to solve the cryptographic puzzle. Miners have a financial incentive to process as many transactions as quickly as possible. Once the first miner has found the solution, it provides the other nodes with the solution. The solution is then verified and consensus is reached. The miner who validates the new block is rewarded with Bitcoins. The level of difficulty of the mathematical problem increases as blocks are mined to ensure that only one block can be mined every 10 minutes (Kravisz, 2013).

Proof of Stake (PoS – Nxt)

PoS algorithms are meant to overcome the disadvantage of PoW in terms of energy consumption. PoS replaces the mining operation with rewards in proportion to the amount of the validators' "stake" in the network (ownership or assets of cryptocurrency in the network). This arguably enhances network security. PoS is best used by organizations that have limited computing power.

Proof of Elapsed Time (PoET – Hyperledger Sawtooth)

Used by Hyperledger Sawtooth, PoET uses a random leader election model, or lottery-based election, with the protocol randomly selecting the next leader to finalize the block.

Practical Byzantine Fault Tolerance algorithm (PBFT – Hyperledger Iroha)*

Hyperledger Iroha, developed by the Linux Foundation, uses PBFT. In a PBFT system, each node distributes a public key, and messages are signed by each node. When enough identical responses have been achieved, the transaction is deemed valid. After PBFT, several Byzantine Fault Tolerance protocols were developed to improve robustness and performance.

Federated Byzantine Agreement (Ripple and Stellar)

Ripple and Stellar use a federated voting process that is a variant of the Byzantine Fault Tolerance consensus model.

Endnotes

1. Various properties make hashing an interesting tool to ensure data integrity and prevent forgery:

1. A given set of data (input) will always give the same hash (output). However, a small change in the input – such as a single change in letter cases or in punctuation – will completely and drastically change the resulting hash. This is crucial when it comes to verifying the integrity of data. If a piece of information produces different hashes for the sender and the receiver, this means that it has been tampered with during transit. Likewise, if a record at rest changes hash between the time of its creation and the time of verification, this indicates that it has been subject to modification during the interval. This makes it useful to immediately detect forgery when it occurs.
2. It is infeasible to determine the original input on the basis of its hash value. The probability to "guess" it is so low that it requires a daunting amount of computational power.
3. Comparing an output with an input is very rapid, which is very useful when it comes to digesting big data files and in cases where responsiveness is required – e.g. in user's identity verification processes; when users type their password to access a service, the system immediately hashes the typed password and compares it to the stored hash.
4. Hash functions are said to be "puzzle-friendly": if an output is obtained by combining two sets of input, it is nearly impossible to identify the value of one of them if you already know the second.
5. Hash functions are "collision-resistant": the likelihood that two different inputs would randomly give the same output is extremely limited, which is another aspect that contributes to data integrity.

2. In the case of the proof-of-work protocol used, for example, by Bitcoin, the term used is that the block is "mined".

3. See https://iota.readme.io/docs/what-is-iota

Glossary

Asymmetric key algorithms

One of the two types of algorithms used in encryption.* Asymmetric key algorithms use different keys to encrypt and decrypt the information and fall under the category of public-key cryptography. This type of encryption involves two keys that work in a paired fashion: a public key that is accessible to third parties, and a private key that is kept secret by the generator of the pair. The use of different keys makes this type of cryptography more convenient to implement than private-key cryptography, but increases the risk of malicious attacks. To mitigate this risk, an additional layer of security is provided by the introduction of security certificates, which are digital certificates that link a public key to a particular entity or individual, delivered by trusted certificate authorities.

Blockchain

A blockchain is a time-stamped and distributed digital record of transactions (or ledger) that is secured using various cryptographic techniques. It is a continuously growing list of records, called "blocks", which are "chained" to each other using cryptographic tools. Blockchain is the technology underpinning Bitcoin. The term is often used interchangeably with distributed ledger technology. Correctly speaking, however, blockchain technology is one type of distributed ledger technology.

Byzantine Fault

Byzantine faults or failures can occur because of software bugs or when a node is compromised, causing nodes to behave erratically. This type of fault was identified by Lamport *et al.* (1982) as the Byzantine General's Problem:

> "A group of generals of the Byzantine army camped with their troops around an enemy city. Communicating only by messenger, the generals must agree upon a common battle plan. However, one or more of them may be traitors who will try to confuse the others. The problem is to find an algorithm to ensure that the

loyal generals will reach agreement. It is shown that, using only oral messages, this problem is solvable if and only if more than two-thirds of the generals are loyal; so a single traitor can confound two loyal generals. With unforgeable written messages, the problem is solvable for any number of generals and possible traitors" (Lamport *et al.*, 1982).

Consensus protocol

A protocol through which transactions are validated and blocks signed into the blockchain. The consensus protocol used depends on the type of distributed ledger and the level of trust and control required by the application.

Consensus protocols ensure a common, unambiguous ordering of transactions and blocks, and guarantee the integrity and consistency of the blockchain across geographically distributed nodes*.

Cryptocurrency

A cryptocurrency is a digital currency that uses cryptography for security. The most well-known cryptocurrency is Bitcoin.

Cryptography

Cryptography is the process of communicating securely in an insecure environment. It is the science that constructs and analyses the protocols used to implement information security, such as data privacy and integrity, and authentication. These features have become increasingly important within modern communication, and are key aspects of the discussions that take place in global trade regulatory fora – including the WTO – in relation to e-commerce and the dematerialization of cross-border trade procedures.

The word "cryptography" is often used interchangeably with the term "encryption." However, encryption is only one type of cryptographic technique, along with hashing and digital signatures.

Decentralized autonomous organization (DAO)

A decentralized autonomous organization (DAO) is an organization that is run autonomously through rules encoded in smart contracts. For more information, see: https://blockchainhub.net/dao-decentralized-autonomous-organization/

Digital signature

A digital signature is the digital fingerprint of an electronic record. When data are transmitted between a sender and a receiver, the use of digital signatures guarantees that the message was created and sent by the claimed sender (authentication), and that the message was not altered in transit (data integrity). The sender cannot deny having sent the message (non-repudiation).

Distributed ledger

A distributed ledger is a digital ledger – a list, spreadsheet or database – that is shared among nodes in a distributed network. The term is often used interchangeably with “blockchain”. Correctly speaking, however, a blockchain is only one type of distributed ledger.

Encryption

Encryption is a cryptographic technique that applies a mathematical function (often referred to as an algorithm) to make information hidden or secret. This process converts readable information (plaintext) into an illegible random sequence of characters (cyphertext). Encryption is a two-way process. Encrypted data can be decrypted using a code or key. Encryption contributes to data privacy (confidentiality) as it protects data in transit and at rest from access by unauthorized users through the use of the keys as a means of authenticating users. However, the inherent reversibility of the encryption process makes it insufficient by itself as a guarantee of information security, which is why more secure protocols such as Blockchain use encryption in combination with other cryptographic techniques such as hashing.

Encryption consists of two types of algorithms: symmetric key algorithms* and asymmetric key algorithms.*

Ethereum

Ethereum is the second largest public blockchain after Bitcoin. Ethereum’s quantum leap lies in the concept of smart contracts, i.e. computer programmes that self-execute the terms of a contract when specific conditions are met.

Fiat currency

A fiat currency is a currency that a government has declared to be legal tender, but that is not backed by a physical commodity such as gold or silver.

Hashing

Hashing is a cryptographic technique that applies a mathematical function (hash algorithm) to convert data of an arbitrary size into a new digital string of a predefined and fixed length – a hash (see the example below and Prpic, 2017).

Example of hashing

INPUT	HASH
Hi	639EFCD08ABB273B1619E82E78C29A7DF02C1051B1820E99FC395DCAA3326B8
Welcome	53A53FC9E2A03F9B6E66D84BA701574CD9CF5F01FB498C41731881BCDC68A7C8

Source: https://blockgeeks.com/guides/what-is-hashing/

Hashing has several properties that make it an interesting tool to ensure data integrity and prevent forgery:

- A set of data (input) will always give the same hash (output). This is important when it comes to verifying the integrity of data. If a piece of information produces different hashes for the sender and the receiver, this means that it has been tampered with during transit.
- Hashing is often referred to as "one-way encryption" because it is extremely difficult to determine the original input from its hash value. The probability of "guessing" it would require a daunting amount of computational power.
- Hash functions are very efficient: computing an output from an input is very rapid.
- Hash functions are "puzzle-friendly": if an output is obtained by combining two sets of input (concatenated), it is nearly impossible to identify the value of one of them if the second is already known.
- Hash functions are "collision-resistant": the likelihood that two different inputs would randomly give the same outputs is extremely limited.

Hyperledger Fabric

Hyperledger is an open-source collaborative effort created to act as a foundation for developing blockchain-based products, solutions and applications for use by private enterprises. It is a global collaboration, hosted by The Linux Foundation, including leaders in finance, banking, IoT, supply chains, manufacturing and technology.

Merkle Root and Merkle Tree

The Merkle Root is one element of the Merkle Tree, a hash-based data structure – or hash tree – which is composed of leaves and branches as follows:

- Each leaf represents the hashed value of a transaction.
- Two leaves are then chained ("concatenated") and hashed to form a branch.
- Then two branches are "concatenated" and hashed to form another branch.

This process of re-hashing the branches is performed until the top of the tree – called the "root hash " – is reached.

By organizing the data following this structure, the Merkle trees take large amounts of data and make them more manageable to process. The use of the "Merkle Root" in the block header makes it possible to easily compare and verify large data sets of transactions without having to include the complete set of data of every transaction in the block header, while still providing a way to verify the entire blockchain on every transaction.

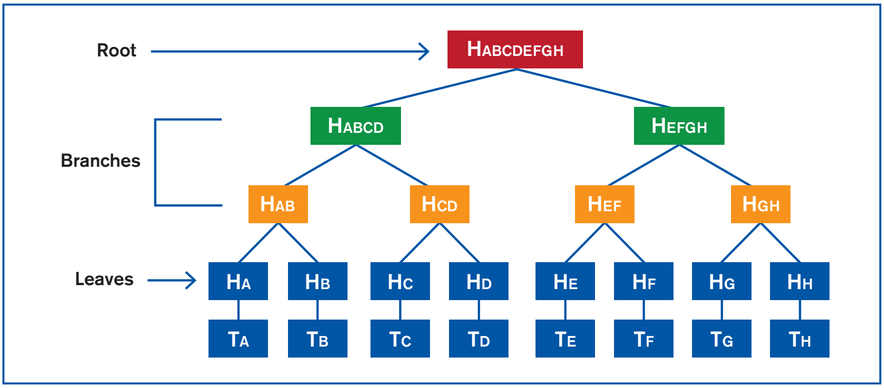
To compare two replicas of data sets (which can be of huge size), there is therefore no need to check all the data elements in both sets, but rather the difference between their two hash trees.

Furthermore, to compare two hash trees, one only needs to compare the root nodes of those trees. This results in much easier and more efficient data integrity and consistency verification.

If the two root nodes being compared are equal, then both the data and their recording order in the tree are valid. If not, then the trees contain inconsistent data records. In this case, tracing the source of inconsistency is also facilitated by the branched structure. To locate the origin of the difference between two trees, it suffices to go through them from top to bottom to find the nodes and then the leaves with different hashes.

The Merkle Tree structure significantly reduces the size needed to perform consistency and data verification, as well as data synchronization in peer-to-peer networks and distributed ledgers. File-sharing systems such as Google Drive and Dropbox are two applications that use Merkle Tree features: changes are detected by comparing the root, branch and leave nodes, and only data that need to be synchronized are transferred between the source and the destination.

Flowchart of a Merkle Tree



Source: Author.

Notes: “T” designates a transaction, and “H” a hash. Blocks contain several hundreds of transactions.

Miner

Someone who performs mining (see below).

Mining

Mining, in the context of blockchain technology, is the process by which transactions are verified and added to a public blockchain – the most well-known of which is Bitcoin. It is also the means through which new bitcoins are released. Mining involves solving a difficult mathematical puzzle. The “miner” who first solves the puzzle gets to place the next block on the blockchain and to claim the rewards. Rewards, which are meant to incentivize mining, consist of both transaction fees associated with the transactions placed in the block and newly released bitcoins. Anyone with the appropriate means (internet access and suitable hardware) can participate in mining.

Node

A node is a computer connected to the network. Each node keeps a copy of the data added to the blockchain.

Nonce

A random sequence of numbers that miners have to find in order to validate the block of a public blockchain and the difficulty target associated with it. Nonces are one of the elements included in the block header of public blockchains.

Blocks of private blockchains do not have nonces.

Open source

Open-source software is software with a source code that anyone can inspect, modify and improve.

Oracle

Blockchains cannot access data outside their network. An oracle is a data feed – provided by a third-party service provider – designed for use in smart contracts on the blockchain, which provides external data and triggers smart contract execution when pre-defined conditions are met. Such conditions could be any data, such as the temperature, payment completion, price fluctuations, etc. Oracles are the only way for smart contracts to interact with data outside of the blockchain environment and are, therefore crucially important.

QR code

A QR code is a machine-readable code consisting of an array of black and white squares, typically used for storing URLs or other information and which can be read by the camera on a smartphone.

Shard/sharding

Sharding means partitioning a very large database into smaller, faster, more easily managed parts called data shards. The word “shard” means a small part of a whole.

Single point of failure

An element or part of a system that, if it fails, will disable the entire system.

Smart contract

Smart contracts are computer programmes that self-execute when certain conditions are met (based on the *if… then…* logic – i.e., if the goods are unloaded at port of X, then the funds are transferred). They state the obligations of each party to the "contract", as well as the benefits and penalties that may be due to either party in different circumstances.

Symmetric key algorithms

One of the two types of algorithms used in encryption.* Symmetric key algorithms use the same key to encrypt and decrypt the text. They fall under what is called private-key cryptography.

Time-stamping

Time-stamping is the operation of using digital time-stamps (data representing date and time) to ensure that the chronological sequence of electronic events (e.g. creating or modifying a data file, submission or receipt of a transaction, etc.) is recorded. Each block on a blockchain contains a unique time-stamp.

Time-stamping is used for multiple purposes, such as computer security, network and database management, and as a proof of timely discharge of obligations among legally (contractually) bound parties in a given transaction. Multiple time-stamping protocols exist; their implementation depends on the outcome desired.

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Abbreviations

ADB	Asian Development Bank
AEO	authorized economic operator
API	application programming interface
ASEAN	Association of Southeast Asian Nations
ASYCUDA	UNCTAD Automated System for Customs Data
B2G	business-to-government
BPO	bank payments obligation
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
DLT	distributed ledger technology
DAO	decentralized autonomous organization
eCO	electronic certificate of origin
EU	European Union
EUIPO	European Union Intellectual Property Office
EUR	Euros
FAO	Food and Agriculture Organization of the United Nations
fintech	financial technology
FSB	Financial Stability Board
G2G	government-to-government
GATS	General Agreement on Trade in Services
GATT	General Agreement on Tariffs and Trade
GDP	gross domestic product
GDPR	European Union General Data Protection Regulation
GPA	Agreement on Government Procurement
ICC	International Chamber of Commerce
IoT	Internet of Things

IPPC	International Plant Protection Convention
ISO	International Organization for Standardization
IT	information technology
ITC	International Trade Centre
ITU	International Telecommunications Union
KWh	kilowatt-hours
KYC	"know-your-customer"
LDCs	least-developed countries
LEI	legal entity identifier
MSMEs	micro, small and medium-sized enterprises
MRA	mutual recognition agreement
OIE	World Organisation for Animal Health
OECD	Organisation for Economic Co-operation and Development
QR code	Quick Response code
STDF	Standards and Trade Development Facility
SWIFT	Society for Worldwide Interbank Financial Telecommunication
TFA	Trade Facilitation Agreement
TRIPS	Trade-Related Aspects of Intellectual Property Rights
UN/CEFACT	United Nations Centre for Trade Facilitation and Electronic Business
UNCTAD	United Nations Conference on Trade and Development
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
URBPO	Uniform Rules for BPO
US$	United States dollars
USITC	United States International Trade Commission
WCO	World Customs Organization
WHO	World Health Organization
WIPO	World Intellectual Property Organization
WTO	World Trade Organization

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Can Blockchain revolutionize international trade?

Trade has always been shaped by technological innovation. In recent times, a new technology, Blockchain, has been greeted by many as the next big game-changer. Can Blockchain revolutionize international trade?

This publication seeks to demystify the Blockchain phenomenon by providing a basic explanation of the technology. It analyses the relevance of this technology for international trade by reviewing how it is currently used or can be used in the various areas covered by WTO rules. In doing so, it provides an insight into the extent to which this technology could affect cross-border trade in goods and services, and intellectual property rights. It discusses the potential of Blockchain for reducing trade costs and enhancing supply chain transparency as well as the opportunities it provides for small-scale producers and companies. Finally, it reviews various challenges that must be addressed before the technology can be used on a wide scale and have a significant impact on international trade.

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