Blockchain for supply chains and international trade

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Blockchain for supply chains and international trade

Report on key features, impacts and policy options

This study provides an analysis of blockchain technology in the context of international trade. It analyses the potential impacts of blockchain development and applications in eight use cases for supply chains and international trade. It also provides an analysis of the current legislative framework and existing initiatives.

Based on this analysis, and following a broad consultation of relevant organisations, the study identifies several challenges in international trade documentation and processes, and presents a range of policy options for the European Parliament.

AUTHORS

This study was written by Bertrand Copigneaux, Nikita Vlasov and Emarildo Bani of IDATE DigiWorld, Nikolay Tcholtchev and Philipp Lämmel of Fraunhofer Institute for Open Communication Systems, Michael Fuenfzig, Simone Snoeijenbos and Michael Flickenschild from Ecorys, and Martina Piantoni and Simona Frazzani from Grimaldi Studio Legale at the request of the Panel for the Future of Science and Technology (STOA) and managed by the Scientific Foresight Unit, within the Directorate-General for Parliamentary Research Services (EPRS) of the Secretariat of the European Parliament.

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Philip Boucher, Scientific Foresight Unit (STOA)

To contact the publisher, please e-mail stoa@ep.europa.eu

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Executive summary

This document is the final deliverable of the 'Blockchain for supply chains and international trade' study commissioned by the European Parliament. It presents the complete results of the study, including policy options.

The report is subdivided in three parts, corresponding to the three phases of the study. The study methodology and process are set out in Annex 1.

- Part 1 (Sections 1 to 3) presents the key features of blockchain and the potential use cases in international trade.
- Part 2 (Section 4) presents an analysis of the potential impact of the development of blockchains in eight selected international trade cases studies. For each of them, the analysis is conducted in terms of trade as well as economic development, social perspective, technical and security maturity, environmental impact, data protection and transparency.
- Part 3 (Sections 5 to 8) presents the conclusions of the study and sets out key challenges and policy options.

Blockchain: a tool to promote cooperation

Blockchains comprise several data storage technologies. A diverse range of implementation types and variants exist (as set out in Section 1). They offer secure, robust, authenticated storage that is resistant to modification. Their most distinctive feature is their decentralised control. No single actor has full control of the infrastructure, which is controlled by consensus rules.

The core value proposition of blockchains is their ability to provide an infrastructure that is neutral, in the sense that the control of the technical infrastructure is shared among the stakeholders. This is particularly suitable for ecosystems in which participants need to cooperate while retaining potentially conflicting or competing interests. This applies rather well to international trade processes that involve numerous actors in complex relationships across various regulatory frameworks. It can be seen as a tool to promote cooperation and trust.

Potential applications in international trade

The use of blockchain in international trade is considered in several use cases, in various areas of the overall trade process:

- Commercial transactions can be modified, with fully decentralised blockchain-based marketplaces, or through the use of blockchain to register and follow commercial transactions.
- Trade finance presents several opportunities for blockchain use, from letters of credit to open-account trading and cross-border payments.
- Blockchains could also be used as an infrastructure to digitalise exchanges related to customs duties, as well as other trade-related administrative processes (sanitary certificates, conformity certificates, import and export licences), or even in government to government exchanges.
- In logistics, blockchain initiatives have been launched to streamline and digitalise exchanges of information along the supply chain. Additionally there are some blockchain implementations for maritime insurance.
- Blockchains can also be used to add another level of tracking, traceability and transparency to trade, which could be useful for enforcing trademarks, property rights and regulations, and for providing the end consumer with additional information.

Strong expectations exist around the use of blockchain in international trade as it is expected to decrease costs and delays, optimise efficiency and help to reduce fraud and litigation. However some of these expectations are not specific to blockchain, but rather derive from the digitalisation of trade processes.

While there are many potential uses of blockchain in supply chain management and international trade processes, the present study focused on eight specific use cases:

- decentralised marketplaces;
- blockchain-based letters of credit;
- cross-border payment systems;
- maritime insurance;
- tracking systems for shipping documents and supply chain events;
- blockchain-based e-certificate of origin;
- proof of authenticity of luxury products;
- tracking of ethical sourcing in the food industry.

A sound technological option

The analysis of these use cases shows that they have all achieved an initial, credible level of technical proof of concept. Overall, this shows the viability of blockchain as a technology that could impact trade. In some cases advanced proof of concept and early commercial solutions have been developed, and no major technological barriers exist for the use of permissioned blockchains in trade.

The overall security of blockchain-based solutions can be considered strong. They rely on sound cryptographic principles and architectures. If their usage spreads, however, there could be a need for industrial security standards, certifications and audit procedures to ensure quality and compliance. From a data protection perspective, the technological solution proposed also appears able to ensure data protection and compliance with data regulations. In many of the solutions proposed, the use of permissioned blockchains ensures that data is only shared by the data owner with other stakeholders on a need to know basis.

Trade facilitation

The main impact of blockchain-based solutions on international trade would be to contribute to the facilitation of trade. They are by no means a single solution that would by itself ensure the digitalisation of trade document exchanges, but they have the potential to contribute to the digitalisation process.

Their main benefits would be to provide a trusted and secure infrastructure for documentation exchanges and for the automation of some processes. The decentralised control of blockchains, ensuring relative equality between the stakeholders and peer control over the infrastructure, could also be an argument to convince stakeholders to collaborate openly.

The proposed solutions would, in most cases, result in overall cost reductions. This could be seen as the main economic impact of the use cases, although they could also increase the overall transparency of the trade process and document exchange.

Societal perspective

The study identified societal impacts including better access of SMEs to trade and trade finance (with use cases such as cross-border payments or blockchain-based letters of credit). Other use cases (such as proof of authenticity, traceability use cases, or certificates of origin) could also increase the information available to consumers on products, with potential benefits in more ethical and environmentally responsible consumption. However these positive impacts are not a given for every potential use of blockchain. They are linked to specific use cases, and could require dedicated efforts. They would also have to counterbalance other potential impacts such as an increase in the digital gap (blockchain, like any digital technology, will require access to digital technology, infrastructure and skills, potentially leaving out less advanced actors), or the potential negative environmental impacts associated with an increase in trade.

Perspective and policy options

The study confirms the strong potential of blockchain technology in the domain of international trade document exchange. However, changing international trade processes in this way would require adaptations of the legislative framework and policy-driven initiatives.

Legislative framework and international trade document challenges

The study's analysis of the legislative framework and current policies in both international trade and blockchain technologies emphasised the challenges that international trade faces with regard to paper-heavy trade processes as well as the solutions proposed at EU and international level.

Despite significant regulatory and legislative efforts, the transition towards electronic document exchange and data-processing is still lagging behind. In that context, blockchain technology appears as a potential part of the solution as it can enable trade by providing a digital record of transactions and creating a connected, transparent and data-rich environment.

Use of this technology can raise challenges of its own in terms of legislation however. These relate to data localisation and privacy issues, identification of the applicable law and the allocation of liability, legal recognition and validity of blockchain-based information, and interoperability and standardisation across economic operators and regulatory frameworks. There are various initiatives to address these challenges at EU and international level as well as in the private sector.

Policy options

The options result from the study itself, including consultation with organisations including the World Trade Organization, various Directorates General of the European Commission (DG CNECT, TAXUD, TRADE, JUST, and DIGIT) and the STOA Panel. A total of 20 policy options are proposed alongside an assessment of their feasibility and the need to involve external actors in their implementation. They are organised into six themes, chosen based on their potential impact, but also the possibility for policy-makers to act:

	Policy options
1 - Customs	Parliament could recommend that the European Commission act as a bridge between EU customs authorities interested in employing distributed ledger technology for the digitisation of custom to jointly develop further proofs of concept.
	Established EU single window working groups could be encouraged to run through the blockchain key questions to be addressed within the guidelines developed by the World Economic Forum, by means of consultations with authorities, private sector groups and mixed focus groups, to explore whether there is a business case for its development.
	The European Commission could be encouraged to look to its partners in mutual recognition agreements to explore the possibility of a blockchain-based solution on sharing authorised economic operator information.
2 - SMEs	Parliament could recommend that the Commission help SMEs to keep abreast of blockchain applications relevant for their particular role in the value chain, so as to be able to make business decisions related to the technology.
	Funds could be made available for a call focused on collaboration between SMEs as both suppliers of the solution and end users on global value chains.

3 – Sustainable trade	The Commission could be provided with a budget to scale up the solutions being developed under Blockchain for Social Good, particularly those pertaining to the support of fair trade.
	The Commission could be encouraged to consider blockchain solutions when designing the practical aspects of an EU carbon border tax.
4 -Standardisation	The Commission could continue playing a leading role in the process of standardisation and continue its close collaboration with international partners and strive to provide a platform for the various actors working on pilots and standards to engage with each other in order to avoid fragmentation.
	Parliament could call on the Commission to make use of the Multistakeholder Platform on ICT Standardisation (MSP) to further collaborate with the various stakeholders on standardisation of blockchain technology.
	Beyond dialogue with third countries on standardisation, the European Union could lead by example and set standards itself by introducing blockchain-based services for example in customs or financial transparency, based on which private actors, third countries, and international standardisation organisations could orient themselves.
	Parliament could support the work of the European Blockchain Partnership and encourage collaboration with the International Association for Trusted Blockchain Applications to work towards a comprehensive ecosystem of international supply chains connected through blockchain technology.
5 – Evidence-based policy-making	Considering the large amount of work already happening at EU level with regard to blockchain technology and international trade, the European Parliament could consider engaging more actively in the work by observing relevant organisations such as the European Blockchain Partnership or asking the European Commission for regular updates on their work.
	The European Parliament could promote networks such as the European Blockchain Partnership, the Observatory, and others. To this end it could also promote research results and approve and support the funding of further research in the area, such as a mapping of regulatory readiness in the EU, its Member States and international partners.
	Parliament could point out to the European Commission that calls for innovative solutions should include reporting indicators and specific plans on how results will be measured, communicated and developed into lessons learned.
	Having regard to the work already being done to pilot blockchain at EU level, the European Parliament could monitor progress closely and support the set-up of future use cases and pilots under the European Blockchain Services Infrastructure and the Connecting Europe Facility.
	Given the early development stages of many blockchain-related projects in trade and supply chains, Parliament could support EU efforts through funding schemes for research and business in the area.
	Having regard of the creation of the International Association for Trusted Blockchain Applications, Parliament could support and encourage the European Commission in establishing a public-private partnership in the area of blockchain in trade and supply chains.
6 – Awareness raising	Having regard to the potential blockchain technology has to improve efficiency and in support EU values such as transparency, fair trade, and social and environmental responsibility, the European Union could promote recognition of the technology and its use in trade and supply chains.
	Parliament could promote successful proofs of concept, pilots and the available building blocks on the Connecting Europe Facility platform among Member States, private stakeholders and citizens in order to increase familiarity among stakeholders with the technology and its uptake.
	Parliament could recommend that the Commission and Member States make use of their roles as members in international organisations such as the World Trade Organization, the World Customs Organisation and the United Nations Centre for Trade Facilitation and Electronic Business to promote trade digitalisation and the use of blockchain technology.

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Glossary

ASYCUDA	UNCTAD Automated System for Customs Data
CEF	Connecting Europe Facility
CEN	European Committee for Standardisation
CENELEC	European Committee for Electrotechnical Standardisation
DIH	Digital Innovation Hub
DLT	Distributed Ledger Technology
EBO	EU Blockchain Observatory and Forum
EBP	European Blockchain Partnership
EBSI	European Blockchain Services Infrastructure
eCO	Electronic Certificate of Origin
EUIPO	European Union Intellectual Property Office
ETSI	European Telecommunications Standards Institute
ICC	International Chamber of Commerce
ICT	Information and communications technology
IEEE	Institute of Electrical and Electronics Engineers
INATBA	International Association for Trusted Blockchain Applications
IPR	Intellectual Property Rights
ITU	International Telecommunication Union
ISO	International Organization for Standardization
JRC	Joint Research Centre
LC	Letter of Credit
OECD	Organisation for Economic Co-operation and Development
PKI	Public Key Infrastructure
PoA	Proof of Authority
PoC	Proof of Concept
PoS	Proof of Stake
PoW	Proof of Work
SEPA	Single Euro Payments Area
SICC	Singapore International Chamber of Commerce
TBT	Technical Barriers to Trade
TFA	Trade Facilitation
UCC	Union Customs Code
UN/CEFACT	United Nations Centre for Trade Facilitation and Electronic Business
UNCITRAL	United Nations Commission on International Trade Law
UNCTAD	United Nations Conference on Trade and Development
WCO	World Customs Organisation
WTO	World Trade Organization

Part 1 - Key features and use cases of blockchain in international trade

1. Blockchain concepts and technologies

1.1. General concepts of blockchain

1.1.1. Origins

Blockchain as a ledger for Bitcoin

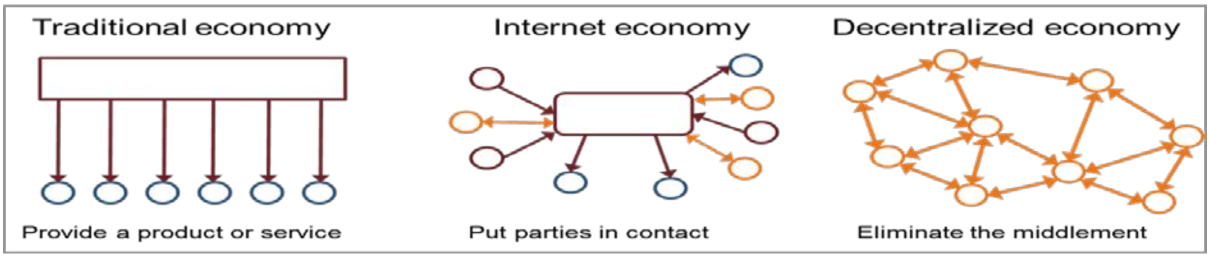
The concept of blockchain emerged in the wake of the 2008 global financial crisis, when an anonymous individual (or group) denoted as Satoshi Nakamoto published the white paper 'Bitcoin: A Peer-To-Peer Electronic Cash System'.[1] The paper described a new peer-to-peer payment system which allows the transferring of digital currencies from one party to another without the need of financial institutions or state government.

This emerging decentralised digital currency required a dependable digital infrastructure to ensure the security and validity of transactions. This led to the creation of the blockchain concept: a secure robust and resistant to modification digital registry relying on a combination of decentralised networks and cryptographic technics. In the case of digital currencies, blockchains are used to monitor, validate and store every transaction with a high level of security and dependability.

The initial vision

Initially created as a support for Bitcoin, the blockchain concept is often associated with a libertarian vision of a decentralised Internet. This vision aims to transform the economy into a fully peer-to-peer exchange, where the mediating role of both financial institutions and governments is abolished. Therefore, in this decentralised electronic payment system, trust is based on transparent, cryptographic proof used to validate transactions, rather than trusted third parties.

Figure 1 – Blockchain early vision of a decentralised internet



Source: IDATE DigiWorld, blockchain, October 2016.

Blockchain use as an infrastructure

This initial vision remains still present in some blockchain communities. However the blockchain ecosystem rapidly diversified and numerous blockchain initiatives have appeared making blockchain just a new type of digital infrastructure rather than a political revolution.

In general, blockchains have broadly diversified their uses. Financial services remain its most common application but even in this domain a distinction should be made between its applications targeting cryptocurrencies and its use by established financial institutions (banks and insurance) as a means of establishing distributed trust and storing robust data entries and transactions in a peer-to-peer and resistant to tampering and modification manner.

1 Satoshi Nakamoto; Bitcoin: A Peer-To-Peer Electronic Cash System; 2008; pp. 1-9; https://bitcoin.org/bitcoin.pdf.

Beyond finance, other sectors such as manufacturing, logistics, health care or public services are also considering the use of blockchain for specific applications.

1.1.2. Definition and value proposition

Definition and key features

A blockchain is a shared digital infrastructure used to store data securely and enable the data exchange with third parties. As such blockchains can be considered a specific type of distributed database. Different implementations of blockchain exists, but the core principles can be considered to be:

Duplicated storage

Blockchains are used to share data within an ecosystem. Each participant of the ecosystem is expected to participate to a global infrastructure by providing resources to store the data (i.e. providing a node with a local copy of the blockchain content). As such, several synchronised copies of the information exist, distributed on the network, to guarantee the resilience of information.

Decentralised control and consensus

Blockchains are used to share data in ecosystems that are decentralised and horizontal, meaning that a single hierarchical leader, who has a strong control over the ecosystem or the infrastructure, does not exist. In addition, there is no central trusted third party in charge of validating and storing information. No single actor has the ability to single-handedly add or modify information to the blockchain without a proper validation from the other participants. This process relies on predefined algorithms (called consensus algorithms) that enable a trustful verification of new transaction entries by multiple actors.

Immutability, Authentication and Timestamping

Blockchains are used in ecosystems were trust between the different parties is not taken for granted. Thus, blockchains rely on cryptography to ensure the security of information stored and exchanged: Stored data must be clearly authenticated, non-reversible and timed.

Blockchains rely on cryptographic algorithms that ensure the immutability of the information stored and thus, everything that is saved on a blockchain cannot be modified or deleted. Every piece of information logged on a blockchain is associated with a single user thanks to the use of cryptographic techniques and the utilisation of proprietary digital signatures. Additionally, every piece of information stored on a blockchain is robustly associated with the time at which it was first added to the blockchain.

Main value proposition

The following characteristics define the core value propositions of blockchains.

Blockchains are to be used in situations where:

- an ecosystem needs an infrastructure to exchange information
- reliance on a single authority able to operate this infrastructure is not feasible or not desired
- complete trust in different players of the ecosystem is not provided
- there is a need for strong accountability, dependability and security.

When implemented, blockchains are used to:

- store transactions between different parties
- securely archive any type of information

- identify with certainty who (i.e. with a pseudonym as an identifier) and at what time a specific data has been entered
- and automate some interactions between the different parties (see smart-contract in Section 1.1.3).

As such, blockchain are infrastructures that are best suited for enabling exchange of information in ecosystems where the different parties interact both through cooperation and competition or could have conflicting interests.

Examples of use

To illustrate how this principle can be implemented and this value proposition achieved, we present some more concrete examples of potential implementation and use. Some additional details are also provided in the annex to present some of the technologies involved.

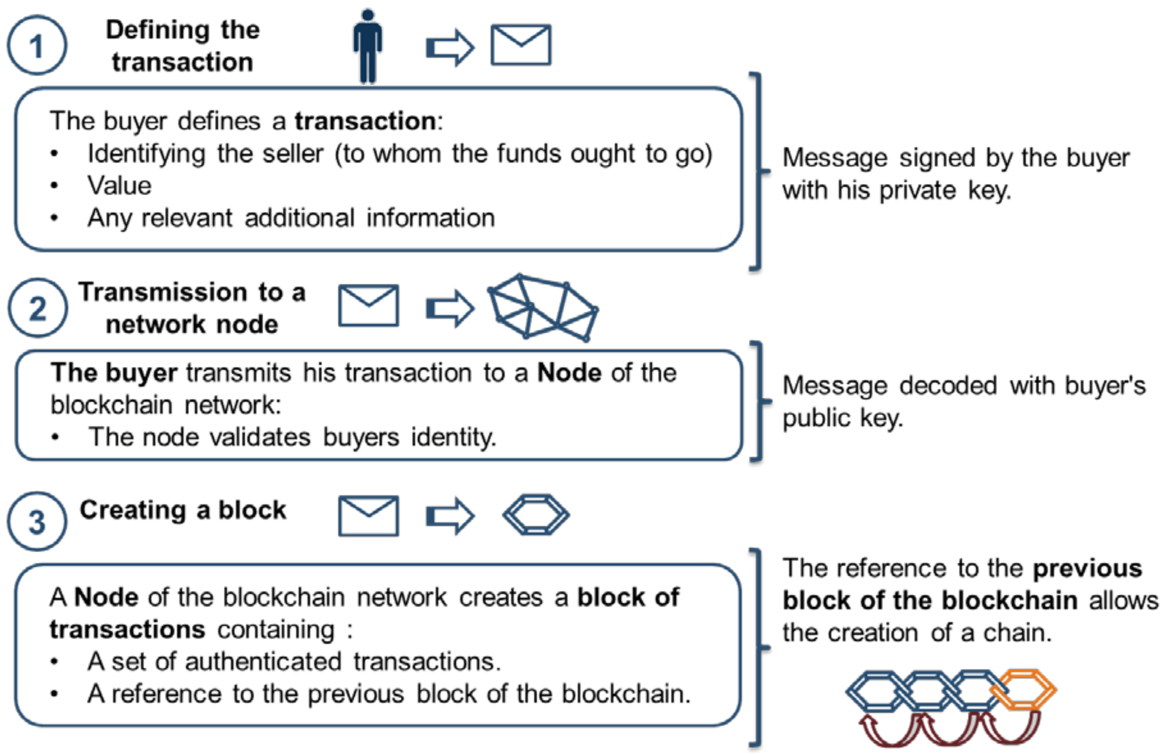
General principle of a blockchain

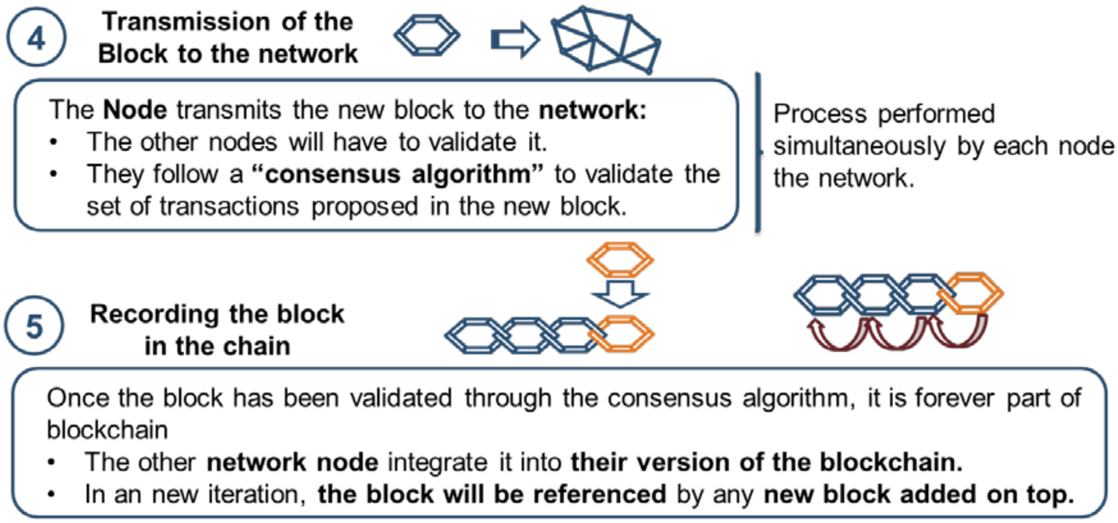
In the blockchain system, transactions are carried out between members of a network and information on these transactions is collected in the form of a 'block'. These blocks are validated by network members and added to a chronological list (the 'blockchain') that is recorded on all network members' computers (also called 'network nodes').

The process of bookkeeping this information is done by the participants of the network (known as 'miners' in the cryptocurrency context). They individually verify the authenticity of the transactions stored in a block and collectively (through a consensus mechanism) decide to validate the new entry. These processes are solved using computational resources, for which miners get rewarded either with transaction fees or, in the case of cryptocurrencies, with recently minted 'coins'.

We present in a synthetic way the different steps of blockchain functioning and validation of the transaction history.

Figure 2 – Process of recording of a transaction in a blockchain





Source: IDATE.

Blockchain application in the supply chain

In section 2. we present, in more detail, the potential application of blockchains in international trade and supply chain. But we will use here an example to illustrate how a blockchain can operate in this context.

Blockchain can be used by all the participants along the supply chain (exporters, importers, transporters and custom authorities) to exchange information, track products and keep records of supply chain transactions and exchanges.

These participants currently don't have a mutual data sharing system, which makes it difficult for them to exchange information and coordinate processes. Hence, the expectation is that the integration of blockchain in the supply chain could eliminate the inefficiencies and vulnerabilities of the current system.

In such a setting, the different participants of the supply chain (exporters, importers, transporters, custom authorities) would each host a node of a blockchain network. The blockchain would then be used to record all information on a shipment at every stage in the process: from its creation by the exporter, to its transit in the transport and custom systems, and eventually to the importers reception.

At each step of the process, the parties responsible for the step would send the relevant information (and any additional documentation) as a new block on the blockchain network. It would then be validated by the other parties (checking that the new block is authenticated and legitimate) and then registered in the blockchain, creating a precise history of the shipment process along the supply chain.

The cryptographic algorithms of the blockchain would be used to ensure that all information written in this common history is authenticated (linked with a clearly identified stakeholder) and that the associated documents have not been tampered after their writing in the blockchain.

Of course this is a simplified vision of how such a system could work, refer to section 2. for a more detailed presentation of potential use cases and real world examples.

1.1.3. Key concepts

To provide a better understanding of blockchain-based solutions, this subsection introduces some of the key concepts of blockchain technologies.

Public, permissioned and hybrid blockchains

As blockchain emerged as an infrastructure solution for many industries and use cases, the initial technological implementations have evolved to fit different types of deployment scenarios and use cases.

Different types of blockchains for different use cases

The operation and security of blockchains depends on the use of a peer-to-peer network, and important variations of blockchains are influenced by the way the network is constituted. Variations are based on how data is read (private/public) and written (with/without permission) on the blockchain.

Public blockchains are open to everyone willing to become a network node, i.e. to provide new inputs in the blockchain, perform transactions on the blockchain and access the transaction history. This type of blockchain is used for the implementation of fully decentralised large-scale systems such as Bitcoin or Ethereum.

Storing data in the public blockchain, requires a transaction validation mechanism secured by an algorithm of the proof of work type, or another variant such as a proof of stake algorithm. These types constitute high security consensus algorithms with the goal to enable the distributed establishment of the trust within the ecosystem in question.

On the other hand, a **permissioned blockchain**, refers to a blockchain whose network nodes belong to a closed consortium or even a single organisation. On that account, the consortium controls access to the ledger as well as the ability to input new blocks and authorises the newest transactions on the blockchain. This type of blockchain is mainly used when a group of actors in the same ecosystem want to set up a common infrastructure without providing full control (i.e. establishing a centralised trusted entity) to any of the actors in the ecosystem. This is the most common setting for B2B blockchains. Since the stakeholders using the blockchain are known and can be made accountable for their actions, permissioned blockchain require less strict security of the utilised consensus algorithm.

A hybrid blockchain is midway between the previous two. Hence, the possibility of adding new nodes to the blockchain is confined to a network of trust (subject to obtaining permission), but the blockchain's visibility and the ability to perform transactions can be open to anyone. Hybrid blockchains can be used to store information of public interest, however allowing only well identified actors, such as land or private property registers, to create/edit information.

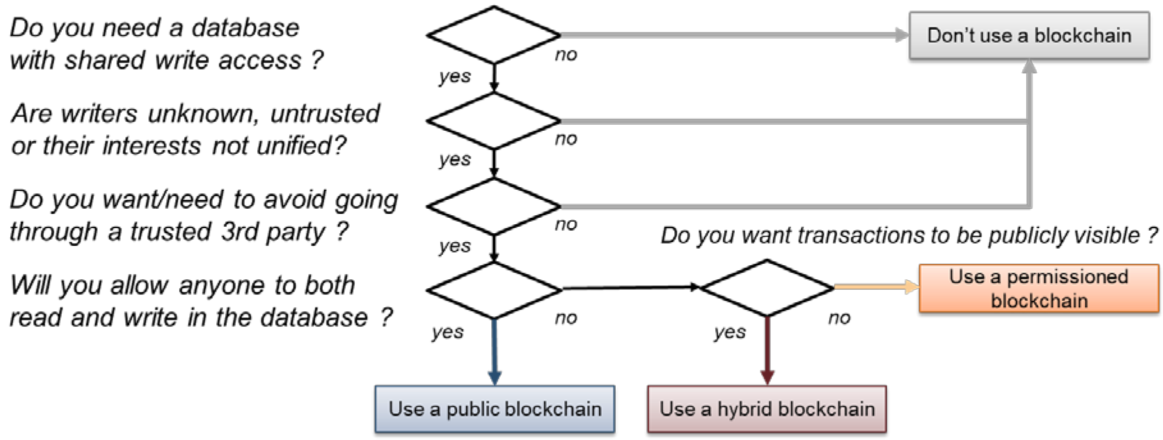
Table 1 - Public, permissioned and permissioned blockchain

	Read permission	Write permission
Public	Open to everyone	Open to everyone
Permissioned	Subject to restrictions	Subject to restrictions
Hybrid	Open to everyone	Subject to restrictions

Source: IDATE DigiWorld, *blockchain,* October 2016

The following diagram displays which type of blockchain to use depending on the specific project requirements. The choice on the type of the blockchain depends on the need to control various aspects of the intended data sharing as well as on the functionalities of the blockchain. Furthermore, the described decision process clearly indicates that the choice to use a blockchain should be systematically worked out and reasonably argued without blindly following the general blockchain hype of the recent years.

Figure 3 – Analysis of the different types of blockchain



Source: IDATE DigiWorld based on data from multichain.com, blockchain, October 2016

Impact on consensus algorithms

Consensus algorithms ensure that the next block (i.e. transaction) in the blockchain is fully validated and secured. Currently, several types of consensus algorithms with fundamentally different processes exist and can be applied. As mentioned above, the various consensus algorithms also correspond to different types of ecosystems: the open ecosystem of a public blockchain requires a stricter consensus algorithm than a closed and controlled ecosystem, where the involved stakeholders are well identified and can be made accountable for their actions.

Proof-of-work The principle of this process is to solve a complex mathematical puzzle whose solution is impossible to guess and requires significant computational power. The need to spend a large amount of computational power (i.e. work) to validate a transaction is what makes the consensus algorithm safe. Proof-of work is very efficient from a security standpoint but very costly in terms of energy and resource consumption. It is well adapted to public blockchains.

Proof-of-stake is considered as an alternative that reduces the amount of computing power needed to validate the blocks according to the amount of cryptocurrency (or whatever resource the blockchain uses) each node has. Thereby, a node is chosen to validate the transaction based on its economic stake in the network, as nodes owning more value loose the most if the blockchain is compromised. However to be fully secure, the proof of stake algorithms require that enough individuals have enough interest in the security of the system to be trusted. This often requires, at least in public blockchain, to use a different algorithm initially (such as proof of work) and switch to proof of stakes once the community is strongly established (this is the case of Ethereum which consider a switch to proof of stakes).

proof-of-capacity is a consensus algorithm used in blockchains that allows the network nodes to use their available hard drive space (requires less energy) in the validation process, instead of using nodes computing power (requires lots of energy). Even though this algorithm is considered less secure than the proof of work, it's an interesting option for certain applications, such as a distributed storage of documents.

The principle of the **'federation'** applies only to permissioned blockchains, where the consortium collectively controls the blockchain in a constructive way. Therefore, each of the consortium members is clearly identifiable and accountable for its actions, as the block validation process is subject to a direct vote by the nodes. The Federation's blockchain framework is mostly used in B2B settings.

The following table provides a simplified summary of the comparative advantages of the different consensus methods.

Table 2 - Comparative advantages of consensus methods

Alternatives	Who can validate the transactions?	Choosing the node that validates a transaction	Advantages	Limitations
PoW (proof of work)	Anyone can become a network node	Randomly, indexed on computing power	+ Security + Trust establishment over a trustless network	- High computing power costs - Data storage costs - Speed limitations
PoS (proof of stake)	Anyone can become a network node	Randomly, indexed on economic stake	+ Less computing power costs + Trust establishment over a trustless network	- Favouring the richest nodes - Increased Complexity
Federation	Rules are defined on who can join the network (e.g. peer validation, defined identity and security deposit)	Voting of 2/3 of the nodes	+ Less computing power costs	- The underlying network cannot be truly trustless but rather requires some level of trust and security - No node anonymity - Does not necessarily solve the latency problem (time required for voting).

Source: IDATE DigiWorld

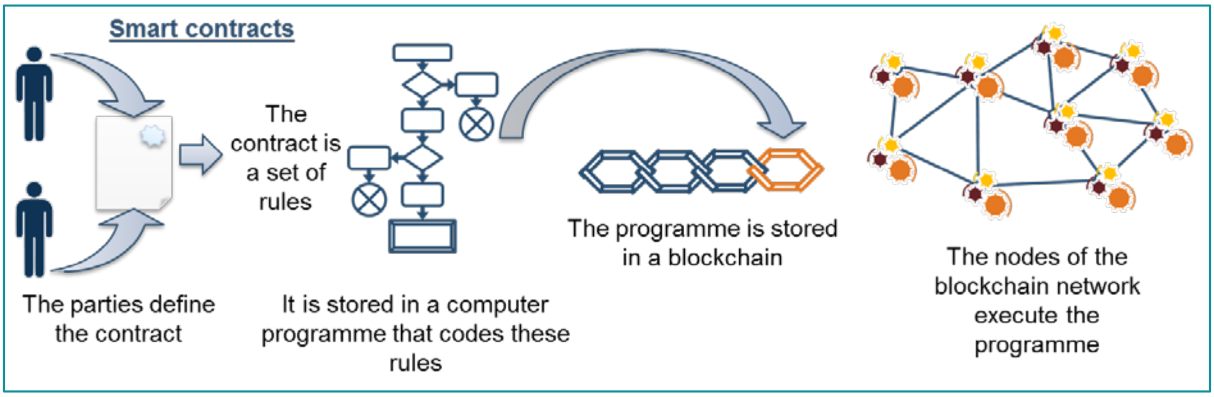
Smart contracts and decentralised applications

smart contracts add an additional level of automation on top of blockchain implementations. They enable more complex interactions and applications but come with an increased complexity and risks.

Automated transactions

Smart contracts are self-executing programming codes that automatically perform the transferring of digital currencies or assets under predefined terms between two parties.

Figure 4 – Smart-contracts concept



Source: IDATE DigiWorld, blockchain, October 2016.

Smart contracts increase the complexity of blockchain-based transactions by adding a set of conditions to meet in order to complete the transaction. These conditions are defined in a computer programme that serves as the contract between the two parties in a transaction, and which is automatically validated and put into effect by the blockchain.

Smart contracts enable alternative uses of the blockchain, notably in the area of financial services, loans, insurance, betting, crowdfunding, recurring contracts, rentals, etc. Thus, contracts become automated conditional transactions. The financial transaction occurs if the conditions set out in the contract are met. In addition to cutting out the middlemen whose job is to draft and enforce contracts, this service of the blockchain also helps to reduce insurance and collection costs on contracts, and could speed up the process. Smart contracts can be put into effect either by making changes or addition to the initial blockchain platform (e.g. Bitcoin), or by using dedicated blockchains (notably the Ethereum project).

Blockchains as an infrastructure for decentralised applications

The use of smart contracts on the blockchain enables the creation of fully decentralised applications (sometimes called 'DApps') and possibly decentralised organisations in the future. The underlying idea of the blockchain is to use a peer-to-peer system to distribute information on the network. Smart contracts make it possible to use this network to execute computer programmes. This opens the way to all types of applications, not necessarily linked to a cryptocurrency or to storing information. It paves the way for fully decentralised applications, such as marketplaces, and possibly fully decentralised organisations or businesses, whose operating rules are entirely defined and maintained by contracts executed on the blockchain.

Blockchains technological limitations

Despite its promises blockchain technology does have certain limitations and inherent risks, in terms of technology as business and societal models. The discussion below provides a brief summary of the main technical risks.

Limits and concerns of public blockchains

Public blockchains, used typically in cryptocurrencies, face specific technical issues that are directly linked with their need for increased security of the transaction validation process. If the security of the validation process (consensus algorithm) would be compromised, it would enable large scale theft and the value of the currency would drop instantly as trust would evaporate.

The need for increased security and the realisation of the belonging measures lead to technical limitations in terms of

- Speed: the number of transaction per second is limited to a few transactions per second (TPS) in most public blockchains, which appear critical when compared to traditional payment systems (2000 TPS for VISA under normal circumstances with peaks at 10000 TPS). [2]
- Latency: the transaction validation time is also limited (around 10 minutes to 1 hour on Bitcoin to consider a transaction as final). This is usually better than some financial transactions (such as international fund transfer which can take several hours to days), but limits the application of public blockchains for more traditional database and payment use cases.
- Size of the blockchain: as all transaction history is stored on the blockchain, the size of the total blockchain can grow rapidly. As of June 2019, the Bitcoin blockchain size has reached 226 gigabytes with a 30% annual growth rate.

In addition to these limitations, the use of 'proof of work' consensus algorithms creates significant issues in terms of resource utilisation, both with respect to network and electricity requirements and consumption. The energy consumption of the Bitcoin blockchain is for instance evaluated at around 64 TWh per year as of June 2019, which is close to the energy consumption of a country like Switzerland.[3]

The oracle problem

One of the main issues of the blockchain concept affecting all types of implementations (public or permissioned) is the so called 'oracle problem'.[4] Within the blockchain context, an oracle is a software component that connects the secure blockchain environment to other systems. Indeed, if blockchains make it possible to ensure the security of the information they store, nothing can be said about the security of the information before it enters the blockchain (or after it has left it). When using blockchains beyond simple 'proof of concepts' several problems appear regularly on how to secure and verify the inputs to the blockchain

- Validation of identities: a blockchain authenticates every transaction through the use of cryptographic identities, however linking this digital identity to a real identity can be a challenge. This often relies on the use of 'trusted third parties' that can act as certification authorities and follow KYC (Know Your Customer) principles.
- Integration of historic data: the integration of legacy data and systems with a blockchain can also prove to be a challenge as they are not designed to work on pre-existing records.
- Integration with other systems: The interconnection of blockchains with other systems (i.e. oracles) can lead to issues ensuring the security of the connection, authenticity and validity of the data the system pushes to the blockchain in question. This problem becomes even more acute in the case of smart contracts that act autonomously on the data entered to the blockchain by third parties.

Limits and concerns relating to smart contracts

As presented above, smart contracts add another layer of services and corresponding complexity on top of the blockchain infrastructure. They enable efficient automated solutions, but this also raises specific technical issues. Smart contracts denote blockchain-based software, whose autonomous execution can automate many critical processes but can also lead to important financial consequences in case of malfunctioning or compromised misuse. An error or a malicious

[2] Jan Vermeulen; Bitcoin and Ethereum vs Visa and PayPal; Mybroadband; 2019.

[3] Alex de Vries; Bitcoin Energy Consumption Index; Digiconomist; 2019.

[4] Mike Fecke; The Problem of blockchain Oracles; Legal Tech Blog; 2018.

compromise of the smart contract code can lead to unauthorised financial transactions. It is therefore of key importance to ensure that the software code for a smart contract is quality assured and corresponds exactly to the intended usage and operations, i.e. executes strictly the terms agreed by the parties in the 'real' contract.

Several solutions can be envisioned to provide this validation

- Limitation of the complexity of the smart contract programming language: The use of computer languages that allow only limited capabilities to smart contract (i.e. non 'Turing Complete' languages) can reduce the complexity of the smart contract and increase their security.
- Formal proof of the smart contract programme: Advanced computing techniques of automated theorem proving can be used to formally validate all the possible outcomes for a defined programme. However the complexity of this type of technique limits its application to specific cases.
- Community based assessment: The validation of the smart contract code can be done through peer assessment by relying on the community for validation of its security.

1.2. Existing implementations

Since its onset with the Bitcoin blockchain, a large diversity of implementations of the blockchain principles have appeared. We review and present here some of the most noteworthy implementations to provide a perspective on the different technical aspects and the variety of the available solutions.

1.2.1. Overview

The following table sums up the main characteristics of the most notable blockchain implementations.

Table 3 - Overview of the most notable blockchain Implementations

	Bitcoin	Ethereum	Hyperledger		R3 Corda
			Fabric	Sawtooth	
Description	Public blockchain used as a support for a cryptocurrency	Public blockchain-based platform designed to run smart contracts	Modular architecture allowing components to be plug-and-play	Modular platform for building, deploying, and running distributed ledgers.	Open source blockchain solution for B2B exchanges
Main value proposition	Alternative to traditional centralised banking system with intermediaries	Platform for the creation of advanced smart contracts	Toolkit to create custom B2B blockchains	Industry solution to create public or permissioned blockchains with an alternative to proof of work	Specialised blockchain platform for the financial industry
Governance	Decentralised (Bitcoin community)	Decentralised (Ethereum community)	Linux foundation	Linux foundation	R3 company

Support of institutional player	None	None	IBM	Intel	R3 consortium (300 financial institutions)
Public or permissioned	Public	Public	Permissioned	Public or permissioned	Permissioned
Cryptocurrency	Bitcoin (BTC or Ƀ)	Ether (ETH)	No	Optional	No
Smart contracts	Limited smart contracts (non turing-complete)	Advanced smart contracts (Turing complete)	Support a variety of language (Java, Go, Ethereum Solidity) and full capability smart contracts		Focused on the automation of financial transaction
Consensus algorithm	Proof of work	Proof of work, with a willingness to make the algorithm evolve	Possibility to plug-in various consensus algorithms	Proof of Elapsed Time (PoET) alternative to proof of work more energy efficient and scalable	Different consensus algorithm available. Only parties involved in the transaction validate it.
Level of usage	+++++	++++	++++	+++	+++

Source: IDATE DigiWorld.

1.2.2. Bitcoin

Purpose and key features

Bitcoin was the first implementation of a blockchain to support the cryptocurrency launched in 2009. The aim of the Bitcoin cryptocurrency was to sever ties between the economy and both the banking system and state governments, in the wake of the economic collapse of 2008. The use of a blockchain enabled the currency to rely on this infrastructure to register, validate and securely store every transaction.

Bitcoin was the very first implementation of the 'cryptocurrency' concept. The underlying principle of Bitcoin is that of a bankless currency, where transactions are conducted from peer-to-peer and validated by the entire network. Bitcoins are created through 'mining' – a process of solving complex equations by multiple computers that requires significant power resources, i.e. the proof of work consensus concept was applied.

Key advantages

The main value proposition of Bitcoin is the absence of any financial intermediaries. It aims to reduce delays in payments as well as transaction costs. This is particularly the case for international payment operations that usually require more time and extra costs compared to those executed in Bitcoins. Aside from its use as a cryptocurrency the Bitcoin blockchain has several advantages that can make it an interesting technology choice for some applications

- The Bitcoin blockchain is both the veteran under the blockchains and the most intensively used one in number of active addresses. Its security and dependability can be considered as very high. Thus it can be an interesting choice for storing a document, a proof of ownership, or for timestamping a document.

- The Bitcoin blockchain only allows limited smart contracts (i.e. a 'non Turing complete' language is in place) and the Bitcoin community is overall cautious with respect to the evolution of its algorithm making it a blockchain solution on which smart contracts can be considered as more secure than on more ambitious implementations (such as Everledger).

Main limitations

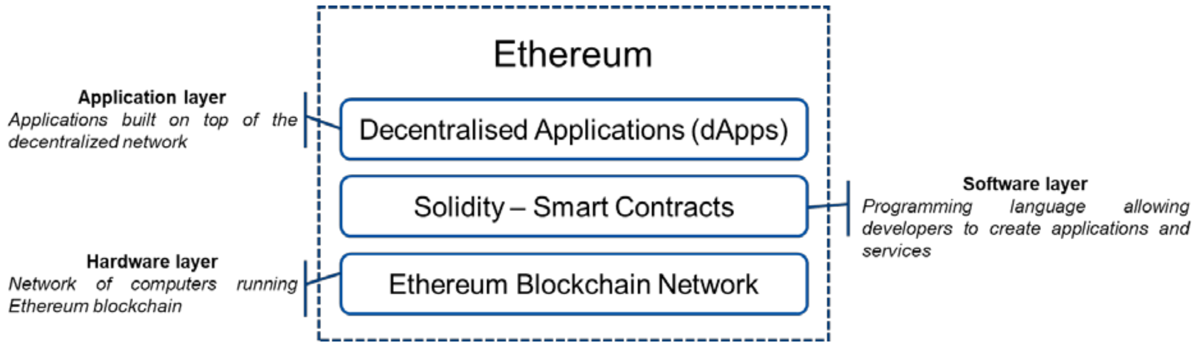
Even though the use of Bitcoin may facilitate payment procedures by reducing costs and time, the currency remains highly volatile and therefore incurs additional risks. It is unfortunately mostly used as a speculative asset. In terms of technology, the Bitcoin blockchain limitations are directly related to the proof of work consensus algorithm limitations (presented above in section 1.1.3), i.e. limit in transaction speed and latency, size of the blockchain and most importantly energy consumption. Finally the use of smart contract is also limited but this can be considered more as a design choice for the Bitcoin blockchain.

1.2.3. Ethereum

Purpose and key features

Ethereum was introduced in 2013 as both a cryptocurrency and a decentralised platform designed to run smart contracts – as described above these are computer programmes that are executed automatically as soon as certain conditions are met. As a platform, Ethereum allows to develop decentralised applications for particular needs regardless of the use case. It has grown to become one of the most valued and recognised cryptocurrencies besides Bitcoin.

Figure 5 – Layers of the Ethereum platform



Source: IDATE based on Medium - How Does Ethereum work? [5]

Even though Ethereum applications extend far beyond cryptocurrencies, the network has also its own currency called 'ether' (ETH/ETC), which is needed for executing operations on the Ethereum platform. Ether can be exchanged for so-called 'gas' – an internal measure of effort required to execute smart contracts. In other words, ether is used by developers building applications on Ethereum and by users interacting with smart contracts on the Ethereum blockchain. It plays the role of a currency and is used as a means to realise transactions fees relating to the required operations on the platform. Moreover, one of the central elements of the Ethereum ecosystem is the Ethereum Virtual Machine (EVM). EVM is isolated from the rest of the Ethereum network and serves as a runtime environment for smart contracts based on Ethereum.

[5] Michele D'Aliessi; How Does Ethereum Work?; Medium; 2018.

Key advantages

Apart from all traditional advantages of blockchain, the most important benefit of Ethereum is the possibility to deploy and use Turing-complete smart contracts. The Ethereum blockchain allows for realising complex smart contracts and the blockchain was designed with the capability to support a large variety of complex applications. Another advantage is the opportunity to adapt blockchain to various different use cases through decentralised applications (built using smart contracts) that can be built on the platform, or are already available on the platform. Currently, Ethereum is in a transition phase towards Ethereum 2.0 – this specification includes a switch to proof of stake as well as Sharding (each node having only a part of the data on the blockchain, and not all the information).[6] These two main changes should enable the processing of up to 10000 transactions per second.

Main limitations

Even though Ethereum has been positioned as a completely secured network due to the blockchain technology use, in 2016 a hacker stole 3.6 million Ether (equal to more than 50 million USD) from a smart contract based, decentralised application: the Decentralised Autonomous Organization (DAO). This incident was linked to the use of smart contracts - while the overall security of the platform was not compromised, the hacker used a security breach created by a specific smart contract. Another problem with Ethereum that is sometimes mentioned is the lack of documentation for developers, although the documentation has greatly improved in the last few months. Finally, ether as a currency is also highly volatile and thus, creates extra risks associated with the belonging cryptocurrency.

1.2.4. Hyperledger

Hyperledger is a project started in 2015 by the Linux Foundation to provide 'an enterprise grade, open source distributed ledger framework and code base, upon which users can build and run robust, industry-specific applications, platforms and hardware systems to support business transactions', according to the projects website.[7] The project is supported by Linux Foundation members such as IBM, Intel, Fujitsu and J.P. Morgan.

The Hyperledger ecosystem is constituted by 12 separate projects: 6 so-called frameworks and 6 tools. All the frameworks are different implementations serving different purposes. Some of the frameworks have been designed by one or several companies: for example, Sawtooth is implemented by Intel. The main difference with regard to the Hyperledger frameworks in comparison to Bitcoin and Ethereum is their permissioned nature which makes them more appropriate in the context of business applications. The different parties participating in the blockchain can be easily identified and made accountable for their actions. Furthermore, different tools are designed to be used in a particular framework and serve as complements to the frameworks. The role of the tools in the Hyperledger project is to support blockchain deployment and maintenance among others. However, as of May 2019, only 4 projects (*Fabric, Indy, Iroha* and *Sawtooth*) out of 12 are active while the others are still in the incubation stage.

Table 4 - Hyperledger frameworks and tools

Hyperledger Frameworks	
Hyperledger BURROW	Permissionable smart contract machine (EVM)
Hyperledger FABRIC	Permissioned with channel support
Hyperledger GRID	WebAssembly-based project for building supply chain solutions

[6] GitHub; Eth2.0-specs; 2019. https://github.com/ethereum/eth2.0-specs

[7] Hyperledger official website. www.hyperledger.org/about

Hyperledger INDY	Decentralised Identity
Hyperledger IROHA	Mobile applications focus
Hyperledger SAWTOOTH	Permissioned and permissionless support, EVM transaction family
Hyperledger Tools	
Hyperledger CALIPER	Blockchain framework benchmark platform
Hyperledger CELLO	As-a-service deployment
Hyperledger COMPOSER	Model and build blockchain networks
Hyperledger EXPLORER	View and explore data on the blockchain
Hyperledger QUILT	Ledger interoperability
Hyperledger URSA	Shared cryptographic library

Source: IDATE based on Hyperledger.org

Enterprise blockchains based on Hyperledger frameworks can be applied to various markets such as finance, healthcare, supply chain, media and others. Typical Hyperledger use cases are cross-border payments, digital identity management, media rights protection, product traceability and more. In the next subsection the two most advanced Hyperledger Frameworks - Fabric and Sawtooth - will be presented.

Hyperledger Fabric

Even though Hyperledger is an umbrella project for an open blockchain that comprises different frameworks and modules, Fabric itself stands for one of the most cited and the most widely adopted projects within Hyperledger.

Purpose and key features

The Fabric framework was originally designed by IBM (based on IBM's Openblockchain) for industrial applications.[8] Fabric is a modular platform solution for developing decentralised ledger applications. Fabric allows plug-and-play development of permissioned blockchain for organisations.

Fabric supports smart contracts with a variety of programming languages (e.g. Java, Go, Ethereum Solidity and Javascript). It also offers a variety of pluggable consensus algorithms that can be chosen depending on the specific needs.

Key advantages

The main benefit of Hyperledger Fabric for organisations is that it can be used to build custom permissioned blockchains adapted to their specific needs. This makes the Fabric framework more suitable for certain B2B applications where permissionless blockchains like Bitcoin or Ethereum do not provide sufficient control over the parties involved in storing and retrieving the data. Another important advantage of Fabric is its modular architecture and plug-and-play functionality. While an organisation can choose to develop a blockchain on its own, the Fabric framework simplifies and reduces potential costs for such a project by allowing the modular extension and realisation of specific requirements. The backing through a large player (IBM) and an Open Source community (Linux Foundation) are also important advantages for this implementation thereby making it more reliable and dependable for developers (e.g. in terms of support and maintenance).

[8] IBM Developer;Open blockchain; 2018. https://developer.ibm.com/open/projects/open-blockchain/

Main limitations

Given the fact that Hyperledger Fabric is a permissioned blockchain platform, its critics argue that the solution lacks transparency and security in comparison to public permissionless blockchains provided the lack of a dedicated proof-of-work (PoW) mechanism.

Another important point is that even though Fabric is the most developed among all the Hyperledger frameworks (as of early 2019), it still remains a relatively recent concept and therefore the number of proven use cases is relatively low.

Hyperledger Sawtooth

Purpose and key features

Sawtooth is another framework of Hyperledger that was originally contributed by Intel and is now maintained by the Sawtooth community. It is positioned as a modular platform for 'building, deploying, and running distributed ledgers'.[9] It accommodates various deployment scenarios and smart contract languages. Sawtooth can be used for creating both permissioned and public blockchains and contrary to Fabric can be used for designing and creating cryptocurrencies.

Sawtooth relies on a specific consensus algorithm - proof of Elapsed Time (PoET) - that is presented as an alternative to proof of work being more energy efficient and scalable. This mechanism relies on a set of specific CPU instructions (Intel Software Guard Extensions (SGX)) developed by Intel.

Sawtooth is an industry-agnostic solution that can be applied to many use cases. The major applications of the platform are supply chain traceability, asset settlement and digital asset exchange.

Key advantages

The main advantage of Sawtooth is the flexibility of the platform due to its modular structure and use case-agnostic design. Besides, Sawtooth is often denoted as the most advanced among the Hyperledger frameworks - it ensures higher transaction speed and adequate integration with other blockchain networks. It is also interoperable with other Hyperledger frameworks and tools. Similarly to Hyperledger Fabric it is supported by a major player (Intel) and an open source community (Linux Foundation).

Main limitations

Given that Sawtooth is still a relatively new project, one of the key limitations is a certain lack of developer documentation, which means that more developer competence is required, in order to contribute to the project. However, this weakness should disappear with the further spread of the solution.

1.2.5. R3 Corda

Purpose and key features

Corda is an open source blockchain platform launched in 2016 by the distributed ledger technology company R3 and by its more than 300 consortium members (mostly financial institutions) as a vertical solution and offers permissioned blockchain development capabilities to enterprises. The platform is available in two versions: Corda open-source and Corda Enterprise. The latter is a commercial distribution of the open-source version and allows for easy deployment within corporate firewalls and environments, thereby offering some additional services such as continuous customer support.

[9] Hyperledger website; 2019. www.hyperledger.org/projects/sawtooth

The platform has a strong focus on the financial industry and is often presented as an alternative to the Hyperledger Fabric framework. However, Fabric remains more flexible as it is applied to various vertical markets from healthcare to media. At the same time, Corda has been seeking to extend to other use cases in supply chain, healthcare and government.

Table 5 - R3 Corda capabilities

R3 Corda key features	
Permissioned network structure	
Consensus achieved on an individual level	
Various consensus algorithms supported	
Flexibility based on a module-based architecture	
High adaptability due to leveraging common technological standards	
High transaction/network performance (parallel processing of transaction inputs)	
R3 Corda key facts	
Privacy	Permissioned network structure, based on a need-to-know principle
	Data is only shared with those parties which are required to see it (if there is a legal permission).
Consensus	Point-to-point consensus handling
	Different notary instances can be used having different consensus algorithms
Performances	1000 transactions per second can be checked / processed
	Pre-buffering of transaction considered as a future development
Interoperability	High architectural modularity based on common technological standards.

Source: IDATE based on P. Sandner, R3 Corda: Implementierung eines Prototyps für Schuldscheindarlehen und Vergleich verschiedener DLT-Frameworks, 2018. https://medium.com/@philippsandner/r3-corda-implementierung-eines-prototyps-f%C3%BCr-schuldscheindarlehen-und-vergleich-verschiedener-26d4f3d58089

Key advantages

One of the key features of Corda is that data is shared on a need-to-know basis, i.e. there is no global broadcast on the network and nodes do not see all the information. There is no unique consensus algorithm in Corda, since it uses different algorithms depending on the scenario, and only the parties involved in a transaction are in charge of using the specific algorithm and validating the transaction in question.

Point-to-point communication can be considered as the key benefit of using Corda that increases privacy and makes the platform more appropriate for enterprise needs (especially in the finance and insurance sector).

Main limitations

First of all, Corda still has a rather narrow market positioning compared to other projects like Hyperledger or Ethereum. Secondly, it needs to be seen if it is sufficient in practice that only the parties involved in a transaction are the ones that are validating the transaction. Critics of the Corda platform often say that the very concept of a decentralised network is not obvious in the case of Corda, as it is governed and steered by the R3 consortium.

1.3. Research perspective

Various challenges and research topics are clearly visible within the publication landscape with regard to blockchain in general and in combination with supply chains in international trading. We observed the following aspects as of challenging research nature and requiring intensive investigation: *scalability*, *availability*, *security*, *large scale data storage*, *performance* and *transaction speed*.

Clearly, Bitcoin as one of the pioneer blockchains and belonging cryptocurrency is suffering and requires improvement on several fronts[10] including its

- throughput - with respect to number of transactions
- latency - in terms of time required to create a transaction block
- size and bandwidth - in conjunction with the increased throughput
- security - with regard to DoS, scams, cryptographic issues and 51% attack
- wasted resources - e.g. with respect to computing power and energy
- usability - with respect to the APIs, the programming languages and the smart contract interfaces, and
- different strategies for versioning, forks and multiple/parallel chain management strategies

The above listed aspects can be easily abstracted and viewed in the context of various other blockchains such as Ethereum, Ripple as well as Mixcoin and Zerocoin protocols.

Another exciting topic is given by the need to identify proper processes to handle lifecycle aspects of cryptocurrency components such as belonging cryptocurrency exchanges. Thereby, important questions are posed by the need to understand and specify the required processes for handling the bankruptcy of a cryptocurrency exchange or the unavailability (e.g. due to death) of key players and stakeholders as in the case of Quadriga[11].

In addition to all above aspects, the application of blockchain to different domains reveals a large number of possibilities for research and optimisation of both the blockchain technology and the belonging domains. Taking as an example the smart City topic of continuous relevance[12], one can easily observe a large number of possible applications including smart Economy, smart Governance, Space, Goods, Food, Transportation and Services thereby touching on key properties of the current topic relating to supply chain management in international trade. Hence, the goal to develop the nuts and bolts of the blockchain technology in a way that makes it applicable to a wide range of domains and services constitutes a key general blockchain related research challenge for the coming years.

The paper *'Understanding blockchain technology for future supply chains: a systematic literature review and research agenda'* of Wang et. al.[13] defines a research path comprising of various challenges and perspectives for blockchain in supply chains and international trade. Thereby, the authors focus on the following question, which is correspondingly cited here

[10] Jesse Yli-Huumo, Deokyoon Ko, et al; 'Where Is Current Research on blockchain Technology? — A Systematic Review'; PLOSONE Open Access journal; 2016.

[11] BBC News; Crypto exchange founder's death locks $140m; 2019. https://www.bbc.com/news/world-us-canada-47123371

[12] J, Sun, J & Zhang et al.; 'blockchain-based sharing services: What blockchain technology can contribute to smart cities'; K.Z.K. Financ Innov; 2016, pp. 2: 26. https://doi.org/10.1186/s40854-016-0040-y

[13] Yingli Wang, Jeong Hugh Han, Paul Beynon-Davies; 'Understanding blockchain technology for future supply chains: a systematic literature review and research agenda'; Supply Chain Management: An International Journal; Vol. 24; 2019; pp.62-84. https://doi.org/10.1108/SCM-03-2018-0148

'How will blockchain influence future supply chain practices and policies?' [14]. This leads to the definition of different research objectives for the study and the systematic review and classification of 227 research articles out of which 29 were selected for in-depth analysis. The results were published in December 2018 and constitute a state of the art reflection on this important topic. The survey concludes a research agenda consisting of the following items for future investigations in terms of blockchain research and applications in the scope of future supply chains and international trading:

- *Cryptocurrency and supply chain finance* – i.e. the requirement to investigate the implication of digital currency and cryptocurrency on international supply chains, including their financial aspects.
- *Disintermediation and reintermediation* – the distributed nature of blockchains and in general the blockchain concept as a whole cast the promise to enable the direct trustful interaction between involved parties, thereby remediating the need for a central authority that facilitates certain transactions in a trustful manner. Hence, blockchains promise to allow direct peer-to-peer asset trading and that way remove various intermediaries. Hence, the societal and supply chain ecosystem wide impact of blockchains needs to be investigated as more and more intermediaries are expected to become extinct with the introduction of blockchain principles.
- *Digital trust and supply chain relationship management* – blockchains are considered a promising approach to introducing an overall trust layer to the Internet, and subsequently have the potential to revolutionise supply chains by introducing in-built trust within the distributed digital processes, thereby lowering the entry barrier for various players and still keeping a high level of transactional trustfulness within the ecosystem. Hence, the resulting processes will need to be explored in addition to fostering and improving the positive impact on innovation, emerging novel blockchain services and applications (e.g. DApps) towards increasing the performance and effectiveness of the international trade and supply chains.
- *Blockchain, inequality and supply chain sustainability* – blockchain promises to remediate key issues of inequality in supply chain processes and across the world in general. As mentioned above, the entry barrier for ecosystem participants is much lower, whilst at the same time trust is established in a way that goods can be tracked in a trustful way and sustainability in international trading can be strengthened in terms of origin and processing characteristics (e.g. type of labour, involved machines, resources and fuels) for the goods in question. Furthermore, blockchain technology could enable people from developed countries to efficiently transfer money, which would be a serious improvement in comparison to current processes involving multiple intermediaries and taking in the magnitude of several days to complete. Moreover, payment for small farmers and low profile participants in an international trade and supply chain ecosystem might be further simplified and made easily accessible based on blockchain technology. Indeed, all the above listed aspects require an intensive amount of research in the coming years towards the establishment of corresponding viable ecosystems.
- *The dark side of blockchain* – the dark side of the blockchain calls for research on all the negative effects and implications of the blockchain technology in the scope of international trade and supply chains. This includes aspects such as *'governance, ethics, law, crime, security, privacy, intellectual piracy, automation-induced unemployment and technical vulnerability issues'*[15]. This implies a wide range of

[14] Ibid.

[15] Ibid.

research topics on multiple levels including technological aspects (e.g. cyber security, scalability, availability, privacy, integrity …), societal, legal and financial issues as well as the combination of several of the above topics resulting in impairments for future supply chains.

- *A design perspective on a blockchain-enabled supply chain* – the design perspective and correspondingly future design principles for blockchain-based and blockchain-enabled supply chains are a hot research topic for the near future. This includes the development of specific distributed apps (DApps) for enabling the interactions and digital processes in future blockchain-based supply chains. The research challenges include (among others): 1) Identifying the blockchain's entry point to the supply chain, i.e. integrating the blockchain technology in an optimal way, 2) Researching and enabling the creation of sustainable blockchain ecosystems for supply chains in international trade, 3) Clearly identifying and formulating the platform value for blockchain-based/enabled supply chains in international trade 4) Creating and examining different governance models for supply chains based on blockchain, 5)Investigating legal aspects, and 6) Research and investigation on scalability aspects towards enabling networks of supply chains.

Hence, besides the general blockchain research perspectives discussed at the start of the current section, the above list contains key research items for the coming years relating to supply chain and international trade.

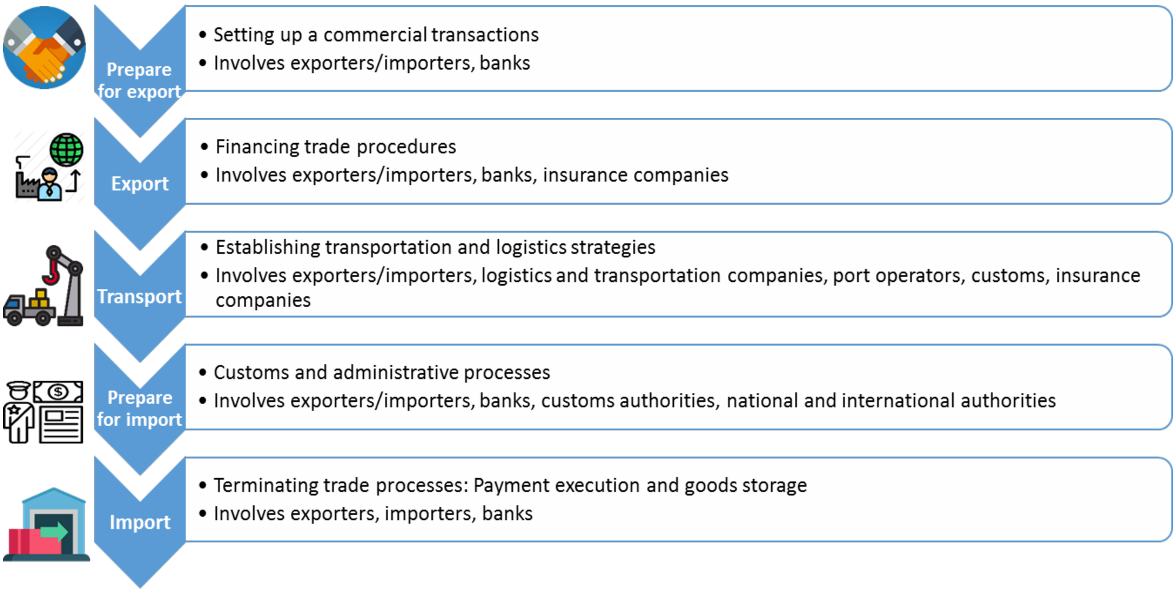
2. Blockchain use cases in international trade

2.1. International trade processes overview

2.1.1. International trade concepts

This section presents an abstract of the concepts, necessary to understand international trade processes. These essential concepts are mentioned in the following sections to explain the implementation of blockchain technology in trade finance processes.

Figure 6 – International trade process Below - setting up commercial transactions



Source: IDATE DigiWorld 2019.

It is also important to note that different use cases and stakeholders are all connected in a continuous process. Thus information collected at one point of the supply chain for a specific purpose can be used by other stakeholders along the chain for different purpose, making the transfer of information a key part of the trade sequence.

Setting up of commercial transaction

A commercial transaction refers to the interaction between two or more parties where goods and services are exchanged for some type of remuneration. Such interaction is possible between two or more companies (B2B) as well as between a company and individual consumers (B2C).

Traditionally, many producers sold their products to retailers from physical locations. However, with emergence of Internet, B2B and B2C business channels evolved in the form of e-commerce marketplaces, where goods and services are sold over the Internet.

Financing trade

Trade finance consists of financial products and services used by companies to facilitate international trade transactions and mitigate risks. The principle of trade finance is to introduce a viable and trusted third-party for exporters and importers to securely transact business through trade. The key stakeholders engaged in trade finance are the exporters, the importers and their respective banks.

Letters of credit

The letter of credit is a financial instrument used in trade finance, where the buyer's bank issues a promise letter guaranteeing its customers obligations to the vendor for the shipped goods.

Most commonly used in global transactions, the letter of credit is crucial in international trade, due to the distance between trade partners and legal complexities in countries of the businesses involved.

While a letter of credit guarantees the security in a trade relationship, banking fees, being time-consuming and formalities are deterrents for the key actors involved in trade finance processes.

Open account trading

Open accounts are trade finance instruments, commonly used by trade partners and their respective banks in cross-border trade transactions. An open account transaction is a sale, where the importer receives goods shipped by the exporter before payment for the goods is effectuated or becomes due.

Open account trading is most commonly used when the exporter trusts buyers' payment records and creditworthiness as well as his country's jurisdiction in case of an arbitration clause initiative.

Considering the intense competition in export markets, open account terms are advantageous for the importer in terms of cash flow and costs, but they remain of high risk for the exporters.

Cross-border payment

Cross-border payment refers to inbound and outbound financial transactions involving companies, individuals and banks that operate in different countries.

Currently, the majority of payment clearing and settlement processes (including FX), is performed by the corresponding banking arrangements for cross-border payments.

Making an international payment via established banking channels is a complex process that involves several intermediaries and ought to be compliant with multiple regulatory regimes.

Customs, regulations and administrative duty

Traditionally, customs duties are forms of taxation paid on imported goods and services. Their primary objective is to protect the community and the domestic production from imported goods and services, as well as collect fiscal revenues for state budget.

In addition, customs duties provide assurance to the importer or the competent authorities in the country of importation that the goods being exported meet the required standards. The most common guarantees of these standards are the certificates of origin, sanitary, phytosanitary certificates, and conformity assessment certificates.

There can be significant challenges for both exporters and importers in the rules used to identify the country of origin of a product and thus on the custom duties to apply.

Logistics

Logistics is an integral part of international trade that involves the process of transportation, material purchasing, warehousing, inventory control and distribution.

By 2018, 80% of the world's trade by volume is carried by sea, which is considered the most cost-effective and efficient means of transportation.[16] Several actors are engaged in logistics, making the process complicated to coordinate resources and necessary documentation.

In the logistics chain, the carrier transports goods by air, land or sea using different means of transportation. Shipment delivery is arranged by the brokers, which are the intermediaries between the shippers and the carriers.

While brokers serve only one aspect of the transportation, 3PL (Third Party Logistics) is an all-in-one logistic provider that offers a broad package of supply chain services.

Tracking and traceability

Current challenges in the supply chain concern the ability to identify, track and trace elements or products that move along its stages. The most explicit case is that of counterfeiting and fraudulent goods, which possess a threat for consumers' well-being, as well as for companies' reputation and revenues.

Among the most vulnerable goods for fraud, are pharmaceuticals, luxury items and other products whose value depends on their originality. Rising importance of product traceability, would help costumers ameliorate their purchasing behaviour, while identifying a product´s origin and its manufacturing processes.

Some of these tracking and traceability requirements go beyond the existing regulations enforcements and can be direct requirements of the importers, the exporters, or other stakeholders in the trade supply chain.

[16] United Nations; Review of Maritime Transport; 2018; pp.1-116.

2.1.2. Overview of blockchain solutions

We present here a general overview of the blockchain-based use cases and solutions targeting international trade.

The following table presents an overview of the main blockchain use cases in international trade, mapped by the different areas of the overall international trade process (presented above). Along with real world examples of implementations the use cases are developed further in section 2.2 to 2.6.

Table 6 - Overview of blockchain international trade use cases by trade area

Transaction type	Key stakeholders	Other stakeholders	Examples of documents processed	Use case	Company/partners	Project description
Commercial	Exporters importers	Banks, insurance companies	Sales contract and trade terms, purchase order, invoice	Decentralised marketplace	OpenBazaar	An open-source protocol for peer-to-peer transactions in a decentralised marketplace
Trade finance	Credit institutions, importers, exporters	Insurance companies	Letter of credit, bill of exchange, insurance	Improving the letter of credit transaction process	ING Brussels and HSBC India with Tricon Energy and Reliance Industries on Voltron blockchain consortium	Digitalising the paperwork with the objective of making the letter of credit process rapid, transparent and secured.
				Limiting the risks of open account financing	UniCredit Italy and KBC Bank Belgium using we.trade blockchain platform to facilitate trade between Gruppo ASA and its supplier, Steelforce	Simplifying trade finance processes underlying international trade for SMEs, to provide security and transparency for the transactions
				Using blockchain for cross-border payment	ReiseBank Germany and ABT Canada using Ripple blockchain for international payments	Enabling financial institutions to process custumers' cross-border payments, at real time and little to no cost.

Logistics	Exporters, importers, transport companies, port authorities	Credit institutions, insurance companies, brokers,	Credit institutions, insurance companies, brokers,	Digitalising supply chain	Maersk, IBM and consortium	TradeLense blockchain Shipping Solution connecting various supply chain participants such as importers/exporters, shipping companies, port operators, customs and other authorities.
					ZIM, Wave, Sparx Logistics	Digitalisation of bills of lading with blockchain
				Marine insurance	Maersk, E&Y, Guardtime, Microsoft and others	Insurwave: Marine insurance platform built on Azure to connect all stakeholders in the insurance value chain with the same accurate, current and secure risk information.
Customs	Customs authorities	Importers, exporters	Export/import licenses, certificate of origin, customs value declaration, customs clearance	Blockchain for customs duties	Korean Customs Service, SAMSUNG SDS Co. and KCNET consortium	Blockchain-based customs platform to facilitate document sharing and information extraction deployed by Korean Customs services as a pilot.
					EU Commission DG TAXUD, International Chamber of Commerce	Verification of the integrity of temporary admission carnets (ATA Carnets). Explore the possible use of the blockchain technology in the context of e-Customs and taxation policies
Administrative	Regulators, national and international authorities	Importers, exporters	Sanitary certificates, conformity certificates	Exchanging trade documentation with other national agencies	Singapore International Chamber of Commerce, vCargo Cloud	Blockchain-based platform for electronic certificates of origin (eCOs) aiming to 'instant verification of eCOs and runs on a private blockchain network that prevents fraud, alterations and third-party interference'
				Using blockchain for government to government exchanges	Mexico, Costa Rica, Inter-American Development Bank	Cadena platform for the management of AEOs

Traceability & transparency	Producers, end users	Authorities	Proof of authenticity, certificates of trademarks	Enforcing trademarks and property rights	Everledger	Blockchain-based system to provide secured proof of origin and ethical sourcing for diamonds
					Modum.io	Track & trace supply chain solution based on IoT, blockchain and AI. Originally launched to track medicines but is also suitable for food, electronics, art objects and valuables.
				Providing additional traceability and transparency	Wal-Mart, IBM	Trace origin and care of food products (e.g. pork from China), Wal-Mart can easily address improper care of food. Wal-Mart joined the Food Trust platform by IBM.

2.2. Blockchain use cases in commercial transactions

2.2.1. Trading on fully decentralised marketplaces

Use case description

The idea of Decentralised Marketplace is to replace traditional e-commerce marketplaces by a decentralised alternative that directly connect buyers and sellers in a Peer-to-peer network.

Decentralised marketplace is rare as a standalone service and does not represent international trade in the common sense of the word, but it represents the applied libertarian vision of the initial blockchain communities of complete decentralisation.

In such a marketplace it is an open-source peer-to-peer platform that constitutes a network without intermediaries where participants can exchange goods (usually with no platform fees for vendors). Items sold via a decentralised marketplace are often paid in cryptocurrencies.

In this simple model, there are two principal stakeholders; the sellers and the buyers.

Benefits and limitations

The key foreseen advantage of a blockchain-based decentralised marketplace is the absence of a middleman taking fees for users. On a blockchain platform vendors are not restricted by any governance, which makes product exchanges more cost-efficient (usually there are no platform fees and costs are only incurred by the use of cryptocurrencies).

In the case of their use in international trading relationships, marketplaces come with added complexity such as different legal systems – from consumer protection to privacy law, or different culture and conception of trust, or simply international fund transfer. A blockchain-based, decentralised marketplace comes with the idea of delegating these issues of trust to algorithms rather than to a centralised platform. This can appeal to a specific tech-savvy market segment.

However these argument are likely to appeal only to a restricted community. Centralised authorities managing marketplaces can provide support to sellers and buyers, assure bank-level security and provide a clear point where states and other regulator can intervene. Additionally current centralised marketplaces benefit from an already strong community that is unlikely to shift rapidly to another provider for a small reduction in transaction fees.

For now, blockchain-based trading platforms remain a niche service rather than a common way of buying and selling goods. This can be seen as a basic limitation of blockchain-based solutions: these technologies are still designed mostly for developers or for tech-savvies.

Examples of existing deployments

The following table presents some examples of existing deployments of this use case:

Table 7 - Examples of fully decentralised marketplaces

Partners	Purpose	Launch date	Status
OpenBazaar	An open-source protocol for peer-to-peer transactions in a decentralised marketplace	April 2016	Active
Particl	An open-source decentralised marketplace with zero fees. It is protocol- and currency-agnostic. The Particl platform also allows smart contracts decentralised applications (Dapps).	March 2017	Beta testing

2.2.2. Storing commercial contracts in a blockchain

Use case description

Blockchain can be applied to facilitate importer-exporter relations by using a blockchain to securely store the contracts and automating sales contract execution through the use of smart contracts.

This can be done with output based smart contracts that are executed when all predefined conditions are met. Two key parties that benefit from blockchain for commercial transactions are an exporter and an importer that want to have guarantees that the contract terms are accurately executed. Stakeholders involved in operations with this type of smart contract solutions are:

- importer
- exporter
- credit institutions
- insurers and insurance brokers.

Benefits and limitations

The main advantage of smart contracts for commercial transactions compared to traditional ones is related to potential cost and time economies for counterparties. International trade deals are usually paper-intensive and involve many intermediaries. All this incurs extra costs and makes the overall contract execution time rather long-lasting. Smart contract applications could replace those intermediaries and help counterparties get full access to contract details faster.

Such blockchain-based solutions could also provide extra guarantees to counterparties as smart contracts are executed based on the output of all the steps of the deal. This might bring more confidence to international commercial transactions and prevent unconscionable deals.

The main limitation comes from the necessity for the different stakeholders to agree on a common infrastructure (i.e. a blockchain) to work together, making the adoption of technology a prerequisite of trade.

Additional limitations can be considered around the risk linked to smart contracts and their legal validity. Major concerns exist along the enforceability of such contracts and the lack of a clear jurisdiction (which national law is applicable and which court is competent considering decentralisation).

Examples of existing deployments

This use case is most often not implemented by itself but rather paired with other use cases presented hereafter such as Trade Finance (linking contract storing and payment), or Logistics (linking contract storing and tracking of products along the supply chain).

Table 8 – Examples of commercial contracts storage in blockchains.

Partners	Purpose	Launch date	Status
Mercedes-Benz Cars, Icertis	Permissioned blockchain-based solution using smart contracts to manage Mercedes's contracts with suppliers. Built on the Icertis blockchain Framework.	February 2019	Development in progress
Maersk, IBM and consortium	TradeLense blockchain shipping solution connecting various supply chain participants such as importers/exporters, shipping companies, port operators, customs and other authorities. The trade document module called ClearWay	2018	ClearWay launched scheduled 2019

2.3. Blockchain use cases in trade finance

2.3.1. Improving the letter of credit transaction process

Use case description

Letter of credit blockchain use cases are highly beneficial to trade finance operations, as they accelerate the transfer of original documents, in a transparent and secured manner. The primary aim is to digitalise the Letter of credit paperwork process, by sharing documents through a permissioned blockchain, with international trading partners and banks being key participants.

Letter of credit blockchain solution, makes it possible to authenticate the source of data and documents enhancing reliability of supply chain financing.

Benefits and limitations

The current Letter of credit process is paper intensive and rather long. In a digital, blockchain-based version, trade partners would benefit from more cost effective transactions and rapid documentation exchange. On that account, blockchain could help their respective banks mitigate fraudulent risks, avoid documentation error and reduce compliance and labour costs. The advantage of a blockchain would be to ensure that none of the two banks can tamper with the digital infrastructure that registers and stores the letter of credit.

Blockchain could also allow in-transit trade finance, for example, through the automated verification of warehousing stocks and shipping confirmations.

However, electronic negotiable instruments registered via blockchain, lack legal recognition at a global level, as laws and regulations differ by the jurisdiction of each country. Even though several countries are revising their laws, most of the jurisdictions give legal effect only to signed writing on traditional paper. Indeed there are significant concerns around the execution of smart contracts, the lack of competent jurisdiction and the automatic completion of contracts.

Examples of existing deployments

The following table presents some examples of existing deployments of this use case:

Table 9 - Example of blockchain use for exchange of letter of credit

Partners	Purpose	Launch Date	Status
ING Brussels and HSBC India with Tricon Energy and Reliance Industries on Voltron blockchain consortium	Digitalising the paperwork with the objective of making the letter of credit process rapid, transparent and secured.	November 2018	Proof of concept successfully completed
HSBC USA, Cargill agriculture firm and ING Netherlands on R3 Corda blockchain platform	Using blockchain to issue a LC and facilitate food trade. Removing the need for paper reconciliation and unlock liquidity for businesses.	May 2018	Proof of concept successfully completed
LC deal of Barclays and Ornua with Seychelles Trading Company on Wave	A blockchain solution to support the supply chain, by digitalising and fastening the transferring of documentation.	September 2016	Proof of concept successfully completed

Bank of America Merrill Lynch (BofAML), HSBC and the Infocomm Development Authority of Singapore (IDA)	Improvement /automation of paper-intensive L/C process with the help of smart contracts.	August 2016	Proof of concept successfully completed

2.3.2. Limiting the risks of open account financing

Use case description

The implementation of blockchain technology in trade finance is expected to facilitate the existing traditional methods that are associated with high costs and paper heavy processes. The primary aim of blockchain solutions for open accounts is to provide fast and transparent transactions while avoiding non-payment risks in the process of supply chain financing.

In this context, blockchain-based platforms facilitate all stages of trade finance, ranging from order creation to payment execution. In particular, the use of a smart contract in a permissioned blockchain, provides guarantees of payment and automatic settlement when conditions determined by the parties are met.

Benefits and limitations

The digitalisation of open account financing is expected to accelerate the trade transaction process while enhancing transparency and security. The creation of a smart contract, would make trade finance transactions considerably faster (by removing long period of time in which actors wait for the other to receive and validate paperwork) and more transparent for both trading partners (by providing a shared, common and secure infrastructure in which transactions are stored and visible).

Additionally, the automated transaction of smart contracts can avoid non-payment risk for the exporters as the transaction is concluded simultaneously and validated by all the actors involved.

Blockchain solution is beneficial to banks, as it avoids the challenge of coordinating multiple players involved in the transaction, fraudulent risks, costly procedures and paper heavy documentation.

However, similarly to the letter of credit use case above, the potential lack of legal recognition of a digital system, and the need to settle for a common technical infrastructure are the main limits to this use case development.

Examples of existing implementations

The following table presents some examples of existing deployments of this use case:

Table 10 - Example of blockchain use in open account trading

Partners	Purpose	Launch date	Status
Eximchain supported MIT and Chinese Trade Manager Platform	Enabling businesses to connect, transact, and share information more efficiently and securely within the supply chain.	December 2018	Proof of concept successfully completed
UniCredit Italy and KBC Bank Belgium using we.trade blockchain platform to facilitate trade between Gruppo ASA and its supplier, Steelforce	Simplifying trade finance processes underlying international trade for SMEs, to provide security and transparency for the transactions.	July 2018	Proof of concept successfully completed

Chinese conglomerate Sichuan Heija using IBM blockchain for Pharmaceutical procurement	Facilitating commerce for pharmaceutical SME, hospitals and banks, to ensure transparency, speed transactions and eliminate inefficiencies in the supply chain.	April 2017	Proof of concept successfully completed

2.3.3. Using blockchain for cross-border payment

Use case description

The blockchain solution for cross-border payment has the potential to resolve inefficiencies and provide a fast, cheap and secured alternative to the traditional banking methods. Blockchain solves these challenges by streamlining the process and simultaneously storing every transaction in a secured distributed ledger.

The transactions in the blockchain are done via digital currencies while the process is accurate, tamper-proof and less costly. They can rely either fully on cryptocurrencies, or use a blockchain to register fiat currency exchanges and transfer.

Many blockchain enthusiast predict that the use of the technology and cryptocurrencies would be of great impact on the financial inclusion of developing countries and highly embraced in international remittances market.

Benefits and limitations

Cross-border payments supported by blockchain could provide significant advantages to businesses and consumers by lowering the transaction fees of international payments. The use of blockchain could also allow for a reduction in delays of reconciliation of payment information.

Companies and individuals would leverage significantly from blockchain technology as the current banking system uses a complex and inefficient infrastructure for cross-border payments that can involve numerous counterparties.

However, the use of blockchain for cross-border payments could increase risks of instability, given the volatile status of digital currencies, used as a medium of exchange in the blockchain. It also raises questions around the ability to investigate and resolve conflict.

In addition, to effectuate a cross-border payment using the blockchain would require an internet connection, while some mobile payment systems operating in the developing countries require only a mobile phone. Therefore, whether this process reduces costs and contributes to financial inclusion is still arguable.

Examples of existing deployments

The following table presents some examples of existing deployments of this use case:

Table 11 - Example of cross-border payment solutions

Partners	Purpose	Launch date	Status
Bank of Canada and Monetary Authority of Singapore partnering with ConsenSys and JP Morgan's Quorum	Transacting via digital currencies to make cross-border, cross-currencies transactions cheaper, faster and safer.	May 2019	Proof of concept successfully completed

KlickEx partners with Stellar.org and IBM blockchain	Transforming the business of remittances by reducing the cost and the speed of the transactions.	October 2017	Proof of concept successfully completed
Circle providing person-to-person payments powered by Ethereum blockchain	Enabling fee-free, instant, cross-border P2P payments.	June 2017	Active service
ReiseBank Germany and ABT Canada using Ripple blockchain for international payments	Enabling financial institutions to process costumers' cross-border payments, at real time and little to no cost.	June 2016	Proof of concept successfully completed

2.4. Blockchain use cases in customs and administrative processes

2.4.1. Using blockchain in customs duties

Use case description

Potential customs-oriented blockchain use cases are majorly related to increasing transparency through information exchange as well as facilitating and reducing the cost and time of customs operations by replacing paper-intensive tasks with relevant blockchain applications. Specifically, customs can improve the process of information extraction from primary sources for declaration purposes through a permissioned blockchain.

Blockchain-based platforms can also optimise the process of customs goods pre-arrival and their expedited release by real-time sharing of the relevant information.

Another possible use case for distributed ledgers at customs is automatic analysis and selection of customs documents based on some pre-determined criteria set in smart contracts.

Potential users of such solutions are typically:

- customs authorities
- exporters
- importers

Benefits and limitations

Blockchain solutions should facilitate and accelerate customs clearance procedures by reducing the time needed for customs declaration processes including data verification. The distributed ledger and tamper proof data stored in the blockchain, would guarantee the authenticity of the information and make its transfer to the authorities of the importing country reliable.

In particular, customs authorities can reduce administrative workload and optimise their receiving capacity. An additional advantage in this use case, would be, through the use of smart contract, to help importers pay custom duties easily and facilitate control over duties payments for customs authorities.

However, such solutions require active participation of importers, exporters and customs in different countries which can be an obstacle as blockchain and smart contracts still lack real-life implementation.

Blockchain use by customs also requires recognition of the technology by national governments. Given the fact that customs applications of decentralised technologies are designed to process sensitive information, governments need to be aware of all possible outcomes of the use of blockchain by customs authorities.

Examples of existing deployments

The following table presents some examples of existing deployments of this use case:

Table 12 – Examples of the use of blockchain in customs duties processing.

Partners	Purpose	Launch date	Status
Korean Customs Service, SAMSUNG SDS Co. and KCNET consortium	Blockchain-based customs platform to facilitate document sharing and information extraction deployed by Korean Customs services as a pilot.	May 2018	Piloting
EU Commission DG TAXUD, International Chamber of Commerce	Verification of the integrity of temporary admission carnets (ATA Carnets). Explore the possible use of the blockchain technology in the context of e-Customs and taxation policies	2017	Development in progress

2.4.2. Exchanging trade documentation with other national agencies

Use case description

Another important opportunity for blockchain is inter-agency exchange of other types of trade-related documents such as:

- sanitary and phytosanitary certificates
- certificates of origin (documents that assert that the goods in a specific shipment comply with the terms of a free trade agreement (FTA))
- conformity assessment certificates
- import and export licenses.

Permissioned blockchain-based platforms can thus serve to share the relevant data issued by various authorities so that importers and exporters can have immediate and easy access to the trusted information.

Smart contract technology can be applied for certificate and licence analysis by customs according to predefined criteria.

This use case usually covers the following stakeholders:

- exporters
- importers
- Government agencies: regulators, tax authorities, police, security services.

Benefits and limitations

Paperless blockchain solutions are expected to considerably facilitate information exchanges and processing among national agencies, importers and exporters. Moreover, blockchain would allow parties to securely store the trade-related documents such as certificates or licenses issued by government authorities so that they are always accessible and cannot be lost.

Apart from that, such faster information exchange can also contribute to identification of fraud related to products' origin or to tackle expired permits. This includes potential tax fraud detection that can be possible in the case of the relevant information exchange between customs and tax authorities.

Yet, actual implementation of decentralised platforms for information exchange might be delayed due to both lack of standards for the technology and generally cautious innovation process among national agencies. Moreover, different authorities have their respective rules regarding documentation processing and the legal framework of smart contract is most often not clearly defined.

Another potential challenge is that customs, importers, exporters, customs and other authorities often do not have the same terminology for the information being exchanged which might raise confusion in document processing. To overcome this difficulty, international organisations such as World Customs Organisation (WCO) and UN/CEFACT have been actively working to develop a standardised language that can be further applied to international trade.

Examples of existing deployments

The following table present some examples of existing deployments of this use case:

Table 13 – Examples of blockchain for exchanging trade documents with national agencies

Partners	Purpose	Launch date	Status
Port of Antwerp, T-Mining, Belfruco, Enzafruit, **PortApp, 1-Stop and T&G Global**	Blockchain-based solution for phytosanitary certificate transfer.	June 2018	Piloting
Singapore International Chamber of Commerce, vCargo Cloud	Blockchain-based platform for electronic certificates of origin (eCOs) aiming to 'instant verification of eCOs and runs on a private blockchain network that prevents fraud, alterations and third-party interference'	June 2018	Active (as a complement to traditional solution)
essDOCS	essCert – an electronic certificate of origin (eCO) solution enabling chambers of commerce to connect eCO data to blockchain platforms and Internet of Things (IoT) devices to improve origin verification	May 2018	Active (as a complement to traditional solution)

2.4.3. Using blockchain for government to government exchanges

Use case description

The principle of G2G information exchange is to use a decentralised permissioned ledger for cross-border exchanges between government agencies dealing with trade (customs, economic chamber of commerce, regulation agencies). Permissioned blockchain-based platforms can be used to store sensitive international trade-related documents, exchange them from one nation state to another and provide immediate access to this trusted data.

The main objectives are facilitation of trade, reduction of the operating costs of the agencies, and an increased efficiency and resilience to fraud.

Benefits and limitations

Blockchain-based inter-government platforms should optimise traditional paper intensive administrative processes, bring more transparency to inter-government trade relations as well as help detect and prevent fraud and other malicious activities in trade at international level.

Such platforms require participation of multiple governments so that participants can maximise benefits brought by trade information exchange. However, implementation of blockchain-based solution for sharing confidential and sensitive data among governments has been rather slow due to complexity of the inter-government document exchange processes and lack of standardisation and trust in decentralised technologies' security. Therefore, it might be hard to assure deployment of a global-scale platform for data exchange as it will require a sufficient number of stakeholders to take part in such a project.

Legal framework is another key requirement for G2G blockchain applications to be massively adopted by government agencies in different countries. Unless the technology is fully recognised at the international level and universal standards, terminology and legal norms are set, widespread use of blockchain-based applications for sensitive government data exchange will be almost impossible.

Examples of existing deployments

The following table presents some examples of existing deployments of this use case:

Table 14 - Example of blockchain use in G2G exchanges

Partners	Purpose	Launch date	Status
Mexico, Costa Rica, Inter-American Development Bank	Cadena platform for the management of AEOs	March 2018	Piloting
Singapore customs, IBM	Singapore Customs Declaration – a blockchain-based platform allowing customs document exchange between Singapore and New York	2016	Piloting

2.5. Blockchain use cases in logistics

2.5.1. Digitalising supply chain exchanges

Logistics is a complex ecosystem that unites multiple stakeholders such as:

- importers/exporters
- logistics and transportation companies
- credit institutions
- insurance companies
- port operators
- customs brokers

- national and international authorities
- customs.

Such a multitude of parties involved in supply chains implies a wide range of documents shared as well as high transaction volumes. The majority of these documents have been created and processed manually. Decentralised ledger-based applications might provide a robust and resistant to modification record of trade history by storing trade-related data in permissioned blockchains so that stakeholders could have real-time access to past transactions and relevant documents such as import and export clearance or bills of lading (a document issued by a carrier (or their agent) to confirm receipt of cargo for shipment).

Logistics also provides opportunities for smart contract implementation: output-based software can be used to automate trade payments as soon as sales contract conditions are executed.

Benefits and limitations

Digitisation of supply chain exchanges can make international trade exchanges faster and more transparent with the help of blockchain. Several potential major benefits of decentralised ledger application to supply chains are as follow.

- Real-time access to all the relevant information by all the participants of international trade processes can reduce administrative costs.
- Asset tracking provides more transparency and can help avoid shipment delays.
- Transport companies can minimise their shipping costs by optimising load capacity.

The entire logistics process can be accelerated by using smart contracts that are executed based on shipping steps completion.

However, while blockchain-based solutions can in theory deliver vast savings to importers, exporters, transport companies and other stakeholders, their implementation effect in real life might be less significant due to certain challenges.

The very first one is associated with current poor adoption of such digital solutions even by commercial operators. Despite growing interest for the technology, companies are still prioritising more traditional procedures in international exchanges.

To unveil maximum advantages of blockchain in terms of rapid and trusted information sharing, a sufficient number of participants (critical mass) of a blockchain-based platform is required.

Examples of existing deployments

The following table presents some examples of existing deployments of this use case:

Table 15 - Examples of blockchain in logistics.

Partners	Purpose	Launch date	Status
ZIM, Wave, Sparx Logistics	Digitalisation of bills of lading with blockchain	November 2017	Preparation for commercial launch
NYK (Nippon Yusen Kabushiki Kaisha, NTT Data Corp + consortium	Blockchain-based trade data sharing platform	August 2017 to March 2018	Pilot completed
AB InBev, Accenture, APL, Kuehne + Nagel, European Customs Organization	Blockchain-based platform to share shipping documents (including bills of lading and customs manifests) among multiple parties	n/a	Tests completed in 2018
Scanlog, ShipChain	Shipchain's end-to-end blockchain platform using sidechains and smart contracts to help with the track-and-trace of Scanlog's freight moving across the company's global logistics network	February 2019	Piloting
Port of Antwerp, T-Mining and NxtPort	Smart contract-based application to track shipping containers during their release to trucks in the terminal: securing transfer of assets and data in the logistics and transport community	June 2017	Piloting
Modum.io	Track & trace supply chain solution based on IoT, blockchain and AI. Originally launched to track medicines but is also suitable for food, electronics, art objects and valuables. IoT sensors and web/mobile apps to track goods along the entire shipment process.	2016	Active

TradeLens

TradeLens is a blockchain platform launched in 2018 by Maersk in partnership with IBM. It aims at connecting various supply chain participants such as importers/exporters, shipping companies, port operators, customs and other authorities.

The following parties have already joined the TradeLens platform:

- DuPont
- Dow Chemical
- Tetra Pak
- Port Houston
- Rotterdam Port Community System Portbase
- The Customs Administration of the Netherlands
- U.S. Customs and Border Protection.

According to IBM and Maersk, more large industrial players (General Motors, Procter and Gamble), port operators (APM Terminals, PSA International) and public agencies (Singapore Customs, Guangdong Inspection and Quarantine Bureau) have also expressed their interest in collaboration with TradeLens.

2.5.2. Blockchain in marine insurance

Use case description

Marine insurance is a supply chain-specific insurance aiming to reduce risks associated with freights such as damages or shipment delays. Blockchain-based marine insurance platform enables automatic claims and premiums though smart contracts according to certain conditions met (Once coverage is approved, policy documents are automatically issued to ship operators). Other typical functionalities of such platforms include real-time shipment information sharing among importers, exporters, insurers and brokers and tracking of exposures by insurance companies.

Blockchain application to marine insurance is different from other insurance types as claim assessment can be held without human intervention and are based on incorruptible data regarding the freight such as weather conditions or vessel speed.

Benefits and limitations

Apart from standard advantages of blockchain such replacement of manual paper-intensive processes, marine insurance platforms might bring individual benefits to all participants:

- Importers, exporters and transport companies can reduce their respective risks so that all potential losses can be covered on time.
- Insurance companies can rapidly manage exposures so that all premiums and claims are paid faster compared to traditional paper procedures.
- Brokers could reduce their administrative charge and focus more on customer relation.

At the same time, while smart contracts seem an efficient solution for marine insurance, certain concerns still exist. To be able to correctly implement blockchain-based solutions to automatically assess and pay claims, insurance companies should be careful with setting adequate parameters for smart contracts to avoid ambiguity in assessment.

Examples of existing deployments

The following table presents some examples of existing deployments of this use case:

Table 16 - Examples of blockchain use in Marine Insurance

Partners	Purpose	Launch date	Status
Maersk, E&Y, Guardtime, Microsoft and others	Insurwave: Marine Insurance platform built on Azure to connect all stakeholders in the insurance value chain with the same accurate, current and secure risk information.	2017	Active
American International Group (AIG), IBM and Standard Chartered Bank	Multinational, smart contract based insurance policy using blockchain. The pilot solution was built in the Hyperledger Fabric framework.	June 2017	Piloted 2017 no info since then

2.6. Blockchain use cases for tracking, traceability and transparency of trade

2.6.1. Enforcing trademarks and property rights

Use case description

Blockchain can be used to store and access securely proof of authenticity, certificates of trademarks and other information identifying the product in order to limit counterfeiting in international trade. Such solutions are usually applied to prevent fraud on such markets as pharmaceuticals, diamonds, art objects, luxury and other complex goods. In other words, they would be useful for any goods, the value of which depends on their originality.

Such traceability solutions usually require labelling with a special tag that contains the information about the product allowing verification of its authenticity by scanning it with a dedicated application. End consumers, authorities and other stakeholders can then check if the product is genuine and not stolen.

There is a range of companies that have been offering blockchain-based anti-counterfeit traceability solutions for several years already. For example, Everledger started with a blockchain-based platform to verify the authenticity of diamonds but later extended its offering to wines, art objects, luxury products and even insurance.

Benefits and limitations

Anti-counterfeit blockchain solutions could help manufacturers save the product value that is strongly correlated to its unique identity. In this context, blockchain technology would help in preventing duplications (providing a unique identifier stored in a secure database) and monitoring the exchange of the product throughout the supply chain.

Given that goods in the blockchain are tracked throughout the supply chain and transactions stored, retailers can verify if the products received are genuine or not. Moreover, the verified history of each product would help consumers identify products authenticity.

Besides, consumers also benefit from more certainty of buying original products (and not counterfeits) which is reassuring especially for critical products (medication) or products with traditionally high prices (luxury). Finally, national and international authorities can use the blockchain technology to investigate and prevent fraud-related crimes, find stolen items and identify fraudulent transactions.

Even though blockchain can be efficient in reducing counterfeit, there is still a discussion on whether such a technology is really needed for these purposes or products' identity can be protected with less advanced and less costly measures.

Examples of existing deployments

The following table presents some examples of existing deployments of this use case:

Table 17 - Example of blockchain use in trademark and property right enforcement

Partners	Purpose	Launch date	Status
Everledger	Blockchain-based system to provide secured proof of origin and ethical sourcing for diamonds	2015	Active
Crystalchain	Blockchain-based solution called Blockpharma built on the Tracey blockchain platform by Crystalchain aiming to identify counterfeit medicines	2016	Active
Block Verify	Blockchain-based anti-counterfeit solution to trace pharmaceuticals, luxury items, diamonds and electronics	2015	Active
VeChain	Public blockchain-based track & trace solution for various industries from retail to automotive	June 2015	Active
Chronicled	A range of blockchain-based supply chain solutions including traceability, revenue management, master data management and compliance solutions. Multiple vertical markets covered from pharmaceutical to agriculture	2014	Active
Modum.io	Track & trace supply chain solution based on IoT, blockchain and AI. Originally launched to track medicines but is also suitable for food, electronics, art objects and valuables.	2016	Active

2.6.2. Providing additional traceability and transparency in trade

Use case description

Not only information on sensitive products such as diamonds or drugs can be shared with the help of blockchain. General data of goods such as their origin, composition or steps followed along the supply chain can be also accessed by final consumers, importers and authorities through blockchain-powered solutions.

Although mostly similar in implementation to the enforcement of trademarks and regulation use case, this use case focuses more on providing additional information to the end-consumer.

One of such applications has appeared in retail and particularly at the largest supermarket chains such as Wal-Mart in the US and Carrefour in Europe: companies allow consumers to get detailed information on a product that is stored in blockchain and importers can easily track the status and location of food products.

Benefits and limitations

Use of blockchain for traceability of goods should help improve market transparency and have a positive impact on product brands. The use of a blockchain would provide a trusted database in which all stakeholders along the supply chain can register in real-time information about a given good (transit location, time and conditions). This would increase the traceability of goods, helping for example to track any violation of the cold chain (key for food safety and medication safety).

Another advantage of this use case is that it differs from most other trade related use cases in that it can be largely deployed in a voluntary basis, without any requirements for global adoption. Producers and consumers that are willing to publish / consult additional information on the product can start the implementation of such a use case without the need for a whole ecosystem to adopt it at once.

At the same time, blockchain solutions are still new and the level of adoption is relatively low which might make their use inefficient. It is also debatable if blockchain is actually needed for such applications or the same result can be reached with less advanced and more widespread technologies.

More importantly, the actual value added for the consumer of increased traceability and information on the product origin are relatively limited, and as such the incentive for implementation can be restricted only to specific products and consumer communities.

Examples of existing deployments

The following table presents some examples of existing deployments of this use case:

Table 18 - Examples of traceability use cases

Partners	Purpose	Launch date	Status
IBM	Food Trust: Permissioned blockchain-based platform for food supply chain visibility connecting growers, processors, distributors, and retailers. Solution built on Hyperledger Fabric	2018	Active
Wal-Mart, IBM	Trace origin and care of food products (e.g. pork from China), Wal-Mart can easily address improper care of food. Wal-Mart joined the Food Trust platform by IBM.	2018	Active
Carrefour, IBM	IBM Food Trust-based solution enabling shoppers to track each stage of production through their smartphones. Carrefour joint Food Trust blockchain platform by IBM	2018	Active

3. Analysis of key expectations and challenges

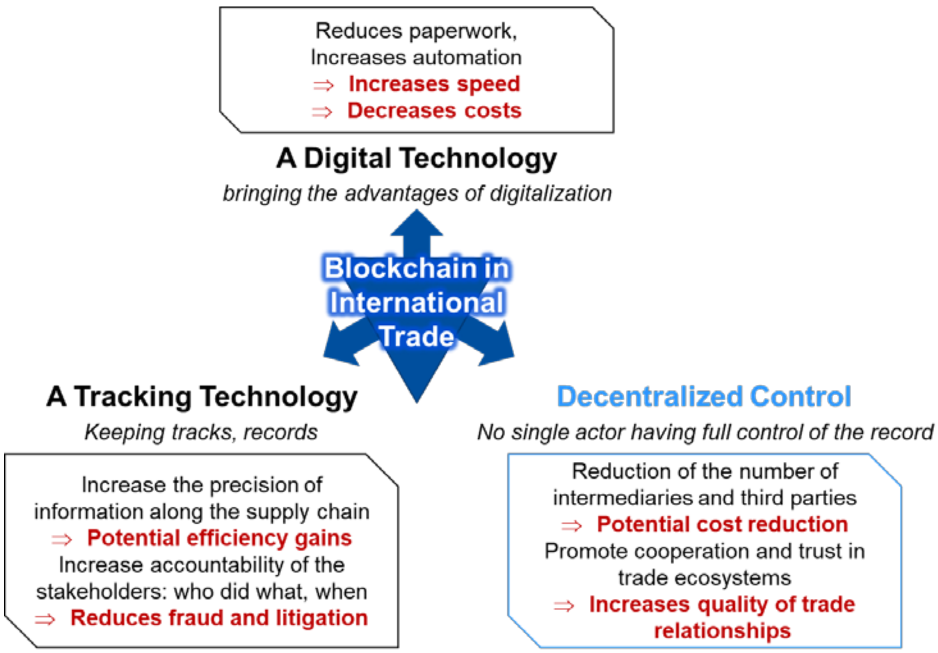
3.1. Expectations on blockchain adoption in international trade

The development of blockchain in international trade is attracting a lot of interest. As presented above in section 2, numerous use cases exist for the adoption of blockchain in international trade. This interest is directly linked with the expectations that blockchain can be a solution to both cut costs, and increase the efficiency of international trade. We present in this section some of these expectations.

3.1.1. Blockchain value proposition for international trade

To understand the expectations regarding the benefits of blockchain technologies in international trade, we propose a mapping of the value proposition of blockchain applied to international trade. To fully understand these expectations it is important to realise that some of them are not specific to blockchain technology, but rather general benefits of the adoption of digital technologies and/or tracking technologies.

Figure 7 – Key value propositions of blockchain for international trade



Source: IDATE DigiWorld, 2019.

The benefits of digitalisation

The first benefits identified for the adoption of blockchains in international trade use case are often mainly linked with the benefits brought by any digital technology: a reduction of paperwork, and potential additional gains linked with an increased automation.

Many of the advantages presented in blockchain adoption scenarios, and especially the increased speed and decreased costs are not specific to blockchain technology, but rather generic to digital technologies.

In many cases, international trade processes rely still heavily on paperwork and paper documentation: bills of ladings, letter of credit, customs documentations, etc. Adopting a digital equivalent to these paper based process would allow a speeding up of the process (reduction of transmission times, reduction of errors, automation of treatment and analysis) and a reduction in cost (personal costs linked with handling of paperwork).

This can be realised both by using a decentralised control system (such as blockchain) or a centralised one (such as a centralised data base). The expected benefit of blockchain would in this case be mainly to facilitate the digitalisation by offering a digital infrastructure that can be trusted by the ecosystem.

A tracking technology

At heart, blockchain technologies are technologies of tracking, keeping records and traces. They are not the only technological option for this and can need the support of other digital tracking technologies (such as IoT sensors) but a significant share of their value proposition comes from this ability to keep traces.

They are seen has having a potential to increase the precision of the information exchanged along the supply chain and trade ecosystems, thus increasing the efficiency of the exchanges.

This would also increase the accountability of the different stakeholders, with an increased visibility on their action and responsibility, leading potentially to a reduction of both fraud and litigations.

Decentralised control

The decentralised control of blockchain technologies is the main differentiator between blockchains and other decentralised data storage technologies.

The decentralised control brought by blockchains can help reduce the number of intermediaries and third parties involved in trade exchanges, with a potential reduction of costs.

But most importantly it is seen as a tool that can promote cooperation and increase the trust between the actors of the trade ecosystem. In international trade, trade partners seek secure and fast commercial transaction to ensure the exchange of goods and services. This requires mutual trust and the setup of complex relationships. Blockchain ability to delegate the trust to algorithms has led to expectations that it can benefit the global trade ecosystem.

3.1.2. Expectations per use case

The following table sums up the main expectations of benefits and drawbacks identified for the different use cases analysed in section 2.

Table 19 - Key benefits and drawbacks of adoption of blockchain by trade use case area.

<table>
<tr><th>Trade use case area</th><th>Benefits</th><th>Drawbacks</th></tr>
<tr><td>Commercial</td><td>• Reduced cost and document processing time.
• Easier information access.
• Easier fraud detection.
• Improved trade data accuracy.</td><td rowspan="2">• Lack of sufficient legal framework Oracle Problem: blockchain can guarantee the origin and non-tampering of the document, does not protect against false declaration.
• Lack of standards.
• Limited interoperability of solutions.</td></tr>
<tr><td>Finance</td><td>• Financing cost reduction.
• Fraud detection.
• Payment automation with smart contracts.</td></tr>
</table>

Logistics	• Easier and more accurate asset tracking. • Minimisation of shipment delays. • Cost reduction due to load capacity optimisation. • Reduced administrative costs. • More transparency.	• Lack of universal language for cross-border information exchange to be used by various stakeholders. • Technology has to be adopted by all stakeholders so that it works properly.
Customs	• Easier fraud detection. • Reduced administrative costs. • More accurate identity verification.	
Administrative	• Easier and faster information exchange among government agencies and other stakeholders. • Easier crime detection. • Reduced administrative costs.	
Traceability & transparency	• Easier fraud detection. • Protection of value of original goods and items. • Food safety with food traceability solutions.	

3.2. Drivers and barriers for adoption of blockchain in international trade

The following section looks at the potential forces that will impact blockchain adoption in international trade, either as drivers of adoption or as potential limits delaying or blocking adoption.

3.2.1. Drivers for adoption of blockchain in international trade

An efficient technical solution

Blockchain solutions start to be well demonstrated both as a general technology and in the specific needs of international trade use cases. Since their onset 10 years ago, they have shown proof of their security.

Although in that respect, no system is ever perfect, and breaches have been exploited on the boundaries of the system (such as local attacks on cryptocurrencies exchanges or exploits in smart contracts), the overall security of the blockchain principles are overall well demonstrated. The relative high prices (despite important volatility) of blockchain backed assets (such as bitcoin and ether) is a good indicator of the trust of the security community in the main cryptographic algorithms behind blockchain. A serious breach in these algorithms would lead these assets to collapse instantly.

The efficiency of the blockchain system is more debatable, especially for public blockchains (energy and resource use). But in the case of permissioned blockchain it is expected that their efficiency is quite similar to traditional centralised digital systems.

As such, blockchain is, from a technical standpoint, a credible technological option, which can be considered as mature enough for adoption in specific scenarios.

Their most notorious use (and thus technology demonstration) remains in cryptocurrencies. Beyond that many sectors (including international trade) are seriously considering their adoption with numerous pilots and early full size applications. This shows a technology that is slowly reaching maturity, thus increasing the prospects of adoption in years to come.

A shared investment

Another potential driver for the adoption of blockchain comes from the relatively low investment needed to deploy blockchain technology.

By essence blockchain is a shared infrastructure, requiring a shared investment. The cost (which in any case is relatively low) can thus be spread among several actors.

Good perspectives of return on investment

The demand for blockchain solution is also driven by relatively clear perspectives of return on investment. As presented above there are important expectations regarding the ability of blockchain to reduce trade costs and delays, improve the overall efficiency through better tracking of goods throughout the supply chain, and reduce fraud through systematic oversight.

A demand for digitalisation

As also explained above some of these benefits are not necessarily specific to blockchain technologies but rather general characteristics of digital and tracking technologies.

As such blockchain is seen by many actors as an occasion to digitalise trade and the processes associated. A part of the interest in blockchain is thus opportunistic: harnessing the blockchain trend to increase the adoption of digital technologies in trade

Beyond that, blockchain´s main advantage can be to facilitate the adoption of digital infrastructure. It can indeed rely on its ability to simplify the question of control of the infrastructure (by ensuring that no single actor has full control over it) in order to facilitate the adoption of a digital solution.

Potential for new services

Although the main benefits of blockchain are, as we have seen, linked with reduction of the cost, and increase of the efficiency of existing processes; there could be opportunities for some actors to set-up new paid for services thanks to blockchain.

The most likely candidates for such new services would be of tracking and traceability services (as described in section 2.). These could be sold to a final customer as 'premium' tracking to increase revenues. The perspective of these new services can thus also act as a driver for the adoption of blockchain.

The support of essential actors

Finally the existing interest and/or support from various important stakeholders of the international trade ecosystem further reinforce the likeliness of adoption of blockchain-based solutions in international trade.

Interest for blockchain solutions has been expressed by various key stakeholders that can each have an ability to push significantly for their adoption

- Financial institutions have expressed an interest in blockchain for trade finance and insurance. Their direct control of financing instruments gives them a strong position to push for technology choices.
- Customs and other administrative authorities have expressed their interest in blockchain-based solution that would facilitate their oversight of trade. They have a significant ability to push for adoption through the set-up of regulations.
- Large players of the logistic world, such as maritime freight company have also expressed their interest for the use of blockchain to digitalise the exchanges throughout the supply chain. Their key position in the trade and logistic ecosystem can also be an asset for them to push for technology adoption.
- Furthermore, IT solution providers are seeing blockchain as an opportunity to provide technology and infrastructures to trade actors and are thus likely to push for the adoption of such solutions.

For now this interest is mainly demonstrated by the resources committed by these actors in technical developments and proofs of concept deployments. Although this could be overestimated and linked with a passing trend, it none the less shows a window of opportunity in which the technology could be adopted.

3.2.2. Barriers for adoption of blockchain in international trade

Despite the many forces pushing for blockchain adoption in international trade use cases, there are some serious limitations that could hamper adoption.

Maturity issues

Although many projects using blockchain have been set-ups on numerous use cases, most of them remain at the stage of proof of concept. Significant technical issues can exist for scaling up these deployments. Ranging from performance issues to the integration of legacy data or the interconnexion with existing IT infrastructure or other blockchains.

As such, although the proof of concept have been able to show the viability and efficiency of blockchain solutions, further delay may be needed to industrialise the solutions and enable them to scale.

Lack of standards

The lack of common standards is another important potential barrier to the adoption of blockchain in international trade use cases.

Indeed the use of a common infrastructure (blockchain) to exchange documents and data in an international context requires that clear and unambiguous standards, templates and data format have been defined beforehand (to ensure semantic interoperability). In many case these standards are still missing or being defined, this is likely to delay the adoption of blockchain in international trade use cases.

Additionally, beyond this issue of semantic interoperability, the offerings of blockchain solutions are multiplying (as described in section 1), often without being interoperable. This can further delay the large scale adoption if several concurrent system start to be implemented in parallel by different actors.

An uneven return on investment

Event though, as presented above, the implementation of blockchains in international trade use cases is likely to have significant return on investment, there are uncertainties on how this return on investment can be spread among the ecosystem.

As blockchain requires a shared investment and adoption, it is likely that disparities in the benefits from blockchain implementation could lead some actors of the ecosystem to try to delay a global adoption.

A need for global adoption

Additionally, to maximise the benefits of blockchain adoption as an infrastructure of international trade, many use cases (such as logistics, trade finance or customs use cases) require a large, if not global, adoption of the technology.

Limited deployment gathering only a handful of actors is likely to generate only minimal cost reductions (or even come as an additional burden for players having to handle this new infrastructure while maintaining the traditional processes fully operational).

This can raise serious concerns on the rapid adoption of blockchain in these use cases.

Adaptation of regulations

The adoption of blockchain in many international trade use cases also requires adaptation of the existing regulations and administrative process. This is especially the case for the customs and administrative duty use cases, but can also concern trade finance, logistics, or commercial transaction use cases.

Although several state actors have expressed their interest in facilitating the adoption of blockchain through evolution of their regulation and processes, this adaptation is likely to take time and potentially delay the adoption.

This is reinforced by the fact that the adaptation is often needed not only in a single state, but in all the participants of international trade. There is thus a need for Government to Government cooperation and harmonisation.

Enforceability of blockchain contracts

Finally, specific legal issues exist around the enforceability of smart contracts. In the current situation, smart contracts cannot be considered to have the same legal force or enforceability as traditional contracts.

First, although improperly named contracts, smart contracts cannot be considered as legal contracts and have no legal value by themselves. They need to be the digital interpretation and implementation of pre-existing, traditional, legal contracts. This can be an issue especially when it is required to validate that the 'smart contract' implementation is indeed strictly compliant with the term agreed by the parties in the real contract (validating all the potential outcome of a computer programme is a non-trivial task).

Secondly, questions exist around the applicable law and jurisdiction around smart contracts, especially in an international context. Potential adaptation of existing regulation could be required.

Finally the nature of traditional blockchains, and especially the irreversibility of transactions can be an issue by preventing appeal and litigations process around the execution of the contract.

These issues do not fully prevent a potential use of smart contracts in international trade, but require a case by case analysis and more scrutiny to ensure their legal validity. This has a potential to delay the adoption of the most advanced use cases of blockchain in international trade.

3.3. Vision of development and key uncertainties

3.3.1. Perspective of development

As presented above, the adoption of blockchain in international trade has raised important expectations from various stakeholders. However the perspective of adoption faces, as we have seen, conflicting market forces (drivers and barriers) that create uncertainties.

Taking these elements into account, at this stage what can be assumed as a major trend is:

- A continued short-term interest in experimentation and proof of concept deployments around blockchain around a large diversity of use cases (presented in section 2).
- The larger scale deployment of solutions mainly around the tracking, traceability and transparency use cases that face significantly less barriers to adoption, as they require neither a global adoption nor significant evolutions of the legal framework. However their impact is likely to stay limited (they provide increased information for the end consumer and can limit fraud and safety infringement but are often specific to a particular type of goods and don't impact the whole international trade ecosystem).
- Another aspect of international trade that is likely to be impacted relatively rapidly is the use of blockchain for cross-border payments. Here again, blockchain-based solutions can be adopted rapidly as they don't often require global coordination or administrative and legal adaptation.
- A more general global trend toward the digitalisation of exchanges of information in international trade, for which blockchain can clearly be an instrument and even a catalyst. Especially owing to its ability to provide a 'neutral' infrastructure for exchanges among stakeholders that have potentially conflicting interests (neutral in the sense that the control of the technical infrastructure is shared among the stakeholders). But the actual extent to which blockchain will be used depending on the use case remains uncertain.

3.3.2. Key uncertainties

We have also identified some key uncertainties related to the development of blockchain in international trade, that spread among different dimensions and that require further investigation.

Trade dimension

The application of blockchain technologies in international trade poses specific uncertainties related to the unique characteristics of international trade.

Cross-border transactions, almost by definition, routinely have to deal with different legal systems, cultures and languages, technical standards and norms, and tax systems, among many others. These differences create challenges as well as opportunities for blockchain. While blockchain can facilitate trade data flows, it also requires adjustments to the systems that have been put in place to ensure data flows are reliable and can be understood and processed by all actors.

International trade deals with cross-border barriers by requiring certification in the form of multiple documents. This burden of proving compliance — through documents such as proof of origin or phytosanitary certificates — can be reduced through blockchain by automating and digitising transactions, which facilitate the integration of the multiple documents that are required. The challenge lies in ensuring that this integration happens in a homogeneous manner, where there are legal equivalents across countries for these 'merged documents'.

One of the things blockchain is set to facilitate is the exchange and use of information across the steps in the value chain, aligning the flow of goods, information and money. Different players across the value chain with access to a ledger would have access to the same documents, such as the purchase order, certification of origin, the product's eligibility for a concessionary European tariff, an updated record of its physical condition, or phytosanitary certificates.

This alignment however, requires a common language. Different actors in trade, such as customs, logistics companies and traders often do not use the same technical language and often view data differently. Blockchain efficiency gains through linking these actors who depend on interoperability across the steps in the value chain. The challenge is developing standard datasets that cover all data used for information exchange for import, export, transit, transportation and finance and having the administrative alignment to implement them.

While digitisation of the burdensome 'paper trail' of trade is neither new nor limited to blockchain, the barriers remain the same. For example, as far back as 2008 a UN convention adopted or extended the recognition of electronic documents. However, to come into force it must be ratified by 20 countries. 10 years later, as of 2018, only four countries had.[17] While technical obstacles in interoperability still exist, institutional barriers create a larger resistance to digitisation.

In addition to legal equivalents and a common language, there is a need to align processes. One example of the translation of international procurement processes into blockchain-friendly legal procedures.

Social dimension

Like all new technologies blockchain also has social implications. The increasing use of blockchain might create winners and losers due to a potentially uneven adoption of blockchain or an uneven distribution of the costs and benefits of blockchain adoption across different social groups.

Just as blockchain can lower barriers to entry into international trade for small companies and producers and so act as a force for inclusion, this relies on actors having the resources to participate in the technology, from the technical knowledge to the internet access. The challenge lies in ensuring that the digital gap is breached as blockchain is taken up – between developing and developed countries but also between actors in the same market.

Furthermore, blockchain can have social effects if improper verification processes exist. For example, the technology is expected to facilitate communication and verification of ethical and social claims in trade transactions. While this has great potential for bolstering sustainable trade, it needs to be backed by an offline verification process that gives credibility to the information that is being shared. Blockchain can only facilitate fair trade insofar as this verification process is in place and connects the online information to the offline processes.

Additionally, the ease of making transactions using blockchain also allows individuals to execute transactions in anonymity. This could be especially a challenge if blockchain technology is used to facilitate illegal activities, including trade in illegal goods or trade-based money laundering. The challenge is to have a network in place that will still allow for some kind of tracking of payments despite this anonymity.

Economic dimension

Widespread adoption requires not only technical functionality but also that the economics of blockchain work out for potential users. Blockchain technology offers economic benefits due to its potential in: 1) reducing the costs of verification and 2) the costs of networking. The first results from lower costs of auditing transaction information and the second from omitting the need for

[17] The Economist, The digitisation of trade's paper trail may be at hand, 2018

intermediaries. In short, blockchain could eliminate the rent extracted by actors currently acting as trusted intermediaries.

These benefits come however with costs. In general, decentralisation is associated with three main costs: 1) waste of resources; 2) problem of scalability; and 3) inefficient network effects. These costs have to be weighed against the benefit of increasing competition when assessing the economic impact. Furthermore, the benefits are associated to the creation of a fully decentralised marketplace, but creating such a market on a large scale requires huge amounts of computational power to make it as efficient as current systems. A permissioned blockchain and therefore a more centralised one might also be required due to the issue of enforcement. While the technology is excellent in transferring ownership, it cannot guarantee transfer of possessions. Therefore, centralised entities such as government agencies might remain necessary for enforcement and supervision.

These economic uncertainties are perfectly summarised in the 'blockchain trilemma'[18], whereby no ledger can fully satisfy the three desirable properties of decentralisation, correctness, and cost-efficiency. Traditional ledgers are correct (or trusted because of the reputation of the intermediary) and cost effective, while blockchain can be decentralised and correct, but not cost-effective at the same time.

Technical dimension

A number of technical uncertainties are identifiable at the current point in time.

First, the aspect of **anonymity** can be viewed as an advantage on one hand, but also as a major issue and uncertainty of the blockchain concept in general. The blockchain anonymity can protect the belonging participants and ensure their privacy thereby fostering the decentralisation of key societal processes, protecting freedom (of speech), supporting democracy and allowing for the development of a fair ecosystem with a minimal burden for on boarding new participants and stakeholders. Especially, in the area of *trade finance*, *tracking and trade transparency* as well as *commercial transactions*, these properties might be crucial for establishing a new advanced level of sophisticated and easily accessible environment for international trade.

On the contrary, the blockchain anonymity constitutes a considerable downside in public permissionless blockchains where it can be misused to facilitate illegal activities, such as the sharing of criminality-related content and the execution of illegal payments and transactions, thereby hindering the traceability of criminal activities (on the blockchain) to real persons.

An additional aspect that was identified and poses an uncertainty in the scope of the described use cases (and other scenarios of a similar type) for blockchain-based supply chains in international trade is constituted by the **splitting of blockchains**, which should be viewed as a major concern in the context of public permissionless blockchain environments. Thereby, the trust space created by a blockchain is potentially divided into small fragments, which can be individually misused for initially unintended goals such as the abovementioned ones (e.g. criminal activities, illegal payments, tax fraud, drug trade …).

The above described aspects would be of major concern in all use cases where the belonging set-up and implementation could use permissionless blockchains, e.g. commercial transactions, logistics, tracking/traceability and transparency of trade.

Another serious technical concern relating to the application of blockchain in international trade supply chains is given by the still rather **slow convergence of the distributed algorithms,** when it comes to the verification and approval of transaction blocks. The current state of the art within the

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[18] J Abadi, M. Brunnermeier, blockchain Economics, June 2018, Princeton University. Available at: https://scholar.princeton.edu/sites/default/files/markus/files/blockchain_paper_v3g.pdf

main available blockchains requires a considerable time for this process, which makes it cumbersome to realise scenarios where fast responses are required from the underlying blockchain-based item tracking system (for instance) – e.g. the tracking of objects based on QR codes would be limited in its manifestations like handheld scanning devices etc. Moreover, the **scalability** of the employed blockchain technology - in terms of response capabilities, resource consumption and integration of growing number of participants – can easily become an issues for large scale use cases in an international worldwide context. Hence, it remains to evaluate the capability of modern blockchain platforms with respect to the required characteristics in global trade and supply chain set-up.

Furthermore, the distributed nature of the mining algorithms might lead to **Increased network bandwidth utilisation**, which could turn into a problem in situations where a particular participant is limited in terms of network resources, e.g. in a mobile set-up with a belonging radio connection.

Potentially, all of the use cases listed in this document might suffer from the above mentioned uncertainties depending on the utilised algorithms, computing resources and available bandwidth.

Security dimension

With respect to security, blockchains might be vulnerable to various cyber-attacks such as manipulation attacks, security channel replay attacks, man-in-the-middle attacks etc. Hence, an uncertainty is provided by the question regarding whether proper countermeasures have been undertaken, in order to protect the blockchain infrastructure and the involved nodes. Furthermore, it is of paramount importance to guarantee the immutability of blockchain blocks and belonging transactions – correspondingly **The risk to breach immutability** should be minimised for blockchain-based platforms and viewed as an uncertainty.

In general, implementation vulnerabilities and cyber-attacks can lead to the manipulation of belonging blocks and destroy the core of the blockchain idea – the unchangeable storing of data in a distributed manner avoiding set-up based on central authorities. Thereby, the attack scenarios can involve the manipulation/hijacking of cryptographic material, man-in-the-middle as well as, replay attacks and further approaches based on gaining unauthorised access to particular blockchain nodes.

In addition, the aspects of anonymity should be carefully dealt with when considering the handling of transaction history (in a permissionless context) given that real persons can easily acquire new identities in a blockchain environment and basically drop previous negative transaction history thereby compromising the trust and reputation space.

The above elucidated aspects are especially critical in open permissionless environments where random persons/institutions/organisations could access the blockchain infrastructure and initiate different types of cyber-attacks as well as potential manipulation of the transaction history. Especially, use cases within the area of traceability and tracking for transparency in trade, in addition to scenarios in the areas of logistics and financial transactions in general, may suffer from shortcomings relating to these security uncertainties.

Environmental dimension

The main environmental risks relating to blockchains are given by the **increased energy consumption** and the belonging **negative impact on CO2 emissions**.

For example in the case of proof of work mining algorithms, it is inherently the case that large amounts of energy are invested in the computational solving of complex mathematical problems towards the validation of the issued transactions. This will have an indirect impact on the amount of CO2 emissions required for energy production within the particular scope.

In order to meet this type of uncertainties, novel transaction validation algorithms and approaches are required as for example the proof of stake and proof of Authority concepts as currently being implemented in key blockchain platforms like Ethereum. In general, all types of use cases described in this document could lead to the above mentioned environmental issues given that corresponding energy demanding transaction validation algorithms are put in place.

Transparency and privacy dimension

Enabling transparency and accountability is one of the biggest potentials of blockchain technology, which provides a fully auditable and valid ledger of transactions. Among the appealing possibilities offered by the blockchain is the degree of privacy that it can provide. However, this leads to some uncertainties on the possible coexistence of privacy and transparency and to the necessity to balance the two concepts to the benefit of users.

Transparency is identified by some authors as the extent to which information is readily available to both counterparties in an exchange and also to outside observers. Specifically, the transparency of a blockchain stems from the fact that rather than relying on centralised intermediaries, this technology allows two parties to transact directly. Consequently, transactions of each public address are open to viewing and are executed without relying on explicit trust of a third party, but on the distributed trust based on the consensus of the whole network, made up by all blockchain users. Through the necessary encryption mechanisms, blockchain safeguards transparency by storing information in such a way that it cannot be altered without recording the changes made.

It has been argued that blockchain, adding a degree of accountability that has not existed to date, may bring supply chain transparency to a new level. The technology can allow, for instance, for the robust tracking of anything across the supply chain, meaning that consumers can know exactly what the products they purchase contain and where they come from, including supply sources and complete manufacturing history, thus providing context to a final product or service.

Nonetheless, both transparency and privacy in the context of blockchain are neither absolute nor unconditional as various degrees of transparency and privacy are offered depending on the domain of application and the type of blockchain which is being used (Kritikos M., 2018).[19]

As pointed out, issues related to transparency and privacy are different depending on whether the blockchain is permissioned or permissionless. The encryption and immutability features of blockchain indicate that certain types of blockchain prioritise privacy and confidentiality at the expense of transparency.

Permissionless blockchains, where data is shared publicly in a format allowing any user to join the network, offer a high degree of transparency. Given that 'no central governance' is an important feature of the network, for participants to be incentivised to run and trust the network, transparency is paramount. On the other hand, they might raise privacy-related risks such as a reversal risk or the risk of linkability of personal data even in encrypted or hashed format. In addition, anonymised information, combined with issues related to enforceability, can make very difficult to identify the one responsible for a possible breach of contract, damages and crimes.

19 Kritikos, M., What if blockchain offered a way to reconcile privacy with transparency?, http://www.europarl.europa.eu/RegData/etudes/ATAG/2018/624254/EPRS_ATA(2018)624254_EN.pdf

This risk is removed in permissioned solutions where a network participant needs authorisation to transact with another participant, and transactions take place in a closed system where transaction data remain confidential and participants are known and authenticated.

In addition, in permissioned blockchains, having transparency in the work performed by each node may not be as important to network members as it is in the permissionless blockchains. It all depends upon how the business relationships are set up and how the blockchain is configured. The primary incentive of permissioned blockchain participants is to minimise the cost, time, and ease of sharing information.

In international trade, permissioned blockchain may be more suitable in certain cases, such as for manufacturing, since it gives control to on-board, only to supply chain partners as a node providing enough transparency for decision making also protecting business secrets.

The security and transparency of a supply chain is granted by the legal obligation of distributors to provide information of sale to their supplier source, and of material information to their customers. Similarly, in banking transaction, permissioned blockchain can provide security, transparency and accountability without putting at risk business and personal data of the parties involved in the transactions.

In this case, transparency works when all the stakeholders are part of the blockchain network. There is the need for supervisors and authorities to be part of the permissioned blockchain in order to exercise the necessary controls.

In other cases, such as foods products, there may be public interest in having access to traceability of the supply chain in order to protect public health and safety. Therefore, permissioned blockchain may limit the provision of such information. Permissionless blockchains seem more suitable for business-to-consumer (B2C) and consumer-to-consumer (C2C) use cases.

Finally, in both permissionless and permissioned blockchain, transparency is granted only when protocols oblige the participants to provide a mandatory predermined set of information, in order to avoid (and detect) discretionary or fraudulent behaviours.

Data protection dimension

As mentioned above, blockchain applications might raise some uncertainties also from the perspective of privacy and data protection law, in particular the Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 (General Data Protection Regulation - 'GDPR'). Several recently published EU and U.S. institutions' and authorities' research papers analyse the relationship between blockchain technology and the GDPR.

In the first place it is important to determine whether data protection rules apply to a given blockchain. To do that, there is the need to assess whether personal data is being processed when blockchain technology is used.

Uncertainty might come from the distinction, in relation to the blockchain, between pseudonymised and anonymised data. In 2014, the Article 29 working Party, provided guidance on the difference between pseudonymised and anonymised data in its Opinion 05/2014 (WP 216). Such distinction is relevant since data protection rules do not apply to anonymised data as such data cannot be traced back to a living individual. In fact, personal data is defined as any information relating directly or indirectly to a living natural person, whether it actually identifies them or makes them identifiable.

Blockchain technology allows transactions between parties without having to disclose their identity directly to the contracting party or the public. However, every transaction that takes place is published and linked to a public key that represents a particular user. Although the key is encrypted (therefore it is not possible to directly identify the individual or entity that represents the user) the re-use of the public key enables authors of a given transaction to be singled out by reference to their public key. This is necessary to ensure that transactions are attributed to the correct individuals.

It follows that the public key, when associated with an individual, will likely qualify as personal data for the purposes of European data protection legislation. In fact, when the public key is visible, it is possible to attain information that enables an individual to be identified and all transactions that the relevant individual has made become publicly available.

Consequently, only where a transaction data cannot be traced back to the involved individuals, are companies legally permitted to use and process such data without being subject to specific data protection restrictions, since these are not affected by the GDPR (as per Recital 26). Nevertheless, the threshold for data to qualify as anonymised is very high and the distinction can be problematic. The Article 29 working Party guidance states that 'anonymisation results from processing personal data in order to irreversibly prevent identification.' Whereas no personal information making it possible to readily identify the users without significant effort are captured in the corresponding transaction data entries of the blockchain, there are various possibilities remaining for the de-anonymisation of information. As encrypted personal data can often still be traced back to a person and hashing permits records to be linked, hashing is likely to be considered a pseudonymisation technique, rather than an anonymisation technique, hence encrypted data could qualify as personal data. This means that in most cases the data protection rules will be applicable to at least some of the data involved in blockchain systems.

If personal data are processed in the blockchain, it is then necessary to define the roles of the data controllers and processors and whether these roles will be singular or joint. In this regard, from a data protection perspective, blockchain technology is particularly interesting because blockchain systems do not rely on a single provider of storage or computing resources but each user of the blockchain participates, on a peer to-peer basis, having a complete copy of the distributed ledger on her own computer. As a consequence, questions might arise concerning the possibility that end-users are treated as controllers or that a party be both a data controller for certain data (i.e. for the data that she uploads into the blockchain), and a data processor for other data (i.e. by virtue of storing the full copy of the blockchain on her own computer).

Further uncertainties might rise about the compliance with the principle of data minimisation, given that data are continuously added to the chain without the possibility of deletion or editing, and blockchains are ever growing.

Concerning in particular public and permissionless blockchains, the application of the GDPR may prove challenging from a legal standpoint, also with regard to the right to erasure or 'right to be forgotten' enforceable against any data controller in accordance with Article 17 GDPR. In fact, the inherently tamper-proofness of blockchain databases can be, from a data protection point of view, a potential threat. This is because, after a public key and the associated transactions are identified, there is no way to erase the information, which becomes part of the blockchain and hence public. The right to be forgotten seems therefore not supported by the technology's design.

Although research on editable blockchain mechanisms is ongoing, the idea of data controllers that can erase personal data from the blockchain does not seem straightforward: a core incompatibility may stem from the fact that the ability of edit data records while maintaining their authenticity requires nomination of trustworthy administrators which can alter the blockchain's ledger according to a predefined set of rules. This seems in contrast to the essential characteristics of the blockchain technology that is inherently decentralised and features only a limited number of central intermediaries.

This incompatibility appears even on a more general level, considering that the GDPR's rules are primarily designed for centralised data collection, storage and processing, while the blockchain technology is intended as a decentralised peer-to-peer database that does not rely on central authorities to process data.

In any case, it should be considered that the GDPR, acting as a framework that allows data controllers and data processors to carry out their business in a manner that protects the rights and freedoms of data subjects, is not technology neutral, therefore the manner in which technology is implemented to suit a particular purpose is crucial to verify whether that technology is GDPR compliant.

The data protection challenges posed by blockchain will therefore vary depending on the specific features of the technology used. For example, according to what data flows are involved in the blockchain, who is able to input data, how nodes interact with each other and who has access to the output data, the implications will differ since if input of personal data is involved, the data controller is required to implement measures to ensure the accuracy of data. Another example is the blockchain type used: permissionless blockchains may rely on the consent of the users while permissioned blockchains may rely on the performance of a contract, with different implications concerning enabling the exercise of data subject rights.

In some cases the nexus to personal data can be so remote that only minimal data governance mechanisms are required, while, by contrast, some other projects might involve high-risk data processing, requiring a full-blown data protection impact assessment. Not surprisingly, different papers and studies grapple with the issue of compatibility of blockchain and the GDPR reaching opposite conclusions.

On the other hand, as indicated by the EP resolution[20], blockchain also supports the emergence of new models to change the current concept and architecture of digital identities; digital identity further simplifies identity processes such as 'Know Your Customer' while enabling personal control over data.

Privacy by design can contribute to the compliance of different blockchain architectures to GDPR when specific issues arise.

Given the huge diversity of architectures and use cases, there is no one-size-fits all solution for blockchain in respect to GDPR compliance. GDPR compliance can only be measured on a case-by-case basis by considering the actual implementation of technology through which personal data is channelled.

20 European Parliament resolution of 3 October 2018 on distributed ledger technologies and blockchains: building trust with disintermediation (2017/2772(RSP))

Part 2 – Analysis of the impact of blockchain on selected international trade case studies

4. Case studies

4.1. Overview of the case studies

4.1.1. General overview of the cases

Blockchain prospects in international trade.

As outlined in our previous report, blockchain technologies have attracted interest from many stakeholders for their potential use in international trade. Some of the main perceived advantages of blockchain technologies are:

- The ability to securely exchange data within an ecosystem of actors who have interests that are not strictly aligned.
- The ability to use an infrastructure on which no single organisation has entire control.
- The ability to record information in a manner that is strongly resistant to tempering and modifications.
- The ability to automate transactions (including financial transactions) based on predefined conditions.

With regards to international trade, this translates into various potential use cases, throughout the trade and supply chain process, from the definition of the commercial transaction, to trade finance, supply chain and regulatory processes. We have selected for this report 8 representative case studies, or scenarios, in the different phases of a trade process and different areas of international trade to look in more detail into the potential impacts of this technology in international trade.

The following cases are thus considered:

- Decentralised marketplaces
- Blockchain-based letter of credits
- Cross-border payment systems
- Maritime insurances
- Tracking systems for shipping documents and supply chain events
- Blockchain-based e-certificate of origin
- Proof of authenticity of luxury products
- Tracking of ethical sourcing in the food industry.

Potential contribution of blockchains toward the digitalisation of international trade

It is important to note that the use case we studied relies only partially on blockchain technology. Other key digital technologies are also part of the solution developed in all of the cases considered. Moreover, the contribution of blockchain technology by itself, can only be considered in a larger context of the digitalisation of international trade.

As such it appears that blockchain can address some (but not all) of the issues that delay the adoption of digital solutions in international trade.

Barriers to trade digitalisation

In our perspective the adoption of a digital solution in trade is hindered by barriers that are, on one hand, technological challenges and, on the other hand, issues of adoption within the ecosystem.

The technological challenges can include:

- The need to set up digital infrastructures to facilitate the exchange of information between the trade participants.
- The ability to replace existing documents by an electronic version of trade documentations (being, in a first phase, simple scanned version or electronic versions of paper documentation).
- The ability to move progressively toward more standardised electronic documentations, enabling a higher reusability and machine readability of the document.
- The ability to ensure the overall security of the documentations throughout the exchange, protecting it both from tampering and data theft.
- The ability to ensure that the system is easy to use and interoperable with other systems used by the trade industry.

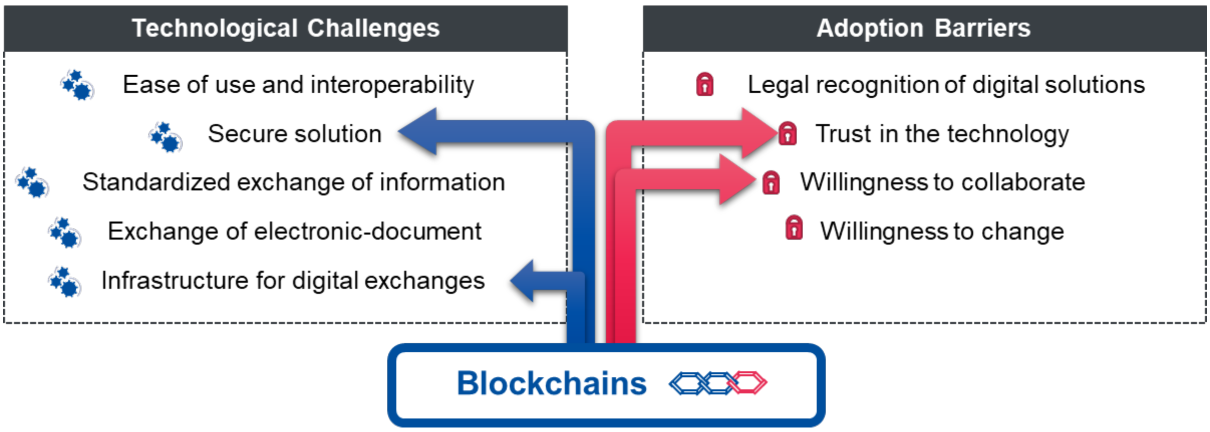
In addition to these technological barriers, trade digitalisation requires transformation of practices:

- A willingness to change within the industry is necessary to adopt digital solutions.
- In addition, to ensure the adoption and success of digital solutions, there is a need for a willingness to cooperate between the different actors of the ecosystem. These actors may have interests that can sometime be conflicting and to ensure adoption of a new technology it is important to ensure that there is a real willingness to exchange information and collaborate efficiently.
- Adoption of digital technology also requires a real trust of the ecosystem in the technology ability to answer its needs efficiently and securely.
- Finally, there is a need for a legal recognition of the digital solutions to ensure their adoption.

Potential contribution of blockchains

Faced with these challenges, we consider that blockchains can provide partial solutions to some of the issues faced by international trade actors in their adoption of digital solutions.

Figure 8 – Blockchain contributions to trade digitalisation



Source: IDATE Digiworld 2019.

The points on which we consider that blockchain can bring the most value are:

- The ability to provide an infrastructure for digital exchanges, as blockchain is by nature an infrastructure for exchange of data.
- The need to ensure the overall security of the system, as the security of blockchain can be considered as relatively strong, resistant to tampering and modifications

- The willingness of the ecosystem to collaborate, as blockchain provides an infrastructure that is truly shared between the ecosystem actors, without a single actor being able to overrule the others.
- The trust in the technology as blockchain may be considered as secure and reliable infrastructures.

Potential impacts

To better understand the perspective of blockchain development and adoption in international trade, this study looked into 8 dimensions of impact for each of the cases considered:

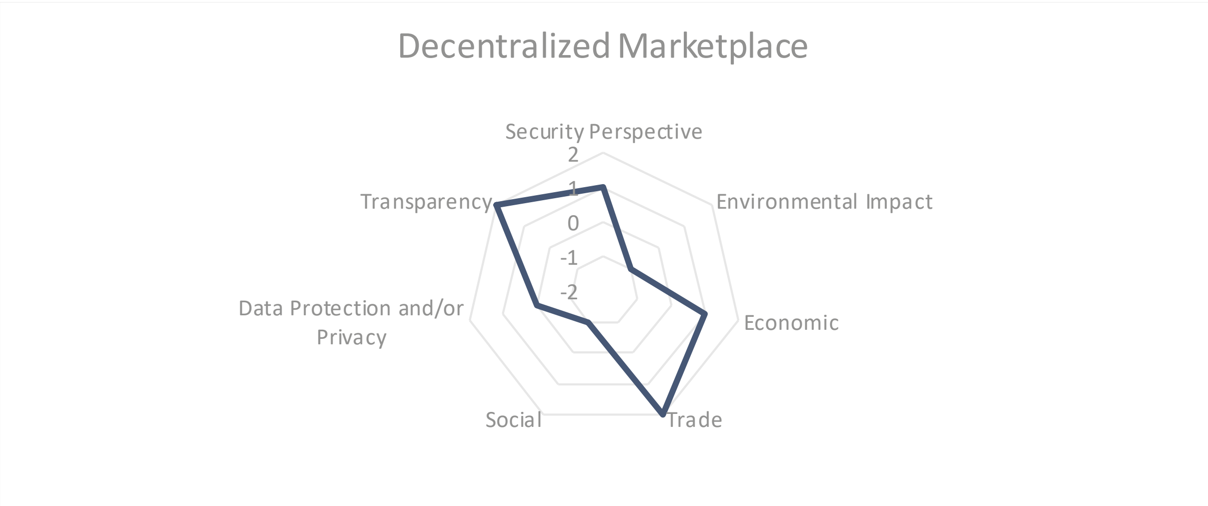
- Economic perspective
- Trade perspective
- Social perspective
- Technical perspective
- Security perspective
- Environmental perspective
- Data protection and privacy perspective
- Transparency perspective

The following diagrams present a global assessment of the different cases performance throughout the different dimensions. Each dimension is evaluated here, in case the use of blockchain in each specific case would generalise, from a qualitative perspective of impact throughout the following scale:

- +2: Major improvement over the state of the art / positive impacts to be expected,
- +1: Minor improvement over the state of the art / positive impacts to be expected,
- 0: No significant changes to be expected,
- -1: Minor deterioration over the state of the art / minor risks / minor negative impacts to be expected,
- -2: Major deterioration over the state of the art / Major risks / Major negative impacts to be expected.

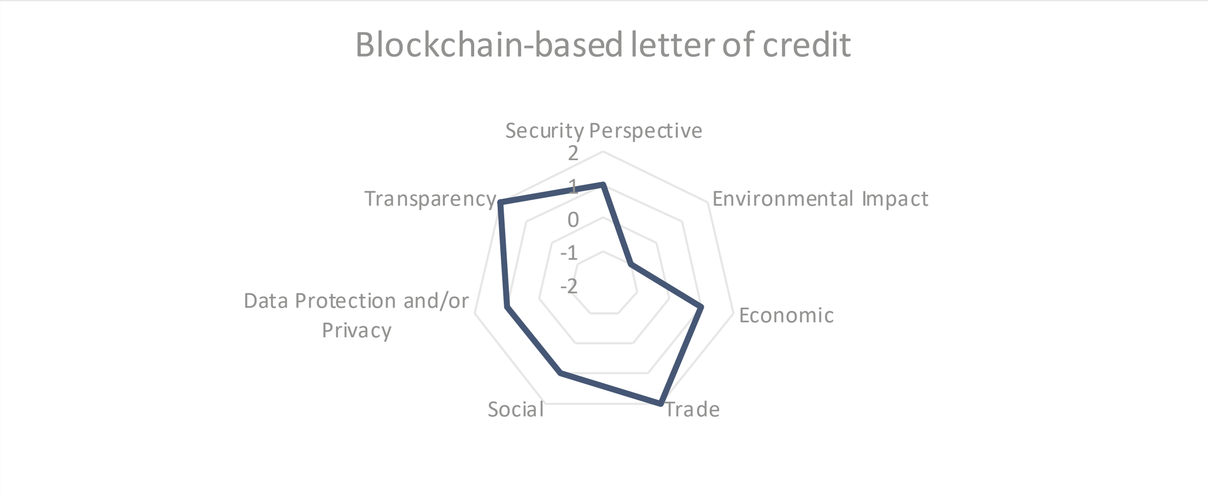
Each impact is analysed in more detail, use case by use case, in section 2 to 9 of this document. Additionally, section 1.2 to 1.9 provide a general perspective on the 8 dimensions of impact in

Figure 9 – Qualitative evaluation of impacts, decentralised marketplaces.



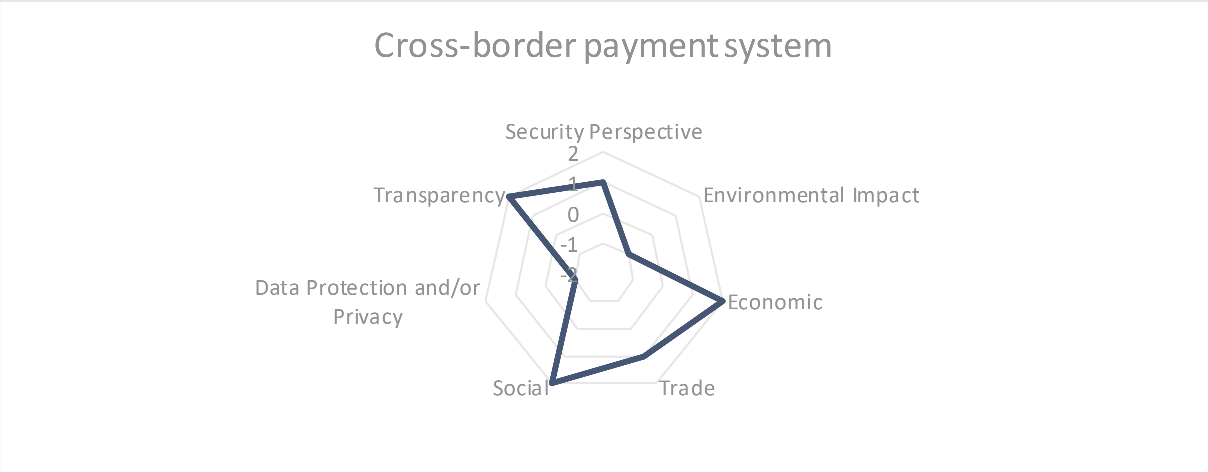
Source: IDATE Digiworld 2019.

Figure 10 – Qualitative evaluation of impacts, blockchain-based letter of credit.



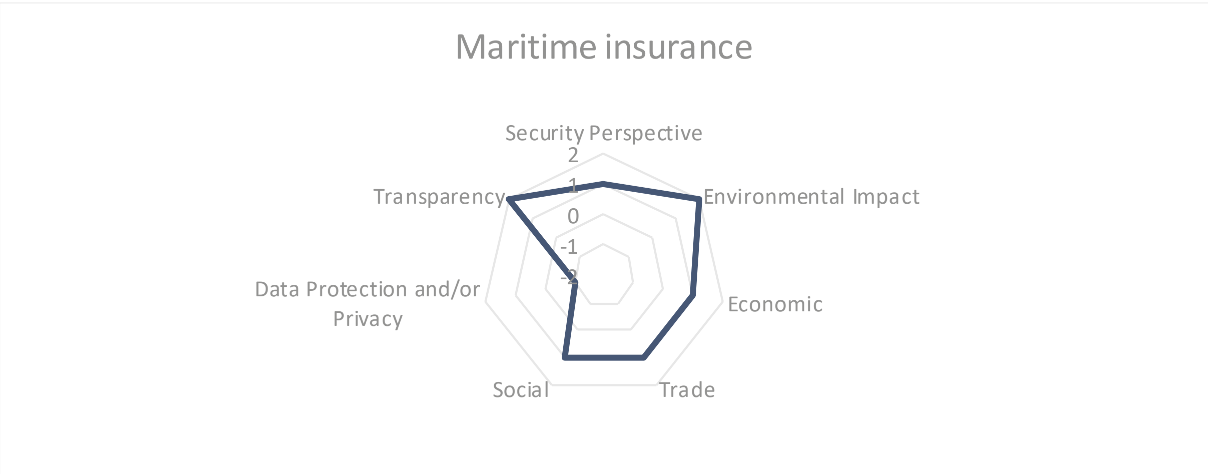
Source: IDATE Digiworld 2019.

Figure 11 – Qualitative evaluation of impacts, cross-border payment system



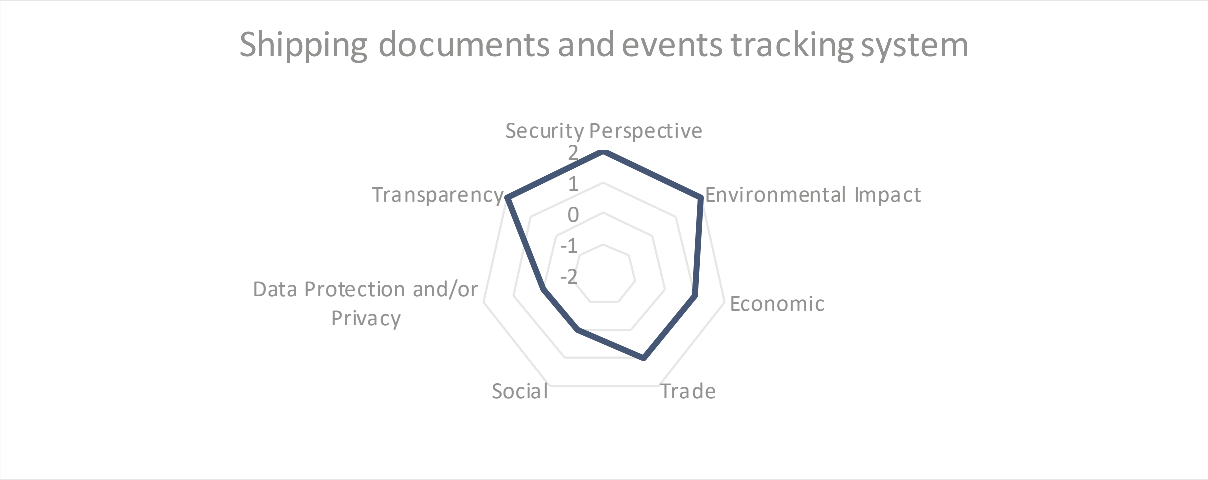
Source: IDATE Digiworld 2019.

Figure 12 - Qualitative evaluation of impacts, maritime insurance



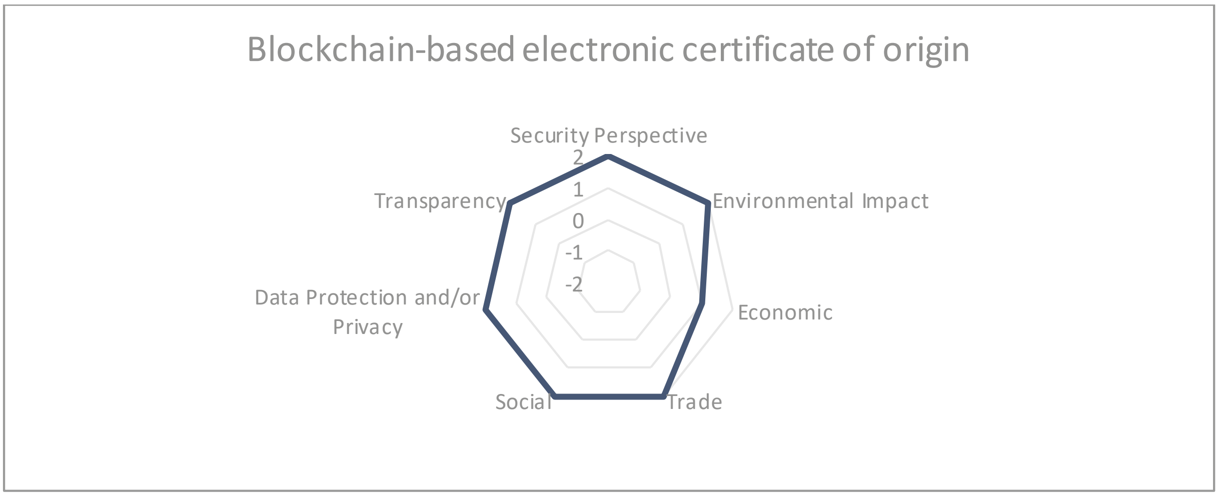
Source: IDATE Digiworld 2019.

Figure 13 - Qualitative evaluation of impacts, shipping documents and event tracking



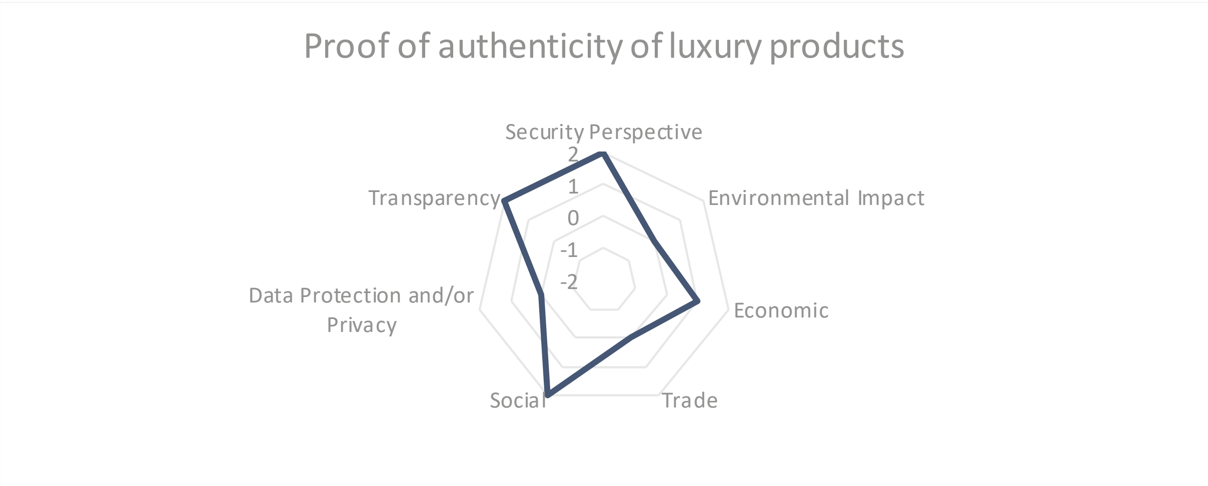
Source: IDATE Digiworld 2019.

Figure 14 – Qualitative evaluation of impacts, blockchain-based e-certificate of origin



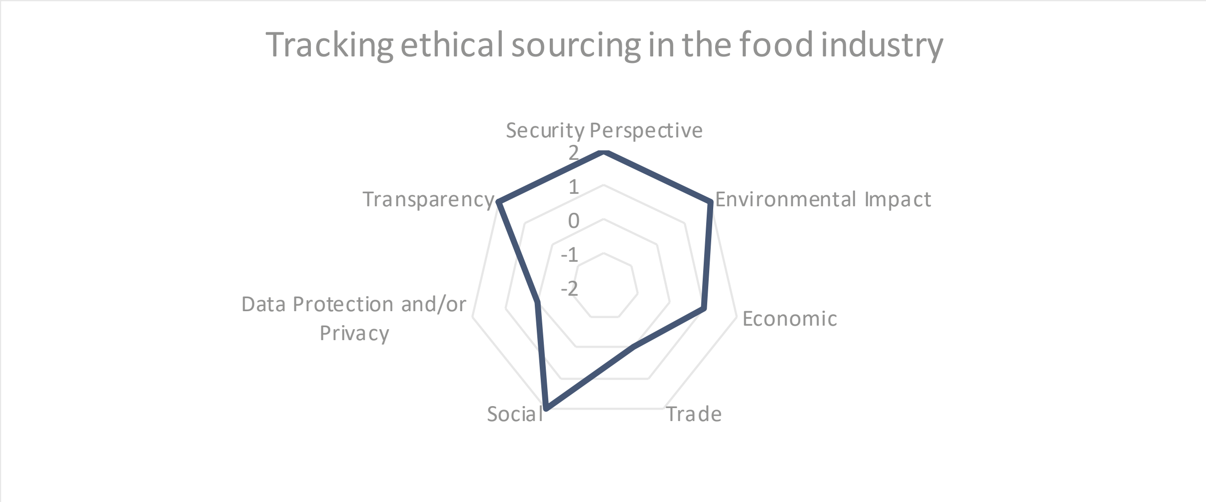
Source: IDATE Digiworld 2019.

Figure 15 – Qualitative evaluation of impacts, proof of authenticity of luxury products



Source: IDATE Digiworld 2019.

Figure 16 - Qualitative evaluation of impacts, tracking ethical sourcing in the food industry



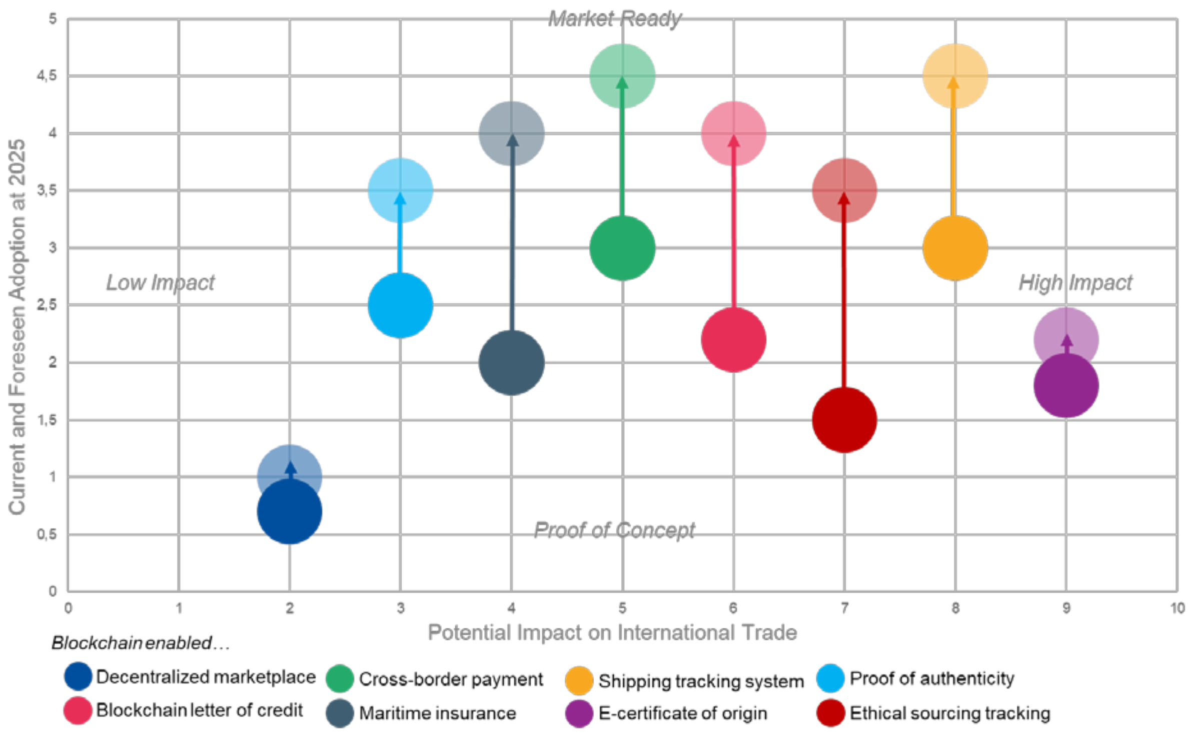
Source: IDATE Digiworld 2019.

Perspectives of adoption

Our analysis of the impacts is also coupled with a perspective on the potential maturity and future adoption of the different use cases.

This analysis is summed up in the following figure, presenting a qualitative assessment of the current and future (2025 perspective) adoption level of blockchain in each use case (X axis) and a general assessment of the overall potential impacts of the use cases. It is to be noted that this diagram presents a general perspective on the use cases, it is however mostly for presentation purpose, and does not replace the more thorough analysis presented in this report.

Figure 17 – Current and future adoption of the use cases.



Source: IDATE Digiworld 2019.

4.1.2. General economic perspective

Widespread adoption requires not only technical functionality but also that the economics of the proposed blockchain solution generate benefits for its potential users. Blockchain technology can offer these benefits due to its potential in: 1) reducing the costs of verification and 2) the costs of networking. The first results from lower costs of auditing transaction information and the second from omitting the need for intermediaries. In short, blockchain could eliminate the rent extracted by actors currently acting as trusted intermediaries.

These benefits come however with costs. In general, decentralisation is associated with three main costs: 1) waste of resources; 2) problem of scalability; and 3) inefficient network effects. These costs have to be weighed against the benefit of increasing competition when assessing the economic impact. Furthermore, the full benefits are associated to the creation of a fully decentralised environment, but creating such a large scale environment requires huge amounts of computational power, therefore many current pilots are mainly done with permissioned blockchains in smaller Consortia that are easier to organise. A permissioned blockchain and therefore a more centralised setup might also be required due to the issue of enforcement. While the technology is excellent in transferring ownership, it cannot guarantee transfer of possessions. Therefore, centralised entities such as government agencies might remain necessary for enforcement and supervision. However, one could end up with inefficient competing private and public networks that cover various aspects of trade and supply chains, where the gains are smaller in scale than some forecasts might promise.

These economic uncertainties are perfectly summarised in the 'blockchain trilemma'[21], whereby no ledger can fully satisfy the three desirable properties of decentralisation, correctness, and cost-efficiency. Traditional ledgers are correct (or trusted because of the reputation of the intermediary) and cost effective, while blockchain can be decentralised and correct, but not cost-effective at the same time.

Looking at the eight case studies we find that interviewees are very positive about the benefits of blockchain in trade. Depending on the specific use cases, either the reduction of verification costs or the facilitation in networking were mentioned as main benefits. In most cases it was highlighted that international trade still requires paper heavy procedures that involve multiple parties. While there are moves towards electronic documentation in many cases this currently is either not possible (due to authorities still requiring proof and a paper trail) or not sought after (for traditional sectors such as the shipping industry, or when the gains from digitisation do not seem large enough). Blockchain could change this as it has the potential to incentivise firms and other actors to work together. The case studies showed the potential that blockchain has to link the various actors in supply chains via one platform and moving them towards paperless trade. In international trade the alternative of a traditional and centrally managed digital platform is less likely as it would require countries to agree on one trusted entity (such as the WTO or WCO) to run such a platform. Blockchain could be an alternative by providing the ability to set-up a decentralised platform which would be accessible and trusted by everyone.

In terms of costs, interviewees were very positive and did not see many direct issues. However, it is certain that efficiency gains will make some actors less needed, such as intermediaries working on the verification of documentation (e.g. custom agents) or intermediaries that connect actors in the supply chain (e.g. insurance brokers). The research found also a plethora of use cases and pilots with blockchain trying to achieve similar things to each other.[22] While this can be expected at an early

[21] J Abadi, M. Brunnermeier, blockchain Economics, June 2018, Princeton University. Available at: https://scholar.princeton.edu/sites/default/files/markus/files/blockchain_paper_v3g.pdf

[22] For a good overview of pilots see: WTO and Trade Finance Global (2019) Blockchain & DLT In Trade: A Reality Check.

stage, it shows also the risk of inefficient network effects, where the current interoperability problem between the many actors is transferred to a multitude of competing platforms.

The following table highlights some of the impacts identified per use case.

Table 20 - Key economic impacts of the case studies

Case	Impacts
#1 Decentralised marketplaces	• Increased efficiency in purchasing processes as, unlike centralised marketplaces, there are no additional fees on buyers and sellers; • Better access for SMEs, as there are no listing or platform fees.
#2 Letter of credit	• Efficiency gains as current trade finance transactions include a multitude of actors and a lot of paper work; • Reduced time for trade transaction will in turn also reduce costs for inventory, indirect labour and transportation; • Increased access to information and transparency (single shared platform instead of multiple systems) makes risk assessments more accurate and increases availability of finance where risks are unclear.
#3 Cross-border payment systems	• Payment processes are faster as clearing settling occurs simultaneously leading to lower costs and increased efficiency: • Eliminates need for having multiple parties processing transactions; • Lower clearing costs and reduced capital requirements; • One exchange fee between all currencies also increases efficiency.
#4 Maritime insurance	• Reduction of information asymmetries: clients, brokers, insurances have asymmetric access to information which leads to inefficient price setting; • Increased data availability has potential for new products such as risk advisory services and better price differentiation depending on risks; • Simplification of transactions and reduction of administrative burden: automation of the claims payment process and reducing clerical errors as well as streamlining risk assessment.
#5 Shipping documents and tracking	• A blockchain-based tracking systems allows actors to record, share and access information in an easy and timely manner, reducing congestion and minimising customs and inspection delays; • Allows actors to react to unexpected changes in the supply chain as they occur, reducing problems with deliveries
#6 Certificate of origin	• Facilitate verification by automating processes related to auditing transaction information; • Would allow companies to more easily fulfill their obligations towards customers and authorities.
#7 Proof of authenticity of luxury products	• Could counteract the increase in counterfeits by improving authentication and traceability.

#8 Ethical sourcing in the food industry	• Better price setting: If consumers have access to the information they wish to verify on products, they are able to better assess their willingness to pay.

4.1.3. General trade perspective

The application of blockchain technologies in international trade poses specific uncertainties related to the unique characteristics of international trade.

Cross-border transactions, by definition, routinely have to deal with different legal systems, cultures and languages, technical standards and norms, tax systems, among many others. These differences create challenges as well as opportunities for blockchain. While blockchain can facilitate trade data flow, it also requires adjustments to the often rigid systems that have been put in place to ensure data flows are reliable and can be understood and processed by all actors.

International trade processes deal with cross-border barriers by requiring certification in the form of multiple documents. This burden of proving compliance — through documents such as proof of origin or phytosanitary certificates — can be reduced by applying blockchain solutions that automate and digitise transactions, which ultimately facilitate the integration of the multiple required documents. The challenge lies in ensuring that this integration happens in a homogeneous manner where there are legal equivalents across countries for these 'merged documents' to avoid creating new barriers.

One of the steps blockchain is set to facilitate is the exchange and use of information across the steps in the value chain, by aligning the flow of goods, information and money. Different players across the value chain with access to a ledger would have access to the same information typically contained in documents, such as the purchase order, certification of origin, the product's eligibility for a concessionary European tariff, an updated record of its physical condition, or phytosanitary certificates.

This alignment however, requires a common language. Different actors in trade, such as customs, logistics companies and traders often do not use the same technical language and often view data differently. Blockchain efficiency gains through linking these actors depend on interoperability across the steps in the value chain. The challenge is developing standard datasets that cover all data used for information exchange for import, export, transit, transportation and finance and having the administrative alignment to implement them.

While digitisation of the burdensome 'paper trail' of trade is neither new nor limited to blockchain, the barriers remain the same. For example, a UN convention adopted in 2008 aimed to improve the recognition of electronic documents. However, to come into force it must be ratified by 20 countries. 10 years later, as of 2019, only four countries have done so.[23] While technical obstacles in interoperability still exist, institutional barriers create a larger resistance to digitisation.

In addition to legal equivalents and a common language, there is a need to align processes. One example is the translation of international procurement processes into blockchain-friendly legal procedures.

The case studies have generated the following lessons:

- The use cases have shown us that current and developing applications of blockchain in international trade show potential for making trade flows more efficient. This

[23] The Economist, The digitisation of trade's paper trail may be at hand, 2018

happens by reducing the number of steps required to connect all the actors throughout an international supply chain. Processes become quicker across a specific step in the chain (be it the payment of a customer on a decentralised platform, or the issuing of a letter of credit by a bank), make processes digital and standardising data across these actors.

- The simplification, modernisation and harmonisation of trade processes—called trade facilitation[24] — is largely accepted to lead to larger volumes of trade, more diversification in trade flows and having more (and smaller) firms participating in international trade.[25] However, trade facilitation has also sparked debates on the distribution of the benefits and costs generated by trade facilitation.[26] An even distribution of these potential gains, as seen in the case studies, depends on equal access to the new platforms and on companies running the platforms not entirely appropriating gains as rent.

Text Box. Disruptive technologies and generated benefits

While the analysed use cases show very large potential impacts on the way trade processes are run, we must be careful with assuming that these changes will generate impact on international trade flows and for all actors in global value chains. In April of 2019, the COO of trade finance platform we.trade, Roberto Mancone left the company. He **categorised the platform as a success** in the sense that the technology applied was found to be robust, and that it resulted in a tangible legal entity with its own clients and revenues. However, he also expressed some hesitation about the **disruptive potential of the technology**. As explained in an interview with Global Trade Review, existing blockchain initiatives in trade finance are all driven by similar stakeholders, mainly banks and insurance companies. These stakeholders do not create new operating models, because as large players in the market, they do not want to change the status quo.

'I have not yet seen something that shows the ultimate benefit of the technology. We are building solutions that are perceived as valuable by the providers of the solutions, not the users. (…) I can see how this technology can change the business model, but to do that you need the stakeholders to come from different industries, not the same industry. That way it will be the final consumer (company or corporate) that reaps the rewards, rather than a group of incumbents.'

Sources:
Coindesk, *We.Trade Co-Founder Mancone Is Leaving the Enterprise Blockchain Firm, April 2019*
Global Trade Review, *Exclusive interview: Roberto Mancone leaves we.trade blockchain company, new general manager appointed*, April 2019

4.1.4. General social perspective

Like all new technologies blockchain also has social implications. The increasing use of blockchain might create winners and losers due to a potentially uneven access to blockchain technology or an uneven distribution of the costs and benefits of blockchain adoption across different social groups.

[24] World Trade Organization, Trade Factiliataion, at: https://www.wto.org/english/tratop_e/tradfa_e/tradfa_e.htm

[25] OECD Trade Facilitation, source: https://www.oecd.org/trade/topics/trade-facilitation/

[26] The is a possibility that all players in a value chain gain from equally from trade facilitation, because producing firms and their suppliers all operate with lower costs and therefore turnover is spread out across the value chain. However, it might be that gains from this facilitation are seized by the larger firms because they have market power or, as might be in the case of blockchain, have better access to specific technologies that lead to this trade facilitation.

Just as blockchain solutions can lower barriers to entry into international trade for small companies and producers and so act as a force for inclusion, it can also act as a barrier. This depends on actors having the resources to participate in the technology, from the technical knowledge to the Internet access. The challenge lies in ensuring that the digital gap is closed as blockchain is taken up – between developing and developed countries, but also between actors in the same market. Nevertheless, in cases where blockchain serves to reduce administrative burden (e.g. trade finance, trade related insurances, custom checks) it could reduce the costs for providing these services and thereby the fees charged to economic operators. These benefits would be less dependent on the digital readiness of individual companies or countries.

Furthermore, blockchain can have social effects where improper verification processes exist. For example, the technology is expected to facilitate communication and verification of ethical and social claims in trade transactions. While this has great potential for bolstering sustainable trade, it needs to be backed by an offline verification process that gives credibility to the information that is being shared. Blockchain can only facilitate fair trade insofar as this verification process is in place and connects the online information to the offline processes.

Additionally, the ease of making transactions using blockchain also allows individuals to execute transactions in anonymity. This could be especially a challenge if blockchain technology is used to facilitate illegal activities, including trade in illegal goods or trade-based money laundering. The challenge is to have a network in place that will still allow for some kind of tracking of payments despite this anonymity.

The case studies showed that the potential social impacts of blockchain applications in international trade are varied. While transparency can create more ethically sustainable trade flows through increased transparency and traceability, it can also be used to connect economic operators undertaking illegal activities or facilitate access to cheaper but less sustainable products (e.g. via decentralised markets). In addition, while SMEs and developing countries face the largest burdens with barriers to trade and could therefore stand to proportionally gain the most from blockchain-led trade facilitation, this will only be the case if there is relative ease of access to this new trade system that might unfold. Here policy-makers should take particular care that solutions are developed that also consider these less integrated actors.

4.1.5. General technical perspective

Basically, the conducted interviews and desktop research related to the scenarios below have outlined a number of characteristic setups and trends for the current state of play of blockchain solutions and prototypes.

Architectural remarks and technologies

Typical technologies which are currently utilised include Ethereum, Quorum, Bitcoin, HyperLedger and Corda with the latter seemingly a suitable choice for many solutions and proof-of-concepts. Furthermore, there is a clear trend for placing the blockchain nodes in a cloud environment with AWS, Microsoft Azure, Google Cloud and SAP cloud being some of the mentioned and identified platforms during the interviews and desktop research activities. Moreover, some solutions might be deployed in a dedicated on-soil data centre depending on the regulation and legislation in the country in question.

It should also be noted that within the field of international trade, the blockchain technology is predominantly used as means for distributed (without central authority) trust creation and as an immutable ledger rather than as a cryptocurrency (as in the case of Bitcoin and others in the past years).

Blockchain access

Another key aspect with relation to functionality and security is given by the decision whether to use a permissioned or a permissionless blockchain. It can be clearly observed that most of the established solutions are based on a permissioned blockchain with a corresponding user and identity management on top. This allows for protecting the blockchain network from issues such as identity swapping – e.g. identity fraud in terms of creating new identities (as an attacker/criminal) and exchanging the old compromised identities for the newly created clean identities - and correspondingly the general fraud issue which might lead to the utilisation of the blockchain for criminal activities. In addition, many of the interviewed solution and prototype stakeholders consider the possible usage of a public permissionless blockchain as a means for easy onboarding of new stakeholders or objects to be managed over the blockchain thereby achieving functional scalability in the long term. The easy onboarding in that case refers to the missing requirement for identity verification[27] as in the case of permissioned blockchain with an identity management component.

Interoperability

Interoperability is another aspect, which is recognised as crucial and not really available/present at the current point in time. There is not enough work on clear and open standards for accessing and enabling the efficient exchange of data between blockchains. APIs are rather proprietary and difficult to integrate. Nevertheless, many of the solutions seem to claim that they are blockchain-agnostic and can easily integrate different blockchains (e.g. Ethereum, Quorum, Bitcoin, HyperLedger and Corda) by implementing corresponding connectors.

Mining and items' tracking

With regard to the utilised mining algorithms, in general PoW is still widely used with increased interest in PoS and PoA types of transaction execution. PoW can clearly lead to some increased response times and scalability issues, which are normally overcome by restricting the access only to onboarded trusted users and reconfiguring the blockchain network so as to allow not so intensive mining processes - e.g. normally the difficulty/complexity level of the mathematical problem to solve is adjusted. In relation to the tracking of items and products in a supply chain, very often the combination of sensors with NFC or QR codes with end user devices (such as tablets or smart phones) is used in order to follow the object and automatically track its processing/origin on the blockchain

Smart contracts

Finally, smart contracts seem to be increasingly deployed in the various case studies. Nevertheless, smart contracts often come with difficult to grasp programming models and structures. Hence, the interviewed partners clearly recognise the need for quality assurance of the smart contracts and the potential vulnerability they can introduce to their solution/prototype.

4.1.6. General security perspective

Permissioned vs. permissionless blockchain

The general security perspective relates strongly with the permissioned vs. permissionless aspects discussed above. Thereby, the permissioned blockchains are integrated with corresponding identity management and/or user management component, which need also to be integrated with

[27] Such an identity verification can be complex and cumbersome to conduct, involving the examination and checks in different registries and institutions.

a process of identity validation/verification. In this manner, the blockchain member group consists only of trusted members that can, in addition, be easily made accountable for their actions and transactions on the blockchain.

On the other hand, the permissionless blockchain concept allows for people to easily join the blockchain network and work under an assigned identity. The negative side is of course provided by the lack of initial trust in the members of the consortium and possibility to anonymously conduct criminal/illegal operations on the blockchain and easily change the identity to a new one, after the current one has been compromised.

Cryptographic aspects

Besides, some cryptographic and general security architecture is required so as to guarantee the secure exchange and data integrity. This is achieved by means of

- traditional *PKI* (Public Key Infrastructure) concepts such as
- belonging *cypher-suites* - these are suites (libraries) of available and mathematically sophisticated algorithms that can be combined in different manners when building up a security concept for a system
- *certificates* – cryptographic artefacts used for encryption, decryption and signing of information
- *keystores* – containers (databases) for securely storing and managing cryptographic material (e.g. certificates or keys)
- *trusted services lists* – lists of trusted service providers with their belonging trusted spaces and certificate/cryptographic material
- DNSSEC[28] keys – cryptographic keys for securing network infrastructures
- *digital signatures* – signatures used to authenticate the origin of a document or a piece of information
- *certificate revocation lists (CRL)* – lists of certificates which have been revoked and are not valid any more for the system

In case of further advances in the area of quantum computing, some post-quantum cryptographic algorithms will need to be put at the appropriate places in exchange for current asymmetric cryptography.

Security certified blockchain platforms

In addition to the above aspects, the blockchain services and the blockchain platform itself need to operate in a secure and certified environment. The trend here clearly shows that solution providers rely on established cloud providers to run their nodes (e.g. AWS or SAP). Thereby, it is presumed that the cloud providers undergo regular security audits and penetration testing sessions in addition to having obtained some general certification regarding the security level of their processes and technical components.

4.1.7. General environmental perspective

Negative environmental perspective

Blockchain is often seen as a very resource consuming technology and requires a lot of computational power and a large amount of energy to function properly. Especially in less developed countries (utilising coal and other non-renewable energy sources) this would lead to

[28] DNSSEC is a secure version of the Domain Name Service (DNS) protocol, which is used for address resolution in the Internet and in IP networks and is one of the key infrastructures attacked by hackers.

increased CO_2 and NO_x emissions putting blockchain in an environmentally negative light. However, there is a remedy for these issues:

- one should avoid the resource intensive PoW algorithms and should try to increasingly use PoS and PoA when available, and
- the usage of a permissioned private blockchain implies that an onboarding process should take place which puts some initial trust in the blockchain participants and
- means that simpler less time-intensive algorithms for transaction execution can be put in place (e.g. specially configured versions of PoW).

In addition to the above aspects, the consortium is aware about the possible dynamic dependencies that can emerge with the introduction of blockchain and the expected acceleration and simplification of international trade processes and supply chains. A realistic scenario is that simpler trading procedures would lead to an increased international trade and increased level of activities within the belonging supply chains and the attached blockchain platforms. The increased international trade would likely have an additional negative impact on the environment given that non-renewable energy is used to enable the production, shipping and processing of products. Hence, we see that the overall picture is extremely important when it comes to accelerating processes and assessing their impact on the environment. Indeed, careful trade-offs will be required and a combination of measures can turn the blockchain into a technology that improves the trade processes and helps to meet the set climate goals.

Positive environmental perspective and expectations

On the contrary, the blockchain is expected to have a largely positive environmental impact when adopted by supply chains in international trade. The overall processes will get less paper intensive and more digitalised. The processing of documents will be extremely accelerated reducing waiting times at borders and terminals and leading to far less pollution than the current state of affairs (e.g. from running engines while waiting at the border). Moreover, the origin and processing history of relevant items is at the heart of blockchain benefits when it comes to supply chains in international trade. Such type of traceability would allow people to judge the sustainability of different aspects relating to the processing of an object or product in its production and supply chain. Hence, a sustainability aware social behaviour can be easily understood and corresponding measures can be introduced – e.g. by refusing to buy particular goods which are not produced in a sustainable way with less local involvement and increased CO_2 and NO_x emissions. In general, the interviewed partners had a rather positive view regarding the environmental aspects of the blockchain introduction to supply chains in international trade.

4.1.8. General data protection and privacy perspective

Data protection and privacy are two connected but different aspects, which refer respectively to the securing of data against unauthorised access and manipulation from third parties, and the control of the authorised access, in terms of permission and extent.

It is argued that blockchain can streamline the management of trusted information, providing an unrivalled level of accountability over the way data is managed, basing on its tamper-proof data store and its consensus mechanism used to edit data. Compared to today, blockchain could bring data protection to a new level, providing users with the possibility to control who processes their data and how and to share data only with trusted parties.

There is legislation both at national and EU level, which grants specific rights on data to individuals and regulates data flows. From a privacy perspective, it is crucial to distinguish whether the blockchain is public, i.e. open to anyone, or private i.e. accessible to selected parties only. In principle, where restricted access is achieved (via encryption or cryptographic tools) it is certainly easier to ensure compliance with the relevant framework. Specifically, whether a given blockchain-based platform meets the requirements of the data law, will vary greatly depending on the technical design of the platform, including the solution adopted to impede the data linkage or tracing and de-anonymisation mechanism.

Nonetheless, when using blockchain, some issues might arise with regard to personal data specifically. This is because the technology, insofar as it processes such data, shall comply with the General Data Protection Regulation (GDPR) and fulfill its high requirements. It is noted, however, that in trade applications personal data are not always at issue, and could not be required among the relevant data processed through the blockchain.

There is a growing literature exploring the uncertainties on the compliance of blockchain-based technologies with the GDPR. Uncertainties relate in the first place to the possibility of identifying personal data among other data recorded on a blockchain. Amongst information on companies, trade documents and transactions might contain data with direct relevance to individuals. As a result, participants could use a generic blockchain to register both non-personal and personal data, without administrators of the blockchain being necessarily aware of which data qualify as personal or sensitive for the purposes of the GDPR. If it is not possible to identify a legal basis and assess the lawfulness of the processing of personal data, it is necessary to seek further mitigation measures to prevent the identification of data subjects (i.e. anonymisation). Additionally, immutability is desired characteristic of the blockchain architecture, yet the compatibility of an immutable ledger with the right to rectification and the right to be forgotten (Art. 16 and 17 GDPR) might be challenging. Other uncertainties in cases where personal data are at issue could be the definition of the roles and responsibilities of the parties involved, in particular with reference to the identification of the data controller and the data processors, since blockchains are operated decentrally, and the compliance with GDPR principles such as minimisation.

Ongoing research is trying to tackle such concerns by using technical methods that add layers of encryption in order to better protect sensitive data while allowing overall transparency. This is an area of technical development for the technology, which aims at enabling decentralised and privacy-friendly solutions.

While some of the interviews noted that data protection and privacy issues are the same with blockchain as in standard 'offline' agreements, some others highlighted that blockchain could entail some uncertainty at the implementation level (difficulties may lie e.g. in the identification of the data owners) which would need to be further explored.

4.1.9. General transparency perspective

Transparency in blockchain defines the ability to view public addresses where one of the parties will be able to access transaction history, assets etc. without limitations or boundaries.

The level of transparency and data monitoring provided depend on the different kinds of blockchain used. The ledger or blockchain is usually accessible to all participants or to a given number of participants. While in private or permissioned blockchains access to the records can be restricted to certain participants; in public or permissionless blockchains everyone can access and update the ledger according to the existing consensus mechanism. Accordingly, permissionless blockchains are highly transparent, because each participant has a complete, traceable record of every transaction recorded.

One of the major challenges in international trade is the lack of transparency in the supply chain throughout all the steps from suppliers to buyers. When the wide array of disparate parties involved in trade are in different countries, as it usually is in international trade, the lack of transparency may represent a crucial hindrance even more.

Blockchain applications in trade may potentially remedy such deficiency of information, providing a great level of transparency and hence facilitating the sharing of authenticated information as well as improving the visibility of the value chain for all participants. This was also confirmed by the interviewees, who have given an overall positive feedback in this regard. When all transactions are transparent and visible there is an increase in the auditability and trust in the network as well as a reduced level of counterfeit.

It can be noted, on the other hand, that transparent data in public blockchains might represent an issue when certain information is not meant to be publicly available, or in cases it is altered due to inaccuracies or faults in the data entry process. Against this background, it is sometimes argued that there is a sort of unsolved trade-off between transparency and privacy in public blockchains. The different practical implementations should therefore strike a balance between transparency and limited access to private information.

4.2. Case #1 – decentralised marketplace

4.2.1. Description of the cases

Definition of the problem addressed and challenges

As the Internet became popular, traditional store commerce shifted to online marketplaces, which today control e-commerce activity and users' data. In 2018, approximately 1.8 billion people worldwide purchased goods online, with China having the highest online shopping penetration rate (83%). In Europe, the penetration rate on e-commerce marketplaces is growing steadily with 69% of EU costumers having bought or ordered goods or services online.

The interaction between the merchant and the customer is centralised in an e-commerce website and involves multiple players. Therefore, to transact, merchants and customers are subject to fees and restrictive terms and conditions from payment providers and the website itself.

Current developments see a centralisation of online trade in large e-commerce marketplaces. For instance, marketplaces like Amazon and Alibaba are capturing a significant share of value while defining their own rules for transaction control, validation, etc.

A widely used decentralised marketplace would help European customers and companies to both buy and sell products inside and outside of Europe at lower prices while preserving transaction privacy and ownership of data.

Solution proposed

E-commerce platforms operating on a blockchain, also known as decentralised marketplaces, aim to allow anyone, anywhere in the world, to transact on the marketplace, free of charge with users governing the development of the protocol, rules and restrictions.

Decentralised marketplace solutions rely on a peer-to-peer network, where user information and trade exchanges are protected by an end-to-end encryption. Instantaneous transactions would be free of charge and independent from third parties, following thus only the terms of trade determined by the merchant and the customer.

Although such solutions rely on a permissionless network, only parties involved in the sale would have access to transaction details. Decentralised marketplace solutions would allow merchants outside the EU wanting to sell to EU buyers to avoid trade restrictions and agree transactions terms and conditions directly with the buyer.

However, the expansion of such marketplaces is often subject to debates; as governments would likely challenge threats coming from trade regulations avoidance and attraction of buyers and sellers targeting illicit goods.

Development and adoption

Decentralised marketplace adoption is still at the very early stages of development in comparison to centralised marketplaces like Amazon, eBay, Alibaba, Aliexpress, etc.

For instance, OpenBazaar, has developed a fee-less peer-to-peer commerce network using Bitcoin, which resembles a sort of hybrid eBay or Amazon for crypto-based transactions.

The general idea of such a decentralised marketplace is that the infrastructure of the marketplace should be run by the users themselves (producers and customers, being able to deploy a node of the network) rather than by a third-party. OpenBazaar's marketplace reports approximately 250,000 nodes in its network since its launch and uses Bitcoin Cash to pay for a growing array of goods and services.

4.2.2. Economic perspective

The economic impact of decentralised marketplaces is essentially to increase efficiency in the purchasing process. A centralised online marketplace (which already has several efficiency related benefits compared to offline marketplaces) has several systems supporting the procedures, which all charge a fee. In addition to the large corporations behind the actual platform, each transaction (banks, credit institutions, logistics providers or a legal entity enforcing a legal contracts) charges a fee, increasing the price for the purchaser and decreasing possible profit for the seller. The need for such actors (as explained in 4.1.2 on the general economic perspective) is to act as trusted intermediary in order to verify information. Their work could be made more cost-efficient through decentralised platforms and thereby also reducing the costs charged by economic operators.

Furthermore, centralised marketplaces have a central entity that decides how products are displayed, how search functions work and what information is available across the platform. While this is typically set up in a way to maximise buyer and seller matching, a decentralised marketplace provides access to information as desired by the seller.[29] Sellers themselves become responsible for creating product listing and the information they provide is also shared in a more transparent manner.

The possibility of selling and buying goods without having to sign up for an account can also be beneficial to smaller firms. As there is no listing or platform fee applied, entrepreneurs or SMEs can experience lower thresholds for using platforms to sell their goods and make use of the beneficial network effects offered by such platforms.

4.2.3. Trade perspective

E-commerce in Europe was estimated to generate 95 billion euro in turnover in 2018. In addition to the sheer size of the modality, 23 percent of European e-commerce was cross-border trade, with the majority of this still coming from within the EU.[30] However, e-commerce makes also non-European markets and their, often cheaper, products more accessible for individual consumers through websites such as Alibaba. Any changes in pricing and efficiency in e-commerce are therefore bound to have large effects on trade flows.

[29] Decentralized Blockchain-Based Electronic Marketplaces, H. Subramanian 2018.

[30] Ecommerce News Europe, 23% of ecommerce in Europe is cross-border, 2019, https://ecommercenews.eu/23-of-ecommerce-in-europe-is-cross-border/

A 2017 paper from the European Commission[31] found that cross-border payments continue to be one of the largest barriers in this form of trade. Complications with payment systems continue to pose significant challenges. The most important international trade-related impact of a blockchain-based marketplace might be the facilitation of cross-border payment through safer and more widespread accepted channels.

4.2.4. Social perspective

One of the larger issues with cross-border e-commerce is the difficulty in checking compliance with internal legislation in the importing country. Despite efforts made under the Digital Single Market Strategy, products brought in from outside the EU through online marketplaces have had lower compliance levels with product safety standards, health and environmental standards, sector-specific standards. Products sold online are harder to screen, track and monitor. A possible increase in e-commerce (especially on a decentralised platform) would therefore mean a possible increase of unchecked products coming into the market. Recent developments in centralised marketplaces (e.g. Alibaba, eBay, Amazon) show how they increase access for consumers to cheaper but also often more unsustainable or even outright illegal products. Enforcement has already proven difficult in cases with a centralised authority running marketplaces; decentralised ones might only complicate this further.

However, consumers do stand to gain in other channels. Transparency is an issue with online purchases, with fake reviews by unidentified sellers distorting the information available to potential buyers.[32] The nature of using blockchain for these purchases will make the buying or faking of reviews nearly impossible.[33] In addition, decentralised marketplaces will increase supply and choice for consumers by allowing more economic operators to make use of online channels.

4.2.5. Technical perspective

With regard to the technical perspective, it is clear that we have to deal with a P2P network architecture implementing different security mechanisms to protect the confidentiality, integrity, availability and privacy of the marketplace in general. Thereby, the blockchain will and can be utilised in different ways as for example as cryptocurrency, ledger, trust building overlay, data storage or as a machinery for enabling smart contracts and smart trading of goods. Various technologies can be utilised for these purposes including Bitcoin, Ethereum, Corda and Hyperledger. Thereby, depending on the specific requirements different mining algorithms can be utilised for the required transactions (e.g. PoW, PoS, PoA …). Indeed, the right type of algorithm must be put in place based on the specific user needs, e.g. whether the transactions should be fast or whether some special focus is set on the energy and resource consumption of the blockchain layer.

Nowadays, many prototypes and first products exist in different domains including energy trading market places, which were of particular interest within EU countries (e.g. Germany and Belgium). Blockchain-based market places allow to reduce the role of central authorities in the markets in question thereby enabling the distributed creation and establishment of trust in a distributed fashion among the participants. In this line of thought, the payments can be often even executed

[31] Alex Coad and Néstor Duch-Brown, Barriers to European Cross-Border E-commerce , 2017

[32] Forbes, From Fake Reviews to Unvetted Sellers: Here's Why Amazon Marketplace Needs More Oversight, 2019

[33] This is a controversial claim. While several blockchain marketplace projects claim that decentralised systems make fake reviews impossible thanks to the transparency and irreversibility of the system, caveats exist. Although once stored (either directly or as a hash) on the blockchain the review would be protected, the necessity to ensure the authenticity of the initial reviewer input could potentially still be questioned.

off-chain thus reducing the role of the blockchain to the domain of trust and reputation whilst allowing for financial transactions, which can be taxed accordingly.

Another important aspect is given by the Smart Contracts which can be implemented in different programming languages (e.g. Solidity for Ethereum) and automate the trading process over the market place. Indeed, as the various interviews have shown, the Smart Contracts as means for automation would require a certain level of quality assurance (testing, model checking, vulnerability analysis …) provided their role as a main automation means for automated trading over the decentralised market place.

4.2.6. Security perspective

With respect to security, one of the key questions is provided by the need to differentiate between permissioned and permissionless marketplaces. Within a permissioned setting a typical access control architecture would be put in place in order to on-board the participants and stakeholders to the marketplace. Hence, a permissioned market place can provide a higher level of trustfulness since the participants are verified in advance and typical identity swapping attacks[34] are not possible as is the case in typically open and public permissionless marketplaces.

Furthermore, we presume that the blockchain marketplace should be secured by an appropriate public key infrastructure consisting of chains of certificates, trusted services list and certificate revocation lists thus providing the means for encryption of data and signature based verification. The sufficient vulnerability protection and general quality assurance is also a topic of paramount importance, which seems to be reasonably addressed by the latest versions of different available products - e.g. Corda or cloud based blockchain solutions as coming from AWS and SAP.

The quality of assurance of smart contracts is another topic which requires the attention when developing trading based solutions including automated transactions and potentially payments. Available smart contract scripting languages might be difficult and cumbersome to use leading to undesired errors and dormant faults in the smart contract code, thereby creating potential vulnerabilities. Hence, careful testing and potentially model checking approaches need to be applied to the belonging development process.

4.2.7. Environmental perspective

With regard to the environmental perspective, it is clear that legacy PoW blockchain algorithms for transaction mining would lead to a higher energy consumption and negative environmental impact. Hence, hopefully in the near future more blockchain solutions would emerge based on PoS mining schemes increasing the responsiveness and performance of the blockchain whilst reducing the carbon footprint of marketplaces in general.

From the interviews that were executed by the consortium, it became clear that most of the available solutions on the market are running on top of a cloud infrastructure. Hence, there is normally one provider that enables the company in question to utilise blockchain on top of a virtual – and respectively physical infrastructure – being taken care of by this one provider and technological operator. Indeed, in case this operator increases the utilisation of renewable energy for his data centres, then this might lead to a reduced generation of $CO2$ and NOx thereby reducing the negative environmental impact of distributed blockchain-based marketplaces.

[34] By 'identity swapping' we denote the case when a rogue member of the blockchain consortium is able to create a new identity and leave his current compromised (e.g. bad reputation) identity for assuming and swapping into the new one.

4.2.8. Data protection and privacy perspective

Data protection and privacy laws are an important part of e-commerce, especially considering the number of online businesses which handle personal electronic data or use cookies to provide customised services and advertising. It is therefore key to treat data rights with care to avoid fraudulent uses of consumers' data.

As observed, blockchain eases transaction processing and other financial and nonfinancial services without the need for intermediaries or central parties for validation. Decentralised marketplace solutions relying on blockchains would be typically based on permissionless networks, where every transaction taking place is published and linked to a public key and each key represents a participant. While public blockchain might entail some risks in relation to data protection and privacy, encryption will ensure that only parties involved in the transaction have access to relevant data, avoiding direct identification and protecting user's information.

Although the GDPR has in principle no direct relevance to trade, as the data involved usually relates to companies rather than individuals, it is noted that blockchain-based decentralised marketplaces could store data related to payment or contact details. To the extent such data fall within the scope of the relevant regulation, they will have to be treated in accordance with it, i.e. they shall be used lawfully and in a way that is adequate and necessary for the relevant purposes, be accurate and up-to-date, kept for no longer than strictly necessary, etc.

Yet, it does not seem that e-commerce operating on a blockchain would imply specific challenges on a data protection and privacy perspective: transactions' terms and conditions for the sale of goods or the supply of services will be typically agreed between the seller and the customer, also covering issues such as data privacy.

4.2.9. Transparency perspective

Transparency from the beginning to the end of the supply chain is key in e-commerce: as noted in a recent report by UPS,[35] it is one of the three main factors that affect online sales (together with incentives and customisation). This is all the more important today insofar as relevant actors in online marketplaces, from manufacturer to end consumer, may each be in a different continent with increasingly remote connections and reduced face-to-face interactions. Accordingly, there is growing market pressure in favour of transparency in online marketplaces, driven by all parties from consumers to business and regulatory requirements. Permissionless blockchains, whereby the parties involved in the sale have access to relevant transaction details, not subject to tamper, allow immediate and all-embracing transparency together with the possibility to easily trace transactions and products throughout the supply chain. As a consequence, the technology lays the foundations for a truly transparent e-commerce marketplace, which reduces business risk (by enabling companies to trust their partners and shedding light on corporate responsibility) and encourages integrity to the end consumers, maintaining control and visibility throughout the entire network.

[35] UPS Global Study 'Pulse of the Online Shopper' (https://www.ups.com/assets/resources/media/knowledge-center/ups-pulse-of-the-online-shopper.PDF). The study collected responses (from among 4,000 consumers and 240 businesses) collected between December 2018 and January 2019 to an online survey, providing insight into online shoppers' behaviours and preferences from six regions including the U.S., Asia, Europe, Canada, Mexico and Brazil.

4.3. Case #2 – blockchain-based letter of credit

4.3.1. Description of the cases

Definition of the problem addressed and challenges

Transacting a letter of credit (LC) refers to a complex procedure, where a buyer's bank ought to guarantee its customers obligations via a promising letter to the vendor for the shipped goods, as explained in more detail in the Part 1 of this report. Such procedure involves extensive paperwork and costly operational processes while requiring constant communication among multiple counterparties; banks, shipping companies, etc.

The main challenge is in successfully coordinating actors and processes to eliminate inefficiencies, reduce complexity and transactions costs.

Traditional letters of credit transactions take 5 – 10 days with multiple things dedicated to compliance and other negotiation processes at the back office. Such error-prone processes risk having to restart trade negotiations, thus delaying trade exchanges and incurring costs for both banks and trade partners.

Banks estimate that current forms of documentary trade have high costs, with fees ranging from 0.125% to 1% of a transaction's total amount.

Blockchain's primary aim is to digitalise the letter of credit paperwork process and create efficiencies by transparently sharing data through its digital ledger technology (DLT) between corporates, their trading partners, and banks.

Solution proposed

Blockchain technology holds the promise of completely eliminating paperwork and thus reducing errors and frauds while improving speed and processes. Trade partners, banks and other stakeholders involved in trade finance transactions, would benefit from a solution that solves documents reconciliation issues, stakeholder's coordination and costly transactions, whilst providing an end-to-end visibility.

The electronic transfer of LC and other trade documents, as well as the communication among all stakeholders in a single blockchain network shortens the transaction time. Blockchain would have a transformative impact on trade finance as the automation of LC creation, ensuring quicker turnaround and liquidity for businesses.

The use of blockchain in the banking industry is expected to reduce the risk of fraud in LC and other transactions as well as reduce the amount of paperwork needed. For instance, R3's Corda platform founded by a consortium of banks, relies on blockchain to track, and trace the exchange of LC and other documentation as they move along all parties involved in trade finance.

Development and adoption

The current players that are leading the permissioned blockchain platforms for trade finance are Hyperledger Fabric and R3 Corda. Their current developments are proving the operational viability of the blockchain as an alternative to conventional exchanges of paper-based documentation.

The R3 pilot project was successfully tested on HSBC's transaction with Cargill and ING Bank in May 2018 that marked the first use of a single, shared digital application rather than multiple systems. Blockchain solution was proved to be commercially viable and significantly shortened the document exchange time.

Banks are willing to consolidate the adoption of blockchain, which in addition to cost reduction is seen as a solution to digitalise internal processes and standardise the communication within the trade finance ecosystem.

4.3.2. Economic perspective

It is estimated by the World Trade Organization that 80 percent of global trade relies on trade finance or credit insurance. Trade finance is important due to the time gap between the product leaving the exporter and reaching the importer. The longer this time gap is, the more important are guarantees and third parties such as banks providing them. In 2011 and 2012, the global volume of LCs was estimated to be USD 2.8 trillion. [36]

LCs are a widely-adopted trade finance instrument that ensures payment for buyers and sellers alike. They not only reduce the production risk in case a buyer cancels or changes an order but also provide sellers with the opportunity to receive financing. Moreover, it allows buyers to demonstrate solvency and control the time period for shipping goods. Finally, compared to other options they are seen as relatively safe and risk free.[37] However, traditional trade finance is a labour- and paper-intensive work that involves multiple players and has high verification costs. It is estimated that over 20 parties are usually involved in a single trade finance transaction with various interactions and exchanges of information between these parties. Indeed over half of the price charged to clients for trade finance covers operational expenses even before covering the costs of risk, liquidity and capital.[38] Furthermore, recent years have seen a stagnation of the use of LCs compared to open accounts, the latter, which is more efficient and cheaper but also the highest risk option for an exporter.[39]

Conventional exchanges related to LCs can take between 5-10 days. The previously mentioned LC transaction on R3's Corda blockchain platform for Cargill was done instead in only 1 day.[40] The ability for importers, exporters and their banks to use a single shared application rather than multiple systems led to an efficiency gain of 4-9 days. Permissioned ledger technology might be able to reduce the duration of the process even further, to less than four hours.[41] Reducing the time required for trade transaction will in turn reduce inventory, indirect labour and transportation costs. An additional economic benefit is the increased access to information. This transparency could help make risk assessments more accurate and increase the availability of much needed finance.[42] In a White Paper by the World Economic Forum it is estimated that supply chain finance will expand by 5-15% a year in the Americas and Western Europe and 10-25% in Asia.[43] Other economic benefits noted in the interview with R3 were that a blockchain platform allows for standardised communication and thereby improves interoperability within and across organisations as well as increased efficiency (time saving) and operational savings. In terms of costs, it was reported that

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[36] Christine McDaniel and Hanna C. Norberg (2019) 'Can Blockchain Technology Facilitate International Trade?' Mercatus Research, Mercatus Center at George Mason University, Arlington.

[37] International Chamber of Commerce (2016) Letters of credfit (LCs): recognizing the value of simple trade instruments. Available at: https://iccwbo.org/media-wall/news-speeches/letters-of-credit-lcs-recognizing-the-value-of-simple-trade-instruments/

[38] World Economic Forum (2018) Trade Tech – A New Age for Trade and Supply Chain Finance.

[39] World Trade Organization (2018) Can Blockchain revolutionize international trade?

[40] HSBC (2018) HSBC and ING execute groundbreaking live trade finance transaction on R3's Corda Blockchain platform. Available at: https://www.hsbc.com/media/media-releases/2018/hsbc-trade-blockchain-transaction-press-release

[41] World Trade Organization (2018).

[42] Christine McDaniel and Hanna C. Norberg (2019).

[43] World Economic Forum (2018).

Corda is fully open-source, so costs are only associated with setting it up and maintaining the platform. The latter of which takes the majority of the costs (80%).

Nevertheless, while the current LC system is seen as inefficient and costly, it is set in a clear legal framework and governed by rules agreed by the International Chamber of Commerce. Changing towards a new system that has widespread acceptance might prove difficult and will need political support.

4.3.3. Trade perspective

Blockchain-based LCs could make LC as a trade finance instrument more efficient and increase its use. In terms of trade, reducing existing inefficiencies and barriers could potentially lead to about USD 1 trillion in new trade by 2025.[44] As presented in the World Economic Forum's White this could affect the various trade finance instruments by 2025. Blockchain technology would thus affect LC based trade as well as trade based on open account financing and on payment advances. While the latter would not be affected, both traditional documentary trade (LC based) and open account financing would see changes by adding new DLT based alternatives for both financing options. Foreseen changes include also shifts from open account to LC financing as well as overall increases in trade finance volume.

This increased trade finance mainly comes from addressing the current gap in trade finance by reducing the administrative burden as explained under the economic impacts and thereby facilitating trade. This was also confirmed in the interview with R3. It was also noted that the efficiency gains would be felt by trade finance customers in the form of lower costs. This benefit will be felt across the whole spectrum of exporters, but mainly among those with difficulties in accessing trade finance. Since LCs are a trade finance instrument that is specifically used where there is either a lack of trust or higher risks, its increased use could especially increase exports into and from developing countries and smaller companies. Blockchain in trade finance could also promote better use of data, one example is MonetaGo, which is a solution that prevents fraud related to double-financing by building collateral registries. R3's Corda blockchain platform and other pilots such as BBVA's DLT tested for a transaction between a Spanish and Mexican company, which reduced transaction time from over a week to 2.5 hours, show the potential in shortening transaction times in trade and specifically trade finance. 'Adopted the right way by all participants in the trade ecosystem, [this] could reduce trade finance operating costs by 50-70% and improve turnaround times three- to fourfold.'[45]

4.3.4. Social perspective

Taking the social perspective, one notes that the global trade finance gap of USD 1.5 trillion (2016) stems foremost from SMEs.[46] In 2014, the rejection rate in trade finance was over 50% for SMEs (for multinational corporations it was 7%)[47] and a survey by the US International Trade Commission highlighted that lack of access to credit is the main constraint for exporting among SMEs in manufacturing.[48] This is especially problematic in developing countries, where access to trade finance is even more limited.

The problem is caused mainly by the high costs of trade finance due to a cost-to-income ratio in traditional trade finance of 50-60% for banks. This means that over half the price charged by a bank

[44] Ibid.

[45] Ibid, p.7.

[46] Asian Development Bank (2017) ADB Briefs. Trade Finance Gaps, Growth, And Jobs Survey.

[47] World Trade Organization (2016) Trade finance and SMEs.

[48] US International Trade Commission (2010) Small and Medium-Sized Enterprises: Characteristics and Performance.

to a client needs to cover operational expenses before even considering risks and liquidity, which causes smaller companies to either use more risky open account banking or not to make use of international trade.[49] Blockchain-based LC could reduce these costs and make finance more accessible to SMEs and companies in developing countries. Furthermore, making LCs more accessible could make risks more widely shared in the supply chain instead of putting them mainly on exporters as with open account transactions.

In terms of employment, the effect is unclear. However, it can be assumed that automating many of the processes in trade finance through blockchain-based platforms would reduce the need for labour in verifying and processing documentation. In the interview with R3 Corda it was noted that there would be an increased need for highly skilled labour. However, while the automation of many administrative tasks would reduce overall labour demand, the increased efficiency and thereby the increase in trade finance volumes could create new employment.

4.3.5. Technical perspective

The discussions performed with regard to letter of credit within the study were conducted with established banks of global importance. Hence, their blockchain-based solutions can be considered as an advanced frontier in terms of technical development. In this context, traditional LC systems are inefficient and paper intensive while blockchain promises to accelerate and digitalise trade finance processes. In addition, blockchain technologies allow the involved participants to keep their own data and only participate in the blockchain and share on a 'need'-basis.

The following characteristics were observed with regard to the technical aspects of modern blockchain-based letter of credit solutions. Normally, cloud based permissioned blockchains are utilised allowing to control the identities of the involved stakeholders. The developed solutions seem to be blockchain agnostic in terms that different blockchain platforms (e.g. Ethereum, Bitcoin, Corda …) that can be integrated. Furthermore, the mining effort is strongly reduced thereby configuring the transaction generating algorithms in a way that allows to quickly complete the mining without consuming excessive resources (e.g. computing power and energy). In this case, the trust building procedures within the blockchain rely strongly on the identity/user management aspects of the permissioned blockchain technology. Correspondingly, given the avoidance of excessive mining, the response times of the blockchain and the belonging LC solutions are pretty reasonable and don't hamper related usability aspects.

The deployment and operation architecture of the blockchain is another issue which seems to be varying depending on the characteristics of the country where the letter of credit solution is employed. This means that cloud installations are possible in some countries whilst others impose a regulation requiring the blockchain operation in dedicated on-soil data centres.

4.3.6. Security perspective

A recent WTO report paper[50] states that the most critical issue with fraud in LC stems from the provisioning of false documents and not by manipulating existing documents. This serious source of fraud constitutes an aspect blockchain technology cannot effectively do anything against. However, the choice for a permissioned private blockchain when implementing LC solutions reduces the risks as it enables the examination of the integrated stakeholder responsible for issuing the required documents.

[49] World Economic Forum (2018).

[50] Emmanuelle Ganne, WTO report, 'Can Blockchain revolutionize international trade?', online: https://www.wto.org/english/res_e/booksp_e/blockchainrev18_e.pdf, last visited on 13.11.2019

In general the interviewed solution providers and architects were not very concerned with regard to security, which is of course an expected outcome given that they are biased towards presenting and selling their products in order to position them on the market as reliable and secure systems. It was clearly stated that first the utilisation of established products and technology which undergo regular security audits and certifications (e.g. cloud providers) largely reduces the security risks. Furthermore, within the banking sector, very strict security protocols apply and are imposed for the test and examination of products before deploying them in a production environment and offering belonging services. In general, we believe that security will be a serious challenge in future blockchains and that all deployed products and solutions must undergo a security certification (similar to the BSI[51] one in Germany). This includes rigorous security testing and security audit of the whole blockchain infrastructure.

With regard to Smart Contracts, no extensive use was reported and hence they are not seen as a potential vulnerability. Nevertheless, some thorough security and functional evaluation of the utilised smart contracts is performed.

4.3.7. Environmental perspective

The main environmental benefits of a blockchain LC solution are given by the reduction of the paper intensive documentation of the current processes and the overall digitalisation of the shipping processes - normally couriers and shipping transport such as planes are involved.

The main negative aspect would be naturally given by the high transactions costs in terms of energy and computing power. On one hand, this can be mitigated by dropping the legacy PoW mining scheme and adopting more advanced methods such as PoA and PoS. However, when using private permissioned blockchains, the whole mining aspect can be drastically reduced thereby allowing to configure the transaction processes in a way that energy consumption is strongly reduced. Hence, in this case the overall trust establishment will strongly rely on the identity/user management of the permissioned blockchain.

4.3.8. Data protection and privacy perspective

From a data protection and privacy perspective it is stressed that the efficient exchange of digital data could potentially revolutionise the LC.

The challenge of maintaining data privacy among counterparties to LCs transactions can be overcome by utilising a form of cryptography, whereby parties are only allowed to access permissioned information.

In interviews it was confirmed that private blockchain helps to mitigate the risk of data leakages for the clients who are unable to share only what they want and to control the access. Also banks seem to prefer private blockchain in order to better identify participants.

Finally, one of the main strengths of the LC is the presence of a clear set of governing rules precedents, which clearly set out the roles and responsibilities of each party. However, with digital alternatives to LCs based on blockchain, compared to LCs where each party evidences performance through paper-based documents and manual processing, the allocation of responsibility for the accuracy of data provided digitally might be somewhat challenging, especially between the data provider and the infrastructure provider.

51 BSI stands for Bundesamt für Sicherheit in der Informationstechnik (Federal Office for Information Security)

4.3.9. Transparency perspective

From a transparency perspective, there are several benefits powered by blockchain, as using blockchain technology to execute LCs enables banks and the other parties involved to share transaction details and information on a private distributed ledger, thereby helps making companies' working capital more predictable. The near real-time visibility and transparency obtained by exporters, importers and banks, which can visualise data in real time on their devices, allows capital to move more swiftly and, as a result, can lead to reduced risk, benefiting all stakeholders in the transaction.

It is noted, however, that permissioned blockchains are not necessarily fully private, there are numerous levels of access to blockchain, and restrictions include users' ability to only access transactions that directly involve them. There are also restrictions on both creating new blocks of transactions and proposing new transactions to be included in the blockchain. The third level of access is restricted to a limited number of institutions such as banks, jointly collaborating on the administration of permissioned blockchain granting access to their clients to read their transactions to provide a technical transparent way to guarantee the safety of the client's funds. This type of access offered to clients is limited, full access to the blockchain is granted to regulators to meet regulatory requirements and agreement. Consortium blockchains are not as transparent as public and neither are obligated to be as their creation was designated to meet the specification and standards for particular entities. Applications of consortium blockchain include auditing and database management, which do not necessarily require public access or display. This may create a problem for supervisory authorities when financial transactions are involved. Full access to the blockchain is granted to regulators to meet regulatory requirements and agreement.

4.4. Case #3 – cross-border payment system

4.4.1. Description of the cases

Definition of the problem addressed and challenges

Traditionally, the global payment processes take several days and are often exposed to risks of exchange rate fluctuations. Conducting cross-border payments it's also expensive, as banks do not always cooperate or comply directly with one another at great distances, and thus rely on intermediary banks to facilitate indirect transfers.

Intermediary banks charge fees for this service, which is deducted from the total transfer amount. Moreover, the large amount of daily transactions often causes delays due to errors; such might be missing or incorrect beneficiary information. This impacts international trade directly, adding additional burden and costs to transactions.

As such solutions reducing the delays and processing fees in cross-border payments would be welcome by the whole international trade ecosystem.

Solution proposed

Trade finance blockchain solutions aim to connect banks, corporates, trade partners, payment providers, asset exchanges, etc., to transfer foreign currency (FX) in a transparent, secure and almost free international transactions system.

For instance, when a container ship delivers the cargo at the port, the supplier will be able to automatically receive an instant payment. These automated interactions are possible via a private permissioned blockchain, where details are only viewed by the participants involved in this transaction.

While banks and other financial institutions lack interest to service SME due to high cost systems, interoperable trade finance and payments solutions powered by blockchain would enable them to offer low cost alternative services.

Development and adoption

Financial institutions and blockchain technology companies are creating solutions that would implement instant gross settlement systems while ensuring transactions privacy and immutable settlements.

Their current deployments are proving the operational viability of the blockchain, which is seen as an alternative to traditional banking systems such as SWIFT (Society for Worldwide Interbank Financial Telecommunication), used for international payments.

For instance, RippleNet (Ripple's cross-border payments software for banks) is seen as an alternative to SWIFT, allowing thus payment providers and banks to settle cross-border payments within Ripple's network. Moreover, Visa has globally launched its Visa B2B Connect (VB2BC) network that relies on DTL technology, where financial institutions can settle large corporate cross-border payments at a global level.

4.4.2. Economic perspective

The economic impacts of cross-border payment can be divided into faster processes, lower costs and increased efficiency. The benefits stem mainly from reducing verification costs.

Payment processing is likely to become faster as clearing and settling occurs simultaneously. Basically, the process eliminates the need for having multiple parties processing transactions, reducing the number of steps required to process a specific payment. This leads to lower clearing costs and reduced capital requirements for cross-border transactions.[52] An estimate by Deloitte[53] found that blockchain payments in business to business and person to person transactions results in a 40 to 80 percent decrease in transaction costs.

Having one exchange fee between all currencies also increases efficiency. Deloitte also calculates that average transactions take four to six seconds to finalise, instead of the usual two to three days in a standard transfer process.

The pilot payments run by we.Trade[54] allow small businesses to find partners and transact online, which also helps with networking costs. It covers the process of accessing bank payment undertakings (the equivalent of a letter of credit) and allows businesses to receive early payment from the bank by discounting from this bank payment undertaking. A pilot payment allowed one company to complete its trade finance transactions within a day instead of the traditional 10-12 days

4.4.3. Trade perspective

International payments have long been the instrument enabling international trade. However, the industry has not modernised for quite some time, and yet revenue made on cross-border flows has been increasing. A study on the future of cross-border payments[55] estimated that international

[52] Transform cross-border payments with IBM Blockchain World Wire

[53] Deloitte, Cross-Border Payments on Blockchain, 2016

[54] Blockchain platform developed by twelve major European banks that aims to create a transparent, secure and simplified trading environment for business.

[55] McKinsey, A vision for the future of cross-border payments, 2018

payment revenues (including transaction fees and foreign exchange revenues) have been increasing by six percent annually.

We cannot say with certainty whether more efficient cross-border payment systems will reduce the costs for the customers using these systems. However, platforms (such as we.trade) promise to digitalise the whole process from order creation to payment execution whilst providing visibility on transaction and shipment status. These could take away indirect costs in planning and tracking, borne today by the customer, making it easier to follow through with additional trade transactions and thereby facilitate trade.

4.4.4. Social perspective

Blockchain-based cross-border payment systems could have strong positive impacts for SMEs. SMEs currently represent a significant part of the global payment market, competing with larger enterprises in selling their products abroad, whether through ecommerce or other channels. Given the larger comparative costs that transaction fees represent to their businesses, SMEs stand to gain the most in simplified and cheaper cross-border payment systems.

In Europe, SME-related cross-border revenues more than doubled following the creation of a single Euro Payments Area [56] and a similar effect could be expected if a global payment scheme exists that better fits their needs. However a similar global system would require a certain level of trust between banks and towards economic operators in countries that do not have a reputation of financial solvency. Here blockchain technology could provide some of this trust.

4.4.5. Technical perspective

Cross-border payment systems are likely to utilise the blockchain technology from various perspectives including as a means for trust creation as well as a cryptocurrency. Thereby, an issue of interoperability is possible when integrating the different payment systems and solutions in various countries and administrative domains. The possible deployments would vary from cloud based blockchains to dedicated bare metal data centres depending on the specific regulations of the involved countries. In addition, corresponding PKI based trust anchors/spaces would be required that allow cross-border operations including aspects such as cypher suites, cryptographic material (certificates, keys …), trusted services lists, certificate revocation lists etc. Currently, a set of blockchain technologies can be applied such as Ethereum, HyperLedger, Corda and Bitcoin, with Corda seemingly being a stable solution which is often a suitable choice.

Since payments are a critical aspect of our societies and fraud and misuse should be prevented, e.g. for illegal and criminal trade, the utilisation of permissioned blockchains in combination with proper identity/user management is paramount for the success of such systems.

4.4.6. Security perspective

As mentioned above, a set of cryptographic artefacts would be required to secure the general solution architecture. Furthermore, strict security regulations, certification of modules, regular audits and penetration testing would be required, in order to guarantee a high level of functional security and resilience against cyber-attacks.

Typically such processes are well established within banks and data centre or cloud operators. In addition, permissioned blockchains should be exclusively utilised and proper on-boarding of new stakeholders should be put in place, in order to prevent identity swapping/theft and the compromising of the trust/reputation space.

[56] MicKinsey, Global Payments 2018: A dynamic industry continues to break new ground, 2018

A future issue with potential to endanger the security is constituted by the possibility for advancements in quantum computing – in such cases proper (post-quantum) cryptographic algorithms should be put in place in order to protect the infrastructure. In general, the security for cross-border payment systems based on blockchain can be guaranteed at a reasonable and sufficient level if carefully discussed, prepared and tested - e.g. by utilising proper threat modelling, risk analysis and counter measure implementations.

4.4.7. Environmental perspective

The largest negative impact is again constituted by the mining algorithms, which have the potential to consume excessive resources in terms of computing and energy power. Especially, PoW is a real energy burner and hence cross-border payment solutions should try to avoid it or configure it in an appropriate way within a permissioned blockchain environment. Other algorithms such as PoA and PoS should also be considered. Hence, the overall environmental impact of this scenario should be deemed negative provided that current cross borer payment processes are also pretty much digitised and paperless thereby leaving not much room for optimisation in terms of functionality based on the utilisation of blockchain.

4.4.8. Data protection and privacy perspective

With cross-border payments it is particularly crucial to ensure that there is no breach of data and that it is not altered at any point of the process. This is something that blockchain might help to accomplish.

As far as personal data are concerned, the entry into force of the GDPR significantly transformed the cross-border payments landscape, affecting the way financial institutions process and move data across borders, including data attached to capital transactions. Cross-border payment systems operating with blockchain technology should hence ensure compliance with the regulation, either keeping personal data off the chain or allowing for the possibility to erase/update data. There is ongoing discussion on how this might be achieved, taking into account the immutable nature of the blockchain.

It seems, however, that the main challenges and concerns around data protection and privacy could be possibly addressed by using a permissioned blockchain, requiring trusted parties to register and to use a private key in order to participate in the transactions.

4.4.9. Transparency perspective

Blockchain can drive change in cross-border payment systems by introducing transparency and simplification thanks to the ability to create trust in a distributed system. In general terms, on a blockchain, the identity of a user is covered by a cryptography. This means that it is particularly difficult to establish a connection between a single user and a public address. The degree of transparency pertaining to a blockchain stems from the openness of it: indeed, the holdings and transactions associate to each public address can be viewed by the public or by whoever has access to the blockchain, depending on if the blockchain is open or permissioned. Indeed, the distributed ledger system ensures compliance to transparency requirement. In a public ledger, the identity of a user is kept private, although the holdings and transactions carried out by each address are available to the participants of the blockchain or to the public. In a private permissioned blockchain, the details of the transactions are not available to the general public, but only to the participants involved to the same transaction.

As noted, 'this level of transparency has not existed within financial systems before, especially in regards to large businesses, and adds a degree of accountability that has not existed to date'.[57] This is particularly important when payment systems are concerned, since the increased level of transparency allowed by the technology improves the trust of the users in the system, thereby the security of transactions.

4.5. Case #4 – maritime insurance

4.5.1. Description of the cases

Definition of the problem addressed and challenges

Marine insurance is a supply chain-specific insurance aiming to reduce risks associated with freights such as damages or shipment delays, as explained in detail in the Phase 1 of our report.[58] It is an essential component of international trade that protects vessels and shipments throughout their journey. Its complex multinational ecosystem involves different stakeholders, multiple jurisdictions, and high amounts of transactions.

Coordinating all processes and players while complying with differing jurisdictions is challenging for marine insurance industry. Moreover, human error is a threat due to the volume and the importance of the paperwork involved in the process.

Delays implied by the administrative issues around marine insurance can impact the whole supply chain. Furthermore the impossibility to dynamically adapt insurance terms to changing conditions can generate additional costs on insurances and trade as a whole.

Solution proposed

The implementation of blockchain technology in marine insurance industry aims to assure all participants in a global ecosystem that they access the same information at the same time while connected in a secure and private network.

A blockchain-based insurance system for maritime trade would digitalise all the steps of this process, from automating payments to sharing real-time shipment information among trade partners, brokers' insurers and claim handlers through a distributed common ledger.

In an ideal situation, blockchain solves the compliance and contractual issues with the use of smart insurance contracts, which are non-paper based and self-executing contracts that would optimise the fulfilment process. In addition, smart contracts would solve inefficiencies related to fraud detection, inaccurate product pricing and other specific risks for marine insurance.

On that account, blockchain can help shipping processes evolve towards a higher degree of automation by handling claims and pay-outs faster, cheaper and more accurately. Original marine insurance certificates, copies of bills of lading, claims bills, etc. will be shared in real time via blockchain between all contracting parties, improving thus the efficiency in trade conditions

Development and adoption

As the marine insurance industry is disposed for modernisation, it is also in the mire of blockchain-based solutions. For instance, the current version of Insurwave, a platform establishing a digital insurance value chain, is substituting traditional paperwork documentation and manual processes.

[57] Opennity, The Whitepaper v13, Community and referral economy on blockchain as of 2019.

[58] Blockchain for supply chains and international trade, 2019.

Insurwave connects all participants in marine insurance processes in a secure, private network with an accurate, immutable audit trail, and services to execute processes. Currently in partnership with Maersk and several port authorities, Insurwave platform is providing insurance to several vessels while automating a large number of transactions.

The current state of development for this type of services is that of an advanced proof of concept. While not yet replacing existing systems, the initial tests and proof of concepts have been conclusive and as of Q3 2019, the solution is being tested on a larger scale.

4.5.2. Economic perspective

About 90% of international trade is seaborne, giving marine insurance an important role in trade.[59] Global marine insurance premiums totalled USD 28.5bn in 2017. The industry grew, but mainly due to cargo increases while hull premiums have deteriorated in line with ship values.[60] Despite having to process a lot of information, the marine insurance industry still relies heavily on manual processes and paper documentation – creating inefficiencies in verification and making them prone to human error. Indeed, in an interview with Insurwave it was confirmed that marine insurance is an old industry with a lot of paper work and legislations. There is the need to collect a lot of individual data from various systems to get a contract signed and in addition only limited data is available to judge the value of cargo.

In economic terms, the application of blockchain technology could have various benefits in the area of marine insurance. Foremost among these is the reduction of **information asymmetries**. Currently, clients, brokers, insurance companies and third parties have asymmetric access to information, which leads to inefficient price setting on the market for insurance premiums. A common ledger in the form of a blockchain providing access to all parties equally could improve price setting. As data on ships and cargos is collected and shared at a higher rate, it becomes possible to use this big data to build a dynamic risk profile of routes, ships and items. Indeed, in the interview with Insurwave it was confirmed that there is potential for new products such as in risk advisory (data analytics based on blockchain data) and better price differentiation depending on the routes ships take.

In addition, another benefit is the reduction of **verification costs and administrative burden**: automation of the claims payment process, facilitating claims handling and reducing clerical errors as well as streamlining risk assessment can greatly simplify transactions between the various parties.[61] This benefit is also echoed by the World Trade Organization, which argues that blockchain and smart contracts could help reduce administrative costs and increase trust and transparency through automated verification of the identity of insurance policy holders, contract validity, and automated handling of claims.[62] In interviews cost-efficiency was confirmed as a major benefit since claims can be processed very quickly and it is easy to ascertain who is in charge when it comes to incident data.

4.5.3. Trade perspective

With the majority of international trade being conducted through maritime means, any change in the maritime insurance industry is set to have rippling effects on international trade flows and the actors involved in it. Shipping is what allows the global economy to circulate, and is the most affordable way to transport materials and manufactured goods across countries. Overseas trade is

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[59] World Trade Organization (2018) Can Blockchain revolutionize international trade?

[60] International Union of Marine Insurance (2019) An analysis of the global marine insurance market 2018.

[61] Standard Club (2018) Technology bulletin. Blockchain: some potential implications for marine insurance.

[62] World Trade Organization (2018).

however also a risky endeavour, not limited to the time spent at sea. Risks also exist in delays, theft, damage, and so forth. Maritime insurance is a necessary tool to provide protection to exporters engaged in overseas trade, allowing them to take the risks needed to transport high levels of capital. Even in the case that a trader would be willing to assume such a risk, banks insist on its coverage before emitting a letter of credit.

Covering this risk has increasingly allowed exporters to expand the scope of their operations. Ultimately what a system like the one provided by Insurwave does, is to transform how businesses manage the risk of their operation and how they work together with insurers and re-insurers. This could make the process up to 40 percent more cost-efficient.[63] Costs saved on the exporters' side are transferred through lower prices to consumers or translated into new ventures in the form of increased exported volume, increased product variety or risks being taken to venture into new markets. Overall, this could create new trade flows or deepen existing ones.

Looking forward, it seems likely that blockchain-based systems will get increasingly involved in shipping logistics and thereby facilitate international trade not only through the reduction of costs for exporters but by affecting multiple stages of the value chain. As an illustration, Insurwave has recently signed an agreement with Zhuhai Port Holdings Group Co., Ltd. to promote frictionless trade across the Greater Bay Area of China and beyond by removing existing barriers in port processes.

4.5.4. Social perspective

Smaller scale companies at times do not have access to marine insurance due to complicated insurance policies, long claims settlement procedures and inflexible premium payments that do not align with their cash flows. Small or new (entrepreneurial) ventures are also difficult for brokers to insure, due to a lack of information about members and their activities, their economic status and risks profiles associated to how their goods are processed.

However, with increased data availability transactions costs can be lowered and premiums dropped, making maritime insurance (and therefore international trade) more accessible for smaller scale operators. Furthermore, reducing the distance between the capital holders and the insurers can make premium payments more flexible and adjustable to those with limited cash flow.

4.5.5. Technical perspective

Blockchain technology can be used to create a **decentralised trust space** that is needed in such a diverse and complex ecosystem with many different stakeholders as described in this case study. All involved partners can verify the transactions and thus, are able to trust the underlying technology. Another benefit of applying blockchain technologies in the context of maritime insurance is the **lack of a single point of failure** (i.e. in this context single point of failure stands for the reliance on one single entity for ensuring trust and functioning of the overall system) due to the decentralised nature of blockchains. The peer-to-peer distributed nature of blockchain platforms ensures that even the in the case that single nodes fail to deliver as expected, the functioning and the overall established trust is not hampered. A proper functioning of the system is crucial for information/data retrieval and informed decision making.

In addition to creation of trust and improved availability of the system, it can be foreseen that in the context of this case study blockchain technology will be mainly used for storing data and giving timely access to data. However, response times can vary heavily between different blockchain technologies. Therefore, the aspect of usability and corresponding response times has to be

[63] Based on estimations of Insurwave's first year with Maersk.

evaluated and a blockchain that fulfills the requirements has to be chosen, thereby eliminating the possibility of applying some blockchain technologies (e.g. PoW based Bitcoin).

A third, crucial aspect is provided by the type of blockchain with respect to **permissions**, as often discussed in the paragraphs above. In the context of this case study a permissioned blockchain is beneficial because whenever a new technology is deployed in a fundamental domain such as trade (see section 5.2 and 5.3 for more details) it should be tested and evaluated with a **known set of contributors**. This aspect is additionally underpinned by the pseudonimity of users in blockchains – it is unwanted to have unknown participants that can potentially write claims or other information to the blockchain. However, it should be noted that a transition to a *permissionless* blockchain is not impossible but rather unlikely in the next few years - on one site a permissionless public blockchain would increase the transparency of the trade and supply processes but still bears some potential fraud and identity issues, which would require further research and concepts to handle (e.g. AI based fraud and identity theft detection).

4.5.6. Security perspective

As already stated in section 5.5, it is of paramount importance to be able to trust the proposed solution for maritime insurance. This has implications on security considerations such as **confidentiality**, **integrity** and **availability**. According to the conducted interviews, only known nodes should be able to see the information and participate in the network of insurance related stakeholders. This ensures a first degree of **confidentiality**. **Integrity** and **availability** of data are inherent properties of blockchain technology due to its distributed nature and replication of data on each node. Furthermore, a *private*, *permissioned* blockchain like the one that is used by Insurwave for managing maritime insurance of goods ensures the **privacy** and **data protection of the involved stakeholders**, be it individuals or companies. Only authorised participants are able to see information and can act accordingly.

Another important aspect in the domain of maritime insurance is **data provenance** meaning that first and foremost insurers but also other participants need to have the possibility to access current as well as historic data, e.g. former claims and their status. According to the input we obtained within the interviews, this is very valid for the domain of maritime insurance in order to track back the damage of goods, vehicles etc. and to be able to assess the credibility and accountability of certain stakeholders and their potential claims. Indeed, the storage of historic transactions is another intrinsic characteristic of blockchain technologies because of the chain of blocks that consists of all transactions, thereby enabling the immutable storage of maritime insurance related historic data on the ledger. Thus, this critical aspect can be seen as fulfilled in all blockchain technologies and makes blockchains a useful alternative to traditional (closed) database solutions.

According to a recent WTO report[64], fraud is prevalent in insurance claims – it is estimated at 5 to 10 percent of all claims (McKinsey & Company, 2016a). Blockchain technology could help in two different ways: 1) it could ensure that all transactions, e.g. insurance claims, are **valid** and more importantly, 2) Blockchains could verify in an automated way that only one claim can be submitted for the same incident thereby making it harder to submit fraudulent claims multiple times and reducing the overall workload.

4.5.7. Environmental perspective

The main environmental and heavily discussed impact of blockchain technology is given by the increased need for computational power and correspondingly energy in the course of the mining process (when using Proof-of-Work as a consensus algorithm). The increased energy demand leads

[64] Emmanuelle Ganne, WTO report, 'Can Blockchain revolutionize international trade?', online: https://www.wto.org/english/res_e/booksp_e/blockchainrev18_e.pdf, last visited on 13.11.2019

inevitably to CO2 emissions. However, a switch to other consensus algorithms such as Proof-of-Stake would decrease the demand and would render this impact of blockchain technology negligible in the coming years.

Additional countermeasures could be put in place to reduce the negative impact of blockchains on the environment: In the wider context of maritime insurance blockchain could be used to improve energy consumption tracking in the ports as well thereby indirectly enforcing the selection of environment friendly processes and energy consumption.

4.5.8. Data protection and privacy perspective

From a data protection and privacy perspective, the blockchain-based insurance system for maritime trade would allow the creation and upkeep of a reliable set of data from all parties in the insurance value chain. Data relevant to maritime insurance include data about identities, risks and exposures, which could be automatically linked to policy contracts.

As a result, blockchain facilitates the sharing of standardised data, providing to clients, brokers, insurers and third parties the same risk data at the same time. It is hence paramount that the accuracy of the data is guaranteed by providing sound controls around what data participants register and have permission to use. Indeed, the extent to which blockchain can deliver data protection, facilitating the tracking and changes to the relevant data and contracts, rests on the ability of the system to feed ledgers with accurate and consistent data.

4.5.9. Transparency perspective

Compared to the traditional insurance market, weighed down by paper-heavy processes and burdensome procedures that prevent transparency, blockchain technology employed in the insurance sector, through the standardisation and the immutability of data, enhances the overall transparency of the whole insurance process. As a result, it helps ensure contract certainty, eliminate duplication of data and improve risk-handling capabilities.

Additionally, a transparent blockchain solution allowing multiple companies to collaboratively assemble relevant records could significantly simplify the process of claims recovery. Its multi-level shared ledger system could help insurers and clients to agree on claims and compensation. The overall transparency of the process, given the accessibility of the data to all the parties involved, would enhance trust and improve the overall consumer experience.

4.6. Case #5 – shipping documents and events tracking system

4.6.1. Description of the cases

Definition of the problem addressed and challenges

The shipping industry is still largely dominated by manual, time-consuming, paper-based processes. The ultimate aim of the industry is to facilitate the seamless transit of goods across the supply chain. In that respect, any administrative delay is felt as a direct burden to be minimised. The exchange of goods requires the sharing of documents and data across all stages of the shipping lifecycle. This process can cause serious delays on trade, with estimation that a container can spend half of its time in transit waiting for administrative processing.

The reduction of the administrative delays around shipping documents is thus a serious challenge for the industry. Furthermore, companies involved in global shipping have diverse capabilities and standards, and the exchange of documents comes in different formats, which add another layer of complexity to the issue. Although the information exchanged is often the same from one document to another, change in formatting can cause duplicated work and delays.

Solution proposed

In this context, blockchain technology is able to connect all parties in the trade ecosystem and enable them to interact efficiently while accessing real-time shipping data via a distributed ledger. The aim is to digitalise and standardise the documentation and share it in real time among the stakeholders involved.

Blockchain enables ocean shipping lines, port and terminal operators, customs authorities, freight forwarders and logistics companies to interact efficiently, access real-time shipping data and exchange trade documentation such as certificates of origins, bill of landing, etc.

This data can include any event from vessel arrival time to cargo conditions or containers movement, providing thus a secure and immutable audit trail for the shipping industry and port authorities.

The implementation of blockchain technology in shipping documents and tracking systems will speed up the exchange of goods, automate shipping processes as well as reduce paperwork and human error.

Development and adoption

Recently, there has been a rise in attention towards blockchain solutions in the shipping industry. The industry has seen the emergence of different platforms that are using blockchain technology to digitalise and render the shipping of documents and events tracking systems more efficient.

Digital platforms like Tradelens (launched jointly by IBM and Maersk) offer industry wide solutions by tracking shipping events on the blockchain. The platform rapidly attracted other shipping companies, as well as terminals, port authorities and custom authorities to join the platform. As of Q3 2019, it comprised 150 partners. The platform uses a permissioned blockchain to track documents (based on the IBM backed Hyperledger Fabric), combined with a traditional cloud platform used for handling event data.

Another similar initiative has been launched by a consortium of shipping companies: the Global Shipping Business Network (GSBN), rapidly attracting other shipping lines. It is to be noted that some players are members of both networks.

Table 21 – Membership of shipping companies to blockchain initiatives (TradeLens and GSBN) as of 2019, and shipping capacity in twenty-foot equivalent unit (TEU.

Shipper	Capacity (TEU)	Network member
APM-Maersk	4,087,480	TradeLens
MSC	3,308,955	TradeLens
COSCO	2,792,448	GSBN
CMA-CGM	2,643,745	TradeLens, GSBN
Hapag-Lloyd	1,644,565	TradeLens, GSBN
ONE	1,521,702	TradeLens
PIL	420,039	TradeLens
ZIM	324	TradeLens

Source: www.ledgerinsights.com

As shown in the table above, the adoption of blockchain in this use case is significant. It should be noted however that the membership of a company to a consortium doesn't imply that every container moved will be tracked on the blockchain system. The real usage is harder to quantify but the interest clearly demonstrated.

Among the challenges to adoption, stakeholders cited the need for a neutral platform that would by adopted by the shipping industry (pointing out the risk of competition between the current two frontrunners) and the fact that some actors (especially regulatory and custom authorities) are slower to adopt the solution than shipping companies or terminals.

4.6.2. Economic perspective

Digitising global trade is a way to deal with the chains' slow, friction filled, and paper-based inefficiencies. A blockchain-based tracking systems allows actors to access information in an easy and timely manner, reducing congestion and minimising customs and inspection delays and facilitating verification. Ultimately, it also allows actors to react to unexpected changes in the supply chain as they occur, reducing problems with deliveries.

The largest economic impact for systems like Tradelens is in reducing time-consuming verification of information. Rather than re-producing processing for new documents recording very similar information, a blockchain-based system allows for the information to be recorded and shared in real time. Freight auditing and invoice handling processing for example, can be greatly reduced with the sharing of trusted information.

Cost reduction across the value chain depends on the gains in efficiency. While some lines are already functioning quite efficiency, others face greater opportunities in the reduction of delays. The administrative costs involved in moving a container often exceed the physical cost, given the amount of documentation, verification and auditing that needs to occur.

4.6.3. Trade perspective

In addition to reducing delays, platforms like Tradelens or GSBN directly contribute to another major issues in trade – data inaccuracies. Trade data is rife with inaccuracies and a document tracking system creates data that is verified by multiple parties and shared in real time. Customs can gain majorly from being able to begin their supervisory processes already with the initial commercial information. As soon as a purchase order is emitted and a container is packed in an exporting country, customs from the receiving country can review the packing list. Having access to immutable data this early on in the trading cycle can help customs be more efficient in their processes during imports and reduce steps in verification.

The WTO Trade Facilitation Agreement requires its members to set up a Single Window system, defined as a *facility that allows parties involved in trade and transport to lodge standardised information and documents with a single entry point to fulfil all import, export, and transit-related regulatory requirements*. A blockchain-based system can accelerate the trend of connecting Single Windows to create regional networks, connecting more data and taking the good practice of Single Window use for trade facilitation to another level. However, this would of course require agreements between countries and with economic operators on standardised data.

4.6.4. Social perspective

Integrating into a system like Tradelens does not carry, by itself, any major specific cost for actors making it in this regard equally accessible for smaller and larger companies. However, the level of integration does depend on the technological readiness of the company. Furthermore, the time-saving and cost-reducing effects of the platform depend on the level of integration a player has with the platform, offering more for larger, more integrated players than small actors.

Regarding specific actors, blockchain-based platforms greatly facilitate the work of intermediaries by providing increased (and more accurate) information. However, this increase in information also means that the system's reliance on the work of intermediaries will be reduced. This could ultimately lead to a reduction of workforce in the shipping sector.

4.6.5. Technical perspective

Shipping documents and event tracking systems have great potential to automate processes within ports and other shipping infrastructure across the world, especially with focus on insurance aspects and goods processing. Thereby, the goal is to improve the processes of the various involved intermediaries and streamline these processes accordingly. In that line of thought, the interactions with case study examples have provided interesting insights into some key technological decisions. An important point is given by the statement that blockchain should be not just utilised for the sake of using a modern and hyped technology, but rather a careful set of choices is required that has to lead to the smart deployment of blockchain components across the process chain. Thereby, clearly not everything runs on top of a blockchain system, meaning that also traditional databases and API based integration between different systems is put in place where required.

Clearly, within this use case the trustful handling of documents is at the heart of the problem to be solved. Thereby, the documents are related to various events/milestones in the shipping and delivery process, e.g. arriving in the port. Hence, a digitisation in this process is critical in order to reduce the paper overload and accelerate the processing of the required actions and trustful verification of the involved stakeholders under increased security constraints. This leads to the utilisation of blockchain for storing hash keys relating to relevant documents and that way avoiding the manipulation of the shipping process chain. These hashes are based on digital signatures, which are normally generated based on traditional cryptographic schemes.

Another interesting statement which correlates with the experiences of the technical consortium members leads to the insight that the development of blockchain applications (DApps) is rather cumbersome and takes longer than in the case of traditional IT based applications and services. Partners integrating their systems with respective blockchain-based solutions are often having additional difficulties given the complex nature of the blockchain and its direct APS. Hence, an approach that has been undertaken in industry involves the creation of middleware types of system that hide much of the blockchain complexity and expose easy to use APIs offering the needed level of abstraction.

Further observations of relevance are given by some key design principles and employed technologies. Normally, blockchains in the domain of 'shipping documents and events tracking system' are deployed as permissioned blockchains, in order to restrict the access to the blockchain system to a reasonable verified set of stakeholders.

Typical technologies which were mentioned during the interviews included Hyperledger Fabric and Corda. In general, the goal and intentions on the technological level is to reduce the utilisation of PoW algorithms and to utilise majority based type of voting algorithms. This would improve the response times of the blockchain and is expected to make the overall system more scalable.

At this point, it should be clearly mentioned that the blockchain is not used as cryptocurrency within all systems that were analysed but clearly as a means for trust creation and distributed ledger with corresponding immutable properties. Hence, no money' flows are realised over blockchain in serious trading applications and Smart Contracts running on the blockchain are realised as a means to automate the required workflows, e.g. the automated governance relating to data for submitting EU declaration forms.

4.6.6. Security perspective

With regard to security, a number of exciting topics and aspects were reflected during the interviews and desktop research relating to the case study. The topic of the potential pitfalls coming through the introduction of Smart Contracts was discussed. Thereby, Smart Contracts with their automations are perceived as potential vulnerability in terms of the complexity they try to automate and the possibility for functional and security mistakes which could be introduced intentionally or unintentionally. Hence, one of the required aspects for future development is given by the need for quality assurance and testing frameworks and approaches to the development of Smart Contracts.

The topic of persmissionless vs. permissioned blockchain is also one of relevance from a security perspective. As mentioned above, obviously the industrial grade solutions prefer a permissioned solution with a clear control and verification of the involved stakeholders and customers.

With regards to availability as an aspect of security, no performance drawbacks and potential possibilities for easy attacks in that regard were reported within the conducted interview, which contradicts the lab experiments (based on Ethereum and PoW) of the technical partners of the study. On one hand, the permissioned nature of the utilised blockchain layer seems to provide a remedy for potential performance issues, given that participants can be restricted if needed. Furthermore, special attention is paid on further optimising the processes within the blockchain, e.g. through voting consensus where possible, such that according to the interviewed partners an improvement in scalability is observed with every new version.

The security of the platform in general in terms of protection against hacker attacks and security aspects implemented within the software has also been discussed for this case study. It seems a common choice to rely on a cloud provider (such as SAP, IBM and AWS) and run the blockchain on top of the cloud infrastructure. Hence, the security is then guaranteed by the cloud provider to a large extent. Thereby, aspects such as ISO2700 security certification are in place in order to increase the trust in the deployed technology. Furthermore, data encryption and data protection based on hardware solutions are also employed allowing the communication over different channels in a network of permissioned ledgers with immutability and access control. Potential issues relating to the vulnerability (e.g. Shor's algorithm for cracking asymmetric encryption) of the employed cryptography relating to recent advances in quantum computing are not perceived as a potential threat yet.

4.6.7. Environmental perspective

The environmental perspective of the blockchain utilisation in the domain is twofold. On one hand, it is clear that the transaction mining based on PoW algorithms is highly intensive and leads to an increased amount of energy consumption. This energy is likely to come from non-renewable sources – especially in many parts of the world where the governmental policies are less focussed on CO2/NOx reduction. The increased utilisation of permissioned blockchain provides some remedy for the issue by restricting and controlling the number of participants/nodes in the blockchain and allowing for certain security parameters of the PoW algorithms to be configured in a more energy saving manner. Furthermore, it is clear that in the long term the blockchains would need to migrate to voting consensus schemes which are expected to improve the blockchain scalability and response times and reduce the energy consumption when it comes to transaction mining.

Another key benefit for the environmental perspective is given by the promise of the blockchain technology when it comes to the streamlining, automation and acceleration of processes. For example, the optimisation of trucks waiting in long queues to deliver their goods at ports, terminals and across borders will lead to a clear reduction of CO2 emissions. Furthermore, the overall transparency which will come with the blockchain technology will allow for better optimisation of processes across various involved stakeholders and will lead to better predictability with the potential to establish better flows with less pollution.

4.6.8. Data protection and privacy perspective

The very character of the immutability of the blockchain technology gives stance to the issue of data privacy, especially raising concerns surrounding personal data. Furthermore, the availability of personal data is not necessarily disclosed to the administrators of the blockchain in use (in this case by the shipping industry): its sensitive character may also not be revealed.

However, in many cases the nature of the data stored inside the blockchain is of a heterogeneous nature. Indeed, a generic blockchain might be used by its participants to store different kinds of documents, events and transactions, which may involve non-personal data as well as personal and sensitive data. In the context of the shipping of documents and events tracking system it may indeed be the case that personal data are not relevant, while there is rather a need to protect business data. Against this backdrop, it can be noted that blockchain architecture can be varyingly designed, allowing for a level of data protection which is similar to that agreed in traditional contracts. This is especially true in permissioned blockchain, where the access to the documents and data can be specifically governed.

This was also confirmed in interviews, where it was underlined that it is, indeed, up to the owner of the transport to decide who has access to its data. Data sharing templates exist based on the traditional trade process, defining the default level of access to information and data, which are set by the platform and editable by the transport owner.

4.6.9. Transparency perspective

Blockchain has a great potential to underpin unprecedented transparency in the future of document shipping and event tracking. Real-time visibility and transparency allowed by the technology through an integrated, end-to-end solution system can enable a swift access to live information, conveying trust and closer collaboration and partnership among the stakeholders involved. In fact, critical business decisions in the shipping industry are taken based on information provided by agents and intermediaries. This is often complicated by the very nature of the business, where the operators can be far away from the ports and need accurate information over the physical operation and process, in order to improve their decision-making. As such, reliance on the work of intermediaries can result in strained relations when transparency is lacking and information is not shared well. The process of tracking and tracing, with the aid the blockchain is able to give, can be conducted quickly, efficiently, and accurately to adequately protect consumers and organisations. The immutable structure of blockchain also prevents tampering and provides a reliable mechanism for the stakeholders involved to access the data stored inside the system. This positively affects the level of trust of the relevant actors which are able to drive operational efficiencies through unprecedented access to information.

4.7. Case #6 – blockchain-based electronic certificate of origin

4.7.1. Description of the cases

Definition of the problem addressed and challenges

Certificates of Origin (CO) as essential international trade documents, are subject to manipulation and/or misinterpretation by different actors. Moreover, CO require significant time and attention as they should be manually filled in and physically transmitted when goods are delivered.

In this context, companies are often not confident about the true provenance of goods they have purchased. For instance, in the USA concerns have been raised about companies declaring exports for footwear, food, or other goods 'Made in the EU', as they are suspected to be produced in neighbouring countries to evade restrictions and tariffs. In Europe, worries arise from fashion goods counterfeited in Asia that according to the EU Office for Harmonisation in the Internal Market cost European brands around 10% of their total sales (equivalent to approx €26 billion) every year.[65]

Initiatives for electronic certificates of origin (eCO) have started to develop to attempt to streamline the transferring of electronic certificates of origin (eCO) for goods exchanged internationally, whilst making the processes simpler, transparent and secure by reducing the risk of forged declarations.

Solution proposed

A permissioned blockchain distributed ledger would help in tracking the eCO through all stages of trade, serving thus as an authentic trade document for customs agencies and importers.

On that account, key stakeholders involving a country's chamber of commerce, trade partners, logistics providers, etc. would be able to exchange eCO instantly and securely through a tamper-proof DTL.

Hence, blockchain would facilitate and speed up customs processes by helping stakeholders trace the origin of goods, while exchanging thousands of COs instantly and avoiding risks of tariff-avoiding forgery

Development and adoption

Blockchain-based eCO platforms providers are collaborating with chambers of commerce to provide solutions that would enable chambers in different countries to offer eCOs and connect with each other to exchange documents via a DTL. The main objective is to speed up and secure the authentication of trade documents.

For instance, the Singapore International Chamber of Commerce (SICC) is the first chamber to offer an eCO. By using the services of vCargo Cloud, SICC allows instant verification of CO utilising QR codes to exchange CO via a private blockchain network, thus preventing any attempt of fraud, manipulation or third-party interference.

4.7.2. Economic perspective

The origin or provenance of a good collected in an eCO refers not only to where the good was sourced but also to its chronological record of its ownership and location. In terms of economic benefits, eCOs clearly address the problem of **verification costs** by automating processes related to auditing transaction information. The platform and networking aspect is less important in this use case.

Automating processes as piloted by SICC and vCargo could benefit the whole supply chain, but mainly the end-user and government authorities such as custom authorities. Nevertheless, detailed and traceable information of goods would also allow companies to more easily fulfil their obligations towards customers and governments in demonstrating the origin of their goods and their applicability to, for example, preferential treatment. However, current procedures for obtaining certification for rules of origin are also seen as cumbersome and inefficient for businesses themselves.[66] Blockchain-based eCOs could greatly facilitate processes and make identifying and verifying the origin and supply chain of products more efficient.

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[65] Situation Report on Counterfeiting in the European Union, 2017

[66] European Parliament (2018) Report on Blockchain: A forward-looking trade policy (2018/2085(INI)).

4.7.3. Trade perspective

Blockchain-based eCO platforms would make the work of government authorities more efficient in checking compliance with tariffs and preferential rules of origin set out in trade agreements. Fraud such as circumvention and transhipment, where companies circumvent tariffs or restrictions by sending goods via third countries could be more easily detected. For example the United Nation, Centre for Trade Facilitation and Electronic Business proposes a use case in which national platforms host approved eCOs and share them via a multi-country blockchain ledger backed by multilateral agreements.[67] In addition, such a platform could provide some transparency by hosting eCOs and other trade related documents.

Already countries are moving towards integrated and sophisticated platforms, which also integrate eCOs. For example, the UNCTAD Automated System for Customs Data (ASYCUDA) or the ASEAN Single Window. However, much of trade is still based on paper, but many international trade actors see blockchain as a new opportunity to further digitalise trade transactions[68], since its immutable and verifiable aspects can allow the elimination of paper in areas where it is still required and. Overall, blockchain technology for eCOs could contribute to trade facilitation and ultimately increase trade volumes.

In conclusion, for trade, blockchain technology could be used to prevent fraud and facilitate customs and border-crossing procedures. Additionally, it could be used by shippers to demonstrate the origin of their goods, while customs agencies could more easily verify this information.

4.7.4. Social perspective

DLT can not only make trade more efficient but also more transparent. Especially, regarding eCOs the aspect of social responsibility in sourcing inputs and purchasing final goods as well as health aspects and consumer fraud become prevalent topics.

There are various examples of this in practice. A report by the Mercatus Center[69] highlights a few, for instance tracking the origin of a good is very important in agriculture supply management to identify sources of **food contamination**. In the USA, Walmart has done tests with blockchain technology to maintain its record of food provenance and could trace the origin of a product in 2.2 seconds compared to over 6 days in its traditional approach. Counteracting **food fraud**, also considering for example the EU's rules for geographical origin of agricultural products, is another issue where eCOs could help. An Australian exporter InterAgri has been experimenting with using blockchain to track production and delivery of Australian beef products to prevent counterfeits. Looking beyond agricultural goods, there are also concepts for other product categories. For example, Minehub aims to tackle the digitisation of mine-to-market provenance among other issues in the mining industry.

Overall, for consumers, eCOs can provide better information about the products they are purchasing by informing about the origins of a product and its supply chain, especially in the case of public ledgers. Similarly, for producers, blockchain could facilitate monitoring each step in a product's transaction history thereby helping to prevent theft or fraud in their supply chain as well as facilitating legal compliance.

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[67] UN/CEFACT (2018) Blockchain White Paper. White Paper on the technical applications of Blockchain to United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT) deliverables.

[68] World Trade Organization (2018) Can Blockchain revolutionize international trade?

[69] Christine McDaniel and Hanna C. Norberg (2019) 'Can Blockchain Technology Facilitate International Trade?' Mercatus Research, Mercatus Center at George Mason University, Arlington.

4.7.5. Technical perspective

The technical solutions which are currently state-of-the-art in this area are built in a way that they can be deemed blockchain-technology-agnostic and can easily integrate with different blockchain substrates underneath. Typical examples of technologies for the blockchain part of the solution are given by Ethereum, Quorum, Hyperledger and Corda. The solutions' characteristics which we could obtain in our interviews show that normally cloud provider products are utilised in order to use the blockchain nodes – typically SAP, AWS, Microsoft Azure or Google Cloud.

Within the interviews it was clearly stated that blockchain is used only as means for trust creation and tracking the origin of products and items in an immutable way, thereby conducting all payments off-chain in case financial transactions are deemed necessary. Furthermore, obviously the blockchain technology performs pretty reasonably with regard to response times in the current case allowing to efficiently store and track different information regarding the processing and origin of goods and items in general. Thereby, a suitable acceleration of the computational processes is provided by the fact that only hash values of data items are stored on the blockchain, in order to reduce the read/write blockchain operation complexities.

The origin is often tracked by different sensors or QR codes which are attached and associated with the products. These markers can be easily read with different end user devices such as smart phones and tablets after corresponding apps have been installed. These apps interact with the blockchain-based backend.

4.7.6. Security perspective

With regard to security, the current solution providers rely heavily on the security of the underlying cloud operator (e.g. SAP). In this case the cloud operator emerges as a reliable party having passed various certification processes and deploying the blockchain nodes as yet another service in its cloud.

Another exciting aspect is given by the choice to be made between permissioned and permissionless blockchain technology to be employed. Currently, the focussed solution is built on permissionless solutions but it is considered that the customers and the market will have the final say on the mix of permissioned and permissionless products. In that line of thought permissionless blockchains will be easier for on-boarding new participants and will probably scale more efficiently as more and more specific cases will be integrated - e.g. pharmacy or various types of industrial products requiring origin tracking. On the contrary, permissioned blockchains will allow better control of the involved stakeholders and will enable counter measures against attacks such as identity changing thereby providing a basic initial trust for the overall system.

4.7.7. Environmental perspective

The typical problem faced here is given by the energy consumption of the mining process in the case of PoW. The interviewed stakeholders expressed the opinion that in the future a new wave of blockchains will emerge, where different mining algorithms (e.g. PoW, PoA and PoS) will be combined depending on the concrete use case. In general, a basic view/opinion was formulated that the overall balance of the blockchain introduction eCO will improve sustainability, traceability and will support the transparency and increased sustainable products' market share thereby leading to less CO_2 and NO_x emissions for the involved products.

4.7.8. Data protection and privacy perspective

Blockchained eCO platforms are in their infancy and the measures of security within these platforms are still being improved. Following some fraud cases regarding the origins of goods, the blockchained eCO platforms have created measures to ensure the protection of the data. For example, some platforms have created single-window systems for governments. This means there is only one point of access to the decentralised database. Aside from this, these platforms are currently working to implement ways to restrict the duplication of trade documents, which will ultimately reinforce data protection and privacy within the blockchain-based electronic certification of origin platforms.

4.7.9. Transparency perspective

Blockchain-based eCO platforms lead to more transparency, as they work in a way to efficiently track the goods and services, tracing all stages of trade in a transparent way. The aim is to enable the goods to be traced and verified at all points of the supply chain. This capability to track and see the journey of the goods erases any ambiguous notions throughout the e-commerce system.

Additionally, regional and national Chambers of Commerce have developed e-CO platforms that exporters can use to view and receive their certificates of origin. These platforms are becoming more and more popular due to the support from policy-makers and the business community. The transparency within blockchained eCO platforms provides easier and more trustworthy ways for stakeholders to collaborate and access trade documents.

Besides, it is paramount to ensure that the streamline in the exchange of eCO, provided by the blockchain, does not jeopardise the function of such documents. In fact, exporters or manufacturers prepare eCo to be submitted to the importing country's custom authorities, in order to justify that a given good is eligible for entry and can meet the relevant custom requirements. In principle, the documentation accompanies the product exchanged internationally. With stakeholders able to instantly transfer thousands of eCO through a permissioned blockchain distributed ledger, customs processes are certainly facilitated and speeded up. Nevertheless, despite the ease gained in the exchange of documents, physical goods that eCo refer to will remain subject to usual trade practices. The technology used will hence have to secure a sound connection to the traded product, by linking the authenticated and certified physical good to the legitimate blockchain entry. This way it is avoided that a different or replaced good is associated with the eCo .

4.8. Case #7 – proof of authenticity of luxury products

4.8.1. Description of the cases

Definition of the problem addressed and challenges

Luxury brands are constantly investing time and resources to battle counterfeiters. The main problems arise from fake parts compromising products quality at production stage, as well as from clever look-alikes stealing market share. In the EU luxury goods market, 10% of all items for sale are counterfeited, corresponding to approximately $28 billion in lost value.

Hence, luxury brands are looking for technological solutions to improve counterfeit detection and increase their revenues in their value chain. The end customer may also want to ensure that the product purchased is a genuine one. Finally solutions for authenticating luxury products may also prove useful for law enforcement, to detect both counterfeits and stolen goods.

Solution proposed

Authenticity-tracking blockchain would streamline and trace every stage of luxury goods value chain. Key stakeholders such as luxury goods manufacturers, merchants, banks, or insurers, would be able to provide to the customers a single version of truth thanks to the DTL.

Blockchain can be part of a technological stack to fight counterfeits for luxury product manufacturers, as preventing fraudulent materials to enter the manufacturing cycle would help companies reduce failure rates and costs of replacing defective parts security.

Furthermore, placing certificates for luxury goods on a blockchain would prevent frauds, thus solving the issue of provenance. At the time of purchase, a consumer would be able to use a brand's application to receive a certificate containing all product information.

In addition to a products authenticity, blockchain would also ensure consumers security. For instance, if a stolen luxury item is being resold, the owner would be able to track the product's location via blockchain and notify the respective authorities that the seller unlawfully acquired the said item.

Development and adoption

Blockchain-based start-ups have developed different platforms to help track the origin and authenticity of luxury products. The adoption of such platforms among all industry participants aims to ensure products authenticity thanks to a permissioned distributed ledger system that tracks and protects items of value.

For instance, Ever ledger, aims to place certifications on a blockchain to solve provenance issues. By collaborating with major certification houses around the globe, Everledger was able to create a digital thumbprint that tracks and protects items' values for individual diamonds.

Other consortium models like AURA, which on boards different luxury groups, would enable consumers to access the product history and proof of authenticity of luxury goods from raw materials to the point of sale, all the way to second-hand markets.

4.8.2. Economic perspective

Data from Statista shows that the market for Luxury goods has been growing. In 2018, the luxury goods market in Western Europe had an estimated value of EUR 248 billion and in 2017 Europe's share of the worldwide market was 32%. A study from EUIPO showed that in 2016 imports of counterfeit products into the EU amounted to as much as EUR 121 billion (not only luxury products).[70] Meanwhile, the luxury market is experiencing an increase in online purchases and a strong positive growth trend especially due to increased purchasing power from Chinese customers. The increase in international trade of luxury products and in the use of online channels makes protecting one's brand more difficult for companies, while verifying authenticity becomes a concern for customers. Already, companies such as Entrupy and Real Authentication offer authentication services to consumers and companies.

Counterfeits lead to reduced sales for affected business and thereby economic losses in terms of revenue and jobs. A report on EU customs enforcement states that counterfeit products are increasingly sold at prices similar to the genuine goods, effectively substituting them on the market, however luxury goods are sometimes an exception here.[71] Blockchain is a new technological lever that can be used to counteract this negative trend, while not increasing verification costs exorbitantly. The technology can be used to improve authentication and traceability, even certify the origin of finished products and their raw materials. For example, luxury companies such as LVMH with their platform Aura or De Beers with Tracr have already launched pilots that use blockchain in protecting their goods.

[70] OECD/EUIPO (2019) Trends in Trade in Counterfeit and Pirated Goods, Illicit Trade, OECD Publishing, Paris/European Union Intellectual Property Office.

[71] DG TAXUD (2019) Report on the EU customs enforcement of intellectual property rights: Results at the EU border, 2018.

4.8.3. Trade perspective

As highlighted in the previous section, proof of authenticity based on blockchain technology could counteract current trends towards increased trade in counterfeit products. A widespread adoption could increase trust in products sold online and thereby increase both imports and exports of luxury products, as these can become more trusted and thereby accessible to customers worldwide. It might decrease the purchase of counterfeited luxury wares as these are now more easily recognisable, which in turn would decrease imports from countries that are the main sources of counterfeit products into the EU. In 2018, in terms of value these were China (63%), Hong Kong (16%), Turkey (9%), Vietnam (2%), followed by Cambodia, Bangladesh and the United Arab Emirates.[72]

In addition, to potentially increasing trade and shifting trade patterns, blockchain could also facilitate the work of European customs authorities. In 2018 alone, over 69 000 detentions (a total of 26.7 million articles) were made with a domestic retail value of over EUR 738 million.[73] Here the technology could facilitate the work of customs authorities in checking the origin and authenticity of goods. Simplifying verification could therefore further facilitate and increase trade.

4.8.4. Social perspective

Consumers sometimes actively choose to buy cheap and counterfeited wares, but many times they are misled. By pretending that wares belong to a luxury brand, merchants can often charge a mark-up on these. Especially the Internet facilitates fraud as it makes it possible for counterfeiters to sell fake goods without prior consumer inspection. This **consumer fraud** damages the customers who unknowingly pay more than they would and damages in the long-term also the trust in these products. Here company trademarks and non-legal certifications established by producers aim to counteract and signal to the consumer authenticity and value, however the second-hand market and online sales make policing this field very difficult. Next to producers, policy-makers in the EU are trying to counteract this with the EU Customs Action Plan to combat IPR infringements.

Moreover, counterfeited products can also pose **health risks** as they often do not comply with EU regulations for example on fragrance labelling in cosmetic products or the use of nickel in jewellery, which in some cases can cause serious allergic reactions. In addition, some of these products might also pose **environmental risks**. A 2017 report by Europol states that counterfeiting causes potential harm to the health and safety of EU citizens, but also to the environment.[74] Finally, counterfeited goods are also an important **source of income for organised crime**, which poses a considerable threat to the safety of societies.[75]

Blockchain technology such as Everledger could make certificates of authenticity and trademarks more traceable and purchasing goods in second-hand markets or online more transparent for consumers. Despite this, counterfeiting will very likely continue to be a problem as many people pay little attention to the authenticity of goods and often non-authenticity is accepted by customers as many desire luxury goods at low costs.

[72] Ibid.

[73] Ibid.

[74] To give an example (though not a luxury product), counterfeit pesticides that contain toxic substances may contaminate soil, water and food.

[75] EUROPOL/EUIPO (2017) 2017 Situation Report on Counterfeiting and Piracy in the European Union.

4.8.5. Technical perspective

The proof of authenticity for luxury products is generally setup in a similar way as the case studies relating 'tracking ethical sourcing in the food industry' and 'blockchain-based certificate of origin' case studies.

The best technical choices would relate to cloud based blockchain solutions involving mature technologies such as Corda, Hyperlegder, Bitcoin and Ethereum. The deployed blockchains would be mainly permissioned thereby establishing an additional identity/user management layer. However, public permissionless blockchain may allow for better scalability thereby enabling the easy onboarding of new products and producers to the blockchain.

Scalability issues in terms of performance responce times for storing and reading are expected but would be reduced by some tailored solutions taking advantage of different aspects such as the potential permissioned nature of the blockchain layer and the possibility to reduce the mining complexity in terms of transaction costs, computational and energy power.

The utilisation of smart contracts in the current context is not expected. The blockchain will also not be used as a cryptocurrency but rather as means for trust creation and establishment. The overall architecture will be secured and enabled by cryptological artifacts such as trusted services lists, certificate revocation lists, corresponding keystores and certificates. The interoperability of different blockchain layers will be further considered as a challenge as the authenticity proofs will need to propagate across various systems which require some smart integration efforts in general.

4.8.6. Security perspective

With respect to security, a typical solution could employ both – a permissioned architecture with an identity/user management or a permissionless concept. The general security architecture would be provided by traditional PKI structures – cypher suites, certificate chains, trusted services lists, certificate revocation lists etc.

The security in the product and platform provisioning would be guaranteed by the utilisation of established cloud providers that are offering blockchain nodes as a service. These cloud providers would be generally a subject of regular audits and certification processes towards establishing their functional stability and security.

Another interesting aspect of crucial criticality could emerge in the near to far future based on the developments in the area of quantum computing – quantum computing is expected to make most of the asymmetric encryption obsolete if it becomes operational and offers the promised computational advantage. In such case the PKI algorithms would need to be exchanged with post-quantum cryptographic algorithms - there is a large number of algorithms deeming post-quantum resiliency. To summarise: the security for this use case is expected to align with the aspects discussed for the various case studies so far.

4.8.7. Environmental perspective

The environmental aspects are mainly of a negative nature. The proof of authenticity for luxury products does not have the potential scale as to be an overall game changer in terms of sustainable and ethical production for CO2 and NOx reduction. In addition, the mining algorithms might be another source of CO2 emissions, given the required computing power and associated energy consumption for transaction processing. Hence, the utilisation of permissioned blockchains is recommended in order to be able to reduce the required complexity of the mining processes. Furthermore, it would be required to look into other less intensive transaction execution schemes beyond energy intensive PoW – e.g. PoS and PoA. These schemes have the potential to further reduce the negative environmental impact of the current scenario.

4.8.8. Data protection and privacy perspective

As far as privacy is concerned, authenticity-tracking blockchains for luxury products do not give rise to particular concerns. By contrast, the development and utilisation of authentication systems is one of the main strongholds of the blockchain technology.

Since blockchain is established as a distributed ledger, it is by design intrinsically resistant to tamper or modification of the data. Once recorded, the individual records cannot be altered retroactively without agreement from the other participants of the network. In fact, decentralisation prevents and deters users from manipulating data, since the rest of the network would soon notice and reject it.

Hence, after being stored on the blockchain, individual records are also immutable, in order to prevent their possible editing or change to hide a potential fraud. Decisions about what to share with retailers or final consumers, are taken by the brand owner, in order to ensure the sub mentioned proof of authenticity. Storing data on the encrypted peer-to-peer system allows only the authorised parties to upload relevant data on the blockchain. These characteristics of the blockchain make it a valuable tool to fight counterfeit, improving legal control over access to and use of data on the origin and authenticity of products.

4.8.9. Transparency perspective

Blockchain, being an easily accessible and immutable distributed ledger by design, seems to be the go-to solution for this use case, as it can provide the stakeholders involved reliable and non-modifiable data on luxury goods.

By implementing blockchain technology, merchants and consumers can track the entire life cycle of products. All information necessary relating to the sourcing all the way to final production are made available on a digital ledger, thus implying a high level of transparency that significantly helps reduce frauds and counterfeit goods.

Blockchain-based proofs of authenticity for luxury products eliminate certificate management issues, including expiration and revocation, and allow proving and sharing between participants prove of the time, authenticity, and origin of the input data. With non-expiring data validation transparency in the luxury good industry is hence enhanced, eliminating the need for secrets or other forms of trust.

However, a fortiori as data is more transparently shared and mass-scale available, it is key to ensure trustworthiness of the data. This means that it has to be accurate and relevant to the given product, ensuring that no third-party has purposefully or accidentally altered what has been certificated and documented. By only relying on the good's provenance registry and validations from participants through the blockchain, there is still the risk that the physical item is replaced and then authenticated by linking it to a legitimate blockchain entry. In order to guarantee that the physical good itself is the original and it is not replaced, a secure connection to the good has to be established, by securing way to link physical goods to the provenance on the blockchain.

4.9. Case #8 – tracking ethical sourcing in the food industry

4.9.1. Description of the cases

Definition of the problem addressed and challenges

A number of practices in the food industry are compromising the ecosystem of environment, wildlife and people all over the world. Issues that range from, human rights abuses, illegal, unreported, and unregulated trade practices are harming this ecosystem and creating trade disputes.

Tracking ethical sourcing in the food industry is an essential process for certain industries like fishery. As a significant component of the food industry, the global total capture of fisheries production peaked at 90.9 million tonnes in 2016. However, this amount is arguable as most of the fish catught in developing countries is by purse seiners which are unrecorded as authorities encounter difficulties to trace it.

This opens an opportunity for technologies, ensuring traceability by tracking the sourcing of products in the food industry. Such a system would aid standards compliance and help eradicate fraudulent reporting while contributing to ecosystems preservation.

Solution proposed

Blockchain technology would ensure the secure flow of information by sharing a unique version of truth among all stakeholders involved; from fishermen to factories, certifiers and consumers. This would enable the tracking of the whole value chain; from compliance data, to methods of fishing and vessel type.

For instance, a blockchain-based system could help the tracking of Tuna from the fisheries to the customer's plate, ensuring the respect of fishing quotas, and providing transparency for the end customer. Monitoring fish quotas would also avoid ghost fishing and fish migration thus affecting the fauna of the oceans.

Public blockchains would ensure the provenance of such goods at a broader scale, as they remain open to on-board new stakeholders internationally while keeping the consensus mechanisms unchanged. Certificates or claims stored and exchanged in an immutable, decentralised and globally auditable format would standardise international trade requirements in the food industry.

Development and adoption

Blockchain tracking solutions in the food industry are developing robust proof of compliance to standards at origin and throughout the chain.

The recent adoption of Provenance blockchain solution in tracking fish quotas in Indonesia from landing to the consumer's table is seen as a first step to track sourcing in the food industry. Interoperability with other platforms is also an area for future development; as such solutions in the food industry could also communicate with other industry platforms (e.g. logistics) to add transparency and traceability to the value chain.

4.9.2. Economic perspective

A lack of information across the value chain is not only costly from an ethical perspective. Imperfect information and problems with transparency make it very difficult for consumers to make informed decisions. Lack of access to products differences in terms of quality or other attributes such as sourcing making it near-impossible for a consumer to consider whether the price that is being charged for a product is fair.[76] This leads to information gathering and information processing costs for the consumer and amounts to verification costs that are in most cases too high for individual consumers.

If consumers have access to the information they wish to verify on a product, they are able to more easily compare their actual willingness to pay the price being charged. For a consumer that values ethical sourcing this trust would make it possible to pay the higher premium for this sourcing – and trust that what this premium is being paid for is being delivered.

[76] 2018, Analysis of the trade in Guarantees of Origin, Oslo Economics

4.9.3. Trade perspective

Increased international trade flows have made inspection and quality control at the different stages of the value chain nearly impossible. Not only is it difficult for consumers to know where their products come from and how they have been produced, companies also struggle with making sustainable partnerships and verifying partners' sourcing. Centralised solutions, managed by intermediate parties to register, trace and test products are also expensive and can sometimes bring up discussions on their independence. For example, criticism with Fair Trade labelling organisations have included questions on whether the premium paid by consumers is fairly distributed in the value chain, or whether monitoring standards have been properly implemented.

A distributed ledger makes entered data immutable, so that all players can contribute to the information and data is verified by all required market players. This makes a (costly and at times questionable) centralised entity unnecessary for guaranteeing fair trade practices. Of course it remains open if the data entered in the ledger was trustworthy to begin with. However, in the case where a trusted system to track sourcing (based on blockchain or other technologies) could be established, then one would expect increased trade in ethical goods as consumers could more easily access and verify product information.

4.9.4. Social perspective

The very nature of the use case has very strong impacts on fair trade and ethically sourced products. As it makes verification easier for consumers, it makes them more likely and more willing to pay the 'ethically sourced premium', increasing the prices and thereby the revenue of the producers. Recurring cases of consumer boycotts against multinational companies (e.g. Nestlé, Coca Cola) due to unethical sourced products showcase the need of producers to signal the sources of their products.

In the long-term, blockchain technology could allow consumers to better verify where products came from, raise awareness and overall allow for better informed choices that support ethical and socially good products. This would come in a time where more and more consumers value the sourcing of a product over its price. Nevertheless, as with current promises by companies to source ethically, a blockchain-based platform that tracks the sourcing of food would need to first gain the trust and recognition by consumers.

There are already some examples. Starbucks is looking to connect coffee farmers to the person drinking the coffee in order to verify its ethical sourcing under its Coffee and Farmer Equity practices. Their mobile app[77] will show customers information about where their packaged coffee comes from, where it was grown and what Starbucks is doing to support farmers in those locations. To give more weight to the support, Starbucks has been interviewing farmers in Costa Rica, Colombia and Rwanda to understand their specific needs. Connecting the farmer to the customer through the company allows for more personalisation, both in the support provided to the farmer as well as in the decision making process for the customer.

4.9.5. Technical perspective

The technical perspective is mainly provided by viewing the blockchain as a platform for exchanging and storing information regarding the origin and processing chain within a food delivery process. Thereby, the information is stored in an immutable way as to guarantee the transparency and traceability of the foods origin and its ethical aspects. These type of blockchains should be typically

[77] ComputerWorld - From coffee bean to cup: Starbucks brews a blockchain-based supply chain with Microsoft - 2019 https://www.computerworld.com/article/3393211/from-coffee-bean-to-cup-starbucks-brews-a-blockchain-based-supply-chain-with-microsoft.html

permissioned with on-boarding belonging producers and delivery businesses in order to increase their transparency and promote them better as an incentive for their business. This would allow, on one hand, to verify the participants, make better social advertisement for their products, and reduce the risk for identity based fraud and entering malicious information, since the ledger would be immutably storing the belonging data leading to the demand created by the emerging reputation and trust.

The possible solutions range from the utilisation of Ethereum and HyperLedger to Corda with the latter obviously increasingly becoming a choice for many industrial grade deployed products. Furthermore, electronic based solutions for product tracking such as QR codes, QR scans, NFC (e.g. RFID) and sensors can be used for following the path of a food product and automatically verifying its ethical aspects over the blockchain[78]. The blockchain platforms in place would be typically running over a cloud infrastructure, which would allow the implementation and integration of the above technologies.

4.9.6. Security perspective

Naturally, state-of-the-art security mechanisms are required in order to enable the secure and immutable storage and/or management of relevant data and transactions on the blockchain. Indeed, belonging PKI infrastructure and security measures in general (penetration testing, ISO2700 security certification …) would be required for such a product. The key aspect for such a blockchain-based fair trade initiative is the above mentioned 'permissioned vs. permissionless' aspect. Given that the ethical tracking would require to establish trust and transparency among the various stakeholders and the customers and society in general, there should be no possibility to swap identities and basically improve 'reputation overnight'.

4.9.7. Environmental perspective

With regard to the environmental perspective, the issues relating to the energy consumption of transaction mining are also valid for this case. Multiple solutions are possible, including the utilisation of PoS type of mining algorithms as well as the usage of private permissioned blockchains, in which the mining is not really required in the large scale as in public blockchains.

On the positive side, the tracking of food origin will have an enormous environmental impact in terms of reduction of CO2 and NOx. It will allow citizens to select mainly local products that were grown and produced in a sustainable and ethical way; the selection is carried out based on the transparency and immutable information provided and managed over the blockchain. The utilisation of blockchain concepts would increase the trust, transparency and automation (with regard to the data and tracking management) in comparison to legacy (often closed and centralised) databases and registries. Hence, less gas pollution is generated in addition to reducing the transport ways and correspondingly the CO2 emissions associated with the food products in question. The utilisation of blockchain in that regard will increase the transparency of food supply chains and serve as means to earn better reputation among citizens and customers with environmental awareness.

4.9.8. Data protection and privacy perspective

Similarly to what has been observed in reference to the previous use case, from a data protection and privacy perspective, blockchain inherent characteristics seem very suitable for tracking ethical sourcing in the food industry. This is primarily due to its ability to lower the chance of fraud or data mismanagement.

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[78] In the conducted interviews, a concrete example was given where sensors were placed within packages/boxes. However, different batch size are possible, e.g. per single item or per container.

However, although blockchain can be used to increase data security, its adoption within the food industry might have its own drawbacks. As previously noted, although blockchain allows for the prevention of data falsification, this is only achieved at later stages in the supply chain, while it is not granted that the data that suppliers initially enter is reliable.

Furthermore, if public blockchains are used, control over privacy can be an issue in so far as, in many commercial instances, users prefer not to disclose all details of a transaction history or sensitive information. This kind of privacy control is easier in permissioned blockchains, which are private by default. Therefore, public and/or permissionless blockchain systems may need to be combined with other technologies in order to address the privacy issue.

4.9.9. Transparency perspective

Depending on the type of blockchain platform being used, blockchains can be designed to provide different levels of access to the data stored on the blockchain itself. The technology can provide transparency to the stored data, while keeping other kinds of data private. By investing in a transparent product lifecycle, firms adapt their strategies in response to market forces and inspire confidence in end consumers.

Through a blockchain employed in the food industry, stakeholders are able to track products through the multi-staged supply chain, providing a digital infrastructure that conveys trust and transparency to supply chain participants. Blockchain participants can track specific products in all stages of the chain and they are also able to track any characteristic or attributes about food products involved. As a result of the increased transparency, if a problem should occur with a food product, users who have access to the system, could identify the point at which it originated and act accordingly, saving valuable time, and avoiding serious dangers to the consumer's health and the brand image and minimising damage. When the technology allows to easily identify the root cause of the problem, faster reaction times are indeed possible, because supply chain information is immediately available on the transparent decentralised system. Furthermore, prices in all stages of the chain and the provenence, the production and the producers of the products can be traced. Allowing full traceability of all sources of all inputs used in all stages in the chain, blockchain employed in the food industry ensures a significant level of transparency available to every stakeholder involved, thus enhancing corporate integrity, loyalty and sustainability in the food industry.

Part 3 – Reflections on impacts and policy options

5. Blockchain and related technologies

The following sections discuss blockchain technology as presented during the study and assess its advantages with respect to other technologies and procedures which are currently established in the domain of ICT, and more specifically in the domain of international trade and supply chains. We commence with some general aspects and capitalise on key technological properties of the emerging blockchain solutions and platforms relating to international trade and supply chains. In parallel, we reflect on the differences to established legacy state-of-the-art procedures and approaches.

5.1. General aspects

The blockchain concept emerged as a critical topic in the course of the 2007-2009 financial crises, when trust in the global financial institutions was significantly questioned and the world was shaken by the insecurity within our financial and economic systems. The term was related to the establishment of a distributed cryptocurrency, without the need for a centralised set of financial institutions backed by state governments.

Blockchain was proposed as the platform for realising the digital structure to guarantee the dependable security and validity of transactions in a distributed environment. Thereby, as previously mentioned, the transactions are stored in an immutable distributed manner by utilising appropriate cryptographic operations - such as issuing and storing signatures, generating hashes and further – and logging the transactional information across a distributed peer-to-peer system, such that it can be easily monitored, checked and validated later on.

5.1.1. Blockchain features, added value and comparisons to current practices

The above described infrastructure intrinsically embeds a number of key features, which we compare to the current practices in ICT as well as in supply chains & international trade in the following table. The reflections on the ICT aspects are based on the research and expertise of the study authors, whilst the reflection on supply chains & international trade originate from our observations during the conducted interviews and discussions within the consortium.

Table 22 - Comparison of blockchain technology key features to current practices in ICT and in supply chains & international trade

Blockchain/DLT key aspects	Reflection on traditional/legacy approaches	Reflection on supply chain & international trade
Duplicated and replicated storage of transactional data	Duplicated and replicated storage can be also implemented without the utilisation of blockchain. P2P networks and database clusters are often employed, in order to guarantee a high degree of data availability and infrastructure resilience.	Current processes in supply chains in international trade are largely paper and manual driven (see chapter 7.1), however there is early efforts to digitalise these processes, especially in line with the 'Single Windows' of Opportunity approach[79], in which countries agree to digitally exchange required information for processing import/export transaction of goods. However, these processes are still very isolated – basically each country handling its own processes and just transferring the required information,

[79] World Economic Forum, White Paper, 'Windows of Opportunity: Facilitating Trade with Blockchain Technology', July 2019, online: http://www3.weforum.org/docs/WEF_Windows_of_Opportunity.pdf, as of date 17.02.2020

		thereby storing information redundantly and the belonging data in different formats. Hence, the current blockchain feature would not play a vital role in such an environment whilst it could be a game changer for a complete redesign of the 'Single Windows' approach. In such case the data will be shared in an interoperable way between two countries and the belonging transactions will be stored in a distributed immutable environment on the involved nodes - e.g. each involved authority could represent its own node in the blockchain – and the belonging transactions would systematically lead to the approval or rejection of an import/export procedure.
Decentralised control and consensus by allowing all relevant nodes to become part of the transaction issuing process	This is a key aspect that is not available in traditional approaches in the form we know from within blockchain world. Indeed, this can be considered as one of the key advantages and features provided by blockchain in comparison to legacy architectures.	As mentioned above, most of current international trade & supply procedures are paper based, whilst at the same time the digitisation efforts are mostly isolated and based on country-to-country agreements and procedures. Hence, the decentralised control and consensus provided by blockchain has the potential to scale up the trade and supply chain procedures between multiple countries by enabling the immutable and trustful sharing of transaction information and required data, whilst at the same time guaranteeing that the involved authorities and stakeholders can be held accountable in case of misuse or improper process execution. Besides, blockchain technology can largely increase the transparency in these processes by enabling the distributed immutable transaction and data recording in the process of international trade & supply chains handling.
Immutability by using cryptographic hashes and signatures to insure that the chain of blocks containing the past transactions has not been manipulated	This aspect constitutes another key advantage of blockchain as compared to traditional legacy systems. The immutability of the transaction records in a distributed ledger allows to create trust and ensure integrity and accountability in a distributed environment without a central authority.	As discussed above, the immutability of distributed transaction records and data within a digitalised supply chain & international trade process would increase the trust in the overall process between the different involved entities/authorities from different countries. Hence, blockchain's cryptographic immutability might provide the foundation for scaling up the digitalisation efforts and allowing the platforms to involve a larger number of countries beyond the country-to-country solutions deployed in the 'Single Window' approach.
Authentication by requiring the participating stakeholders to be authenticated to different degrees depending on the type of blockchain (permissionless vs. permissioned)	The authentication aspects can be realised also in traditional systems similarly as in the case of the blockchain considerations. In fact, the technology used to ensure authentication for blockchains is not blockchain specific but rather a common asset in the domain of distributed systems.	Current blockchain-based proof of concept and initial solutions (e.g. IBM Maersk Tradelens) as encountered during the interviews, are based on permissioned blockchains. This means that a number of authorities, companies and stakeholders are granted direct access to the underlying blockchain platform and have the possibility to initiate and approve distributed transactions within the belonging context (e.g. maritime trade insurances as in the case of Insurewave). This allows involving only relevant participants to the platform and processes whilst at

		the same time reducing the need for complex energy consumption intensive mining processes.
Timestamping given that each transaction is immutably stored on the distributed ledger with its belonging timestamp	The timestamping is also realisable in traditional/legacy architectures. However, in combination with immutability and the distributed trust establishment, blockchain has a clear advantage over traditional transaction and data storage systems.	Timestamping is another vital aspect related to the immutability of the stored data and transactions and hence has the possibility to provide a trustful environment and foundation for a digitalised international trade & supply chain process, which can scale beyond the straight country-2-country exchange of information. This would drastically increase the chance and the attractiveness of digitalisation for current paper heavy processes.

These key features lead to a variety of added values which blockchain technology provides in comparison to traditional/legacy technology within the corresponding use cases and scenarios. These aspects are correspondingly summarised in the following table.

Table 23 - Comparison of blockchain technology added value to current practices in ICT and supply chains & international trade

Blockchain/DLT added values	Comparison to traditional/legacy approaches in ICT	Comparison to current approaches in supply chain & international trade
The possibility to establish trust in environments where the single participating entities are not intrinsically trusted	This is a clear advantage over traditional/legacy approaches where trust is either not present or needs to be established through organisational and verification means.	Currently, trust in supply chain & international trade is established through the identity of the involved authorities and stakeholders which in a paper based process is verified by different documents, signatures, certificates and records in belonging registries which are managed or provided by a central authority. This type of trust is further extended to the current digitisation efforts (e.g. the 'Single Window' approach mentioned above), which makes the functional and stakeholder based scale-up and introduction of digital solutions extremely heavy and cumbersome. Hence, the possibility to establish trust in distributed environments – where the participating entities are not explicitly trusted – can be used to quickly integrate new countries, agencies, companies and stakeholders in a blockchain-based platform for international trade and supply chains.
The capability of establishing accountability, dependability and security in terms of data integrity in distributed peer-to-peer environments	This is a clear advantage over traditional/legacy approaches – blockchains come with a higher degree of security and resilience when it comes to preserving the integrity of data and ensuring accountability and dependability for transaction records.	The digitalisation of international trade and supply chains can benefit from these features by adding additional transparency as compared to current paper based processes and the initial non-blockchain-based efforts to increase the usage of IT in these processes. This means that data can be published on (permissioned) blockchain and subsequently cannot be manipulated whilst at the same time providing the basics for accountability and dependability within the DLT environment. However, it is important to carefully consider the type of data to be published – it should be anonymised and de-personalised in order to comply with GDPR and should not contain any sensitive information (e.g. company secrets), since it is going

		to be transparently available to all involved stakeholders.
The possibility to run a transaction based system without a central trusted entity	This is a clear advantage over traditional/legacy ICT approaches. The technology and architecture of blockchains removes the need for a trusted central authority.	Removing the need for central trusted entities could make a blockchain-based international trade & supply chain system attractive for a large number of stakeholders, since the integration of new participants would be easier and more efficient. This blockchain feature provides definitely a big advantage over the current procedures in the paper based manual process and the initial digitisation initiatives.
The capability of easily establishing and providing the basic scalable infrastructure required for a large number of digital solutions	Scalable infrastructures can be easily set up also with traditional approaches. However, blockchain comes with a number of advantages here including the aspects of trust and data integrity even in environments where the different participants don't intrinsically trust each other.	As previously mentioned, this option can be easily utilised to scale-up the digitalisation of international trade and supply chain processes, thereby increasing the attractiveness of automated transactions, processes and information sharing, whilst at the same time offering the means to easily integrate new stakeholders in terms of companies and state agencies.
The capability to automate transactions through the use of smart contracts	The secure and immutable execution of contract automations on blockchain is indeed a great potential and can be a decisive advantage in the future as compared to traditional approaches in the area of rules' application and contract processing. However, at the same time smart contracts also constitute a pitfall with regard to the quality of the automation code, the various legal aspects and the need to carefully verify and validate the correctness of the intended transaction execution logic.	Clearly, there is no similar process as smart contracts within the current paper based processes, whilst at the same time the digitisation efforts have the potential to implement automations similar to the possibilities provided by the smart contracts technology. However, there is one vital prerequisite for the increased utilisation of smart contracts (and similar automations), which is given by the need to integrate and adapt current legislation and regulations in a way that allows the automated performing of transactions. In addition, smart contracts have a clear advantage over straight forward automations which is constituted by the immutable logging of the transaction steps and details in the underlying blockchain.

In general, blockchains should be used and perceived as infrastructures enabling the exchange of information in environments and eco-systems where different players do not know each other, and may even be competing against each other, but are still participating in the overall system requiring a committed degree of cooperation. Currently, such environments and eco-systems are very difficult to establish without a blockchain in-between, meaning that in most cases a credible organisation/body needs to act as the trust creating authority (e.g. a forum or a standardisation body) - this hampers innovative business models and slows down the belonging processes in general.

As discussed in this study, typical domains where blockchains have the potential to play a vital role are given by cryptocurrencies, the financial industry, insurances, the domain of public services, energy trading systems, media and entertainment, micropayments, management solutions for digital rights, health information systems, and different applications in trade, logistics and supply chains.

5.1.2. Blockchain deficiencies

As discussed in the current study, especially based in the specific use cases, blockchain technology also bears a number of explicit disadvantages when it comes to its application for international trade and supply chains. These disadvantages were discussed in detail in the corresponding use case elucidations and are listed here, in order to clearly outline potential pitfalls in case of moving towards blockchain-based digital services within international trade & supply chain in the coming years.

Standardisation: Currently, there is a large need for increased standardisation activities both relating to blockchain technology itself and to international trade processes. From a blockchain technology perspective, there is a need to approach the standardisation of data formats for the blocks, of blockchain APIs, of the utilised cryptographic algorithms, of the configuration languages and APIs, of the access control procedures and technologies and further key functions and aspects of blockchain. These aspects are vital in order to enable blockchain technology to play a significant role in the crucial domain of international trade and supply chains. Moreover to maximise the impact of the technology, there would be also a need for changes from an international trade processes and documentations perspective (which are presented later in this document).

Interoperability: Interoperability is another key aspect which would build on the standardisation activities and strongly suffers because of the limited standardisation in the domain. In order, to enable the application of blockchain to supply chains and international trade, interoperability is required on multiple levels including cryptographic interoperability - e.g. common trusted spaces for blocks and immutable transaction records, cross-certificates for enabling the exchange between different blockchains etc. Furthermore, provided the presence of standardised APIs, the interoperability between different blockchain implementation can be worked towards in order to enable different countries/states and stakeholders to exchange and interoperate on blockchain level. In general, the current limited state of standardisation and interoperability of blockchain technologies is a clear disadvantage for the large scale adoption within the domain of supply chain and international trade. Furthermore, the current market forces and competition in the technology ecosystem is pushing technology providers to currently ignore the interoperability issues.

Security: The overall blockchain technologies can of course suffer various security issues relating to the employed cryptography and security mechanisms. Such mechanisms can naturally be hacked or compromised by negligence in implementation or human errors in operation. Hence, in order to apply blockchain-based solutions to international trade, a sophisticated amount of security analysis and security testing is required, i.e. security certified platforms for blockchain nodes, penetration testing for nodes and protocols, risk analysis and security certification for nodes, components and the platforms as a whole. Furthermore, in the long run, many of the current security solutions used in the blockchain ecosystem could be vulnerable to emerging technologies such as quantum computing – refer to Shor's algorithm for integer factorisation as a main thread for asymmetric public-private-key cryptography. This would thus also require the inclusion of mechanisms allowing for technology evolutions and replacements in any initiative promoting the adoption of blockchains in international trade ecosystems.

Energy consumption: Finally, from a general perspective, the main issue relating to blockchain is given by the energy intensive mining algorithms which need to be in place for the establishment of trust, immutability and reliable timestamping for transparency, accountability and secure data storage. The increased energy consumption of PoW algorithms might lead to negative environmental effects, which need to remediated. However, in the specific case of international trade, current blockchain-based solutions (for international trade and supply chains) focus on the utilisation of permissioned blockchains which involve only pre-authorised participants and hence, some basic intrinsic trust can be presumed. In this specific case, the PoW algorithms do not necessarily need to be deployed in their full complexity resulting in less energy consumption. In addition, recent work by DG DIGIT has shown the possibility to run blockchain nodes on an energy efficient system that uses only 2.2 Watt while validating blocks.[80]

5.2. Blockchain technological aspects

The following paragraphs briefly present some of the main technological aspects and features regarding blockchains and relate them to legacy/traditional ICT technology as well as supply chains and international trade. Typical blockchain and DLT technologies which should be considered and enjoy a wide acceptance within the community and emerging products are given by Bitcoin, Ethereum, Hyperledger, Corda, and Quorum. These platforms were confirmed in the scope of the conducted interviews and literature research.

5.2.1. Permissioned blockchains

Permissioned blockchains are platforms within which the network nodes belong to members of a closed group, be it a consortium or a single organisation. Thereby, the members control the access to the blockchain and authorise the transaction execution processes on the peer-to-peer platform.

Relation to traditional ICT aspects and supply chain & international trade: Basically, this type of blockchains has many commonalities with traditional databases and transaction systems where a pre-authorisation takes place, and only a closed group of partners/customers have access and can issue and view the transactions. However, traditional transaction based systems normally use a centralised database, which is a fundamental difference to the peer-to-peer approach provided by blockchain technology behind the permissioned authorisation layer. The centralised entity/database constitutes technically a single point of failure in addition to requiring all members of the closed group to trust this centralised entity regarding the integrity and authenticity of the transaction. Hence, the main difference is the distributed and immutable nature of the data storage within the blockchain in comparison to the centralised database approach. The distributed and immutable type of storage is much more resilient against cyber-attacks and network/system outages.

Permissioned blockchains are the cornerstone for all current solutions in international trade & supply chains which utilise blockchain technology. The involved participants in this type of solutions are normally the different stakeholders (e.g. agencies, companies, authorities, suppliers …) which are pre-authorised as members of a trusted consortium of business and process related entities.

5.2.2. Public blockchains

Public blockchains are publicly accessible for everyone to join and instantiate a network node. Hence, it is possible for everyone to become a node of the network, to access the information on the distributed ledger and to perform transactions on the blockchain.

Relation to traditional ICT aspects and supply chain & international trade: Public blockchains actually don't have an alternative within the current practices when compared to the structures and architectures in public clouds, Open Data, P2P networks and Big Data for cities and IT services in general. The usage of blockchain technology and principles in the area of public/open data sharing allows to build a trustful environment, where data and information can be exchanged with a high guarantee for its integrity and transactions can be issued without the need for a centralised trusted node, constituting a single point of failure at the same time. Hence, blockchains offer a sophisticated

[80] Sorin Cristescu (2019) EU Blockchain goes mobile: 2 Watts is all it needs. Available at: https://steempeak.com/eftg/@sorin.cristescu/eu-blockchain-goes-mobile.

way to create a trusted environment open for any participants and to enable the exchange of data and the execution of transactions without an initial established trust among the participants.

Public permissionless blockchains are currently not used in the available solutions and PoCs for applying blockchain for international trade and supply chains. This has a number of reasons mainly coming from the trust to be put in the participants and the complexity of the required mining algorithms (mainly PoW) when it comes to handling and maintaining a public permissionless blockchain. During the interviews and desktop research, it became clear that potentially in the area of ethical food sourcing, the utilisation of a permissionless blockchain can be considered in the future given the need to increase transparency and to provide the possibility for a wider range of people to submit data to a blockchain platform.

5.2.3. Hybrid blockchains

Hybrid blockchains constitute a mixture between **permissioned blockchains** and **public blockchains**. In the case of hybrid blockchains, the rights to add new blocks to the network are concentrated within a trusted set of nodes/members, whilst the ledger information is visible to anyone with connectivity to the blockchain platform. It is clear that hybrid blockchains can be used by organisation/consortia, which at the same time want to provide a higher level of transparency to the general public.

Relation to traditional ICT aspects and supply chain & international trade: The user perceived functionality of Hybrid blockchains can be realised by traditional architectures through the provisioning of different rights to the public in comparison to the members of the closed group/organisation/consortium. Basically, the public would be enabled to read the transaction records and the data, whilst at the same time not being able to alter and write to the database. Furthermore, the consortium members would have the right to execute and write transactions and data into the database. Certainly a point that should be mentioned is the decentralised nature of the DLT/blockchain in comparison to traditional centralised database approaches. Hence, within a traditional architecture, the members of the consortium would need to put trust into the entity governing the centralised database, which differs from the blockchain approach where trust is created by the technical architecture and belonging cryptographic operations. Hybrid blockchain platforms are a good option to for international trade and supply chains in case the solutions aims at keeping a close circle of actively writing participants (companies, agencies, etc.) whilst at thesame time providing a maximum level of GDPR compliant transparency to the society of particular scope (country, trade zone/union, etc.). An important aspect in this case is given by the need to carefully check the data which is published on the blockchain for sensitive and personal information which it might contain.

5.2.4. Mining algorithms

Consensus and mining algorithms are utilised within blockchains with the goal to validate and ensure the authenticity of new transactions, finally leading to adding a new block on the blockchain. Non-blockchain systems do not employ mining algorithms and rely normally on a trusted centralised entity to validate the transactions and guarantee the integrity and authenticity of data. As discussed within the study, mining algorithms are a key feature and at the same time a blessing and a curse for blockchain and distributed ledgers. Mining (e.g. based on PoW) can be very resource/energy intensive and can lead to serious doubts as to the sustainability of blockchain applications and services, whilst at the same time enabling the distributed verification and validation of transactions leading to a distributed and immutable storage of transaction records and data, especially without the need for a centralised credible party. Within current blockchain-based solutions for international trade and supply chains, predominantly permissioned blockchains are used, which leads to a situations where all potential participants that can write to the blockchain are intrinsically trusted. In this case, the mining algorithms are selected and configured in a way as to reduce the energy intensity of the belonging computations and be more sustainable in terms of environmental impact.

5.2.5. Smart contracts

Smart contracts provide a new level of automation within blockchain platforms (e.g. Ethereum). They facilitate complex interactions, logic and applications on one hand, but are considered complex and risky on the other hand. Smart contracts are realised through automatically executable software codes transferring blockchain-based assets (e.g. cryptocurrency tokens) between the involved parties. Thereby, the corresponding transactions are automatically submitted to the underlying blockchain and finally added to the distributed ledger underneath. All this comes at the price of increased complexity leading to the need for defining appropriate conditions for transactions and to evaluate those before a corresponding Smart Contract and transaction execution. Hence, a Smart Contract can be viewed as a computer program that runs on the blockchain and enables the automated exchange of digital assets based on pre-defined conditions, according to the rules of the Smart Contract.

Relation to traditional ICT aspects and supply chain & international trade: In current practices, different automations (e.g. BPMN, scripting, ETL, flow description languages, etc.) are being implemented according to the theory of distributed transactions and computing, in order to technically realise the automated execution of policies and rules. However, trust is again not intrinsically verified and validated upon the single transactions in the course of the automation. Hence, trust is either presumed - between the involved components/nodes/stakeholders - or guaranteed through a centralised component/entity. The trusted smart contract execution constitutes the main advantage of the blockchain technology in this regard. Within a blockchain, the automation is immutably protocolled and can be used for trust building, accountability and traceability in general. However, for a full scale deployment of smart contracts for international trade and supply chains, the corresponding legislation and regulations need to be translated/embedded/considered for the belonging smart contracts. Furthermore, many legislations and regulations might need to be adapted in order for smart contracts to comply to them – an issue that needs to be carefully checked and considered. Finally, smart contracts should be carefully tested, simulated and checked with respect to their correctness and quality given their importance within a critical utilisation for international trade and supply chains.

6. Legislative framework and policies related to blockchain

This chapter describes the relevant framework and the initiatives seeking to promote blockchain innovation and uptake. These aim to encourage public administrations, industry and citizens to benefit from the possibilities offered by the technology, to offer greater visibility to blockchain operators and to face the challenges posed by the new paradigms that the blockchain makes possible (such as disintermediation and issues related to trust, security and traceability).

6.1. Initiatives on blockchain at EU level

6.1.1. Policy initiatives

Through the seventh framework program for research (FP7) and the European Union's Horizon 2020 program, the Commission has funded projects related to the blockchain since 2013.[81] There are about 770 blockchain initiatives at EU and Member State level. In February 2018 the European Commission (DG CONNECT), in collaboration with the European Parliament, launched the EU Blockchain Observatory and Forum, a stakeholders engagement platform which monitors key initiatives in Europe allowing to connect European and global expertise, and hence the gathering and sharing of knowledge on the subject. The observatory has published reports on the scalability and operability of blockchain, on the regulatory framework of smart contracts, and on blockchain in trade finance and supply chains.[82]

In April 2018, 21 EU Member States together with members of the European Economic Area (Norway and Liechtenstein) agreed to sign a declaration creating the European Blockchain Partnership (EBP). The declaration aims to join the signatories at a political level, committing to realise the potential of blockchain-based services. In this context, the Partnership is defining a policy agenda for blockchain by identifying critical regulatory areas such as smart contracts. In addition, the EBP is building a European Blockchain Services Infrastructure (EBSI) which aims to deliver EU-wide cross-border public services using blockchain technology. Since then, more countries have joined the Partnership, bringing the total number of signatories to 30.

EBSI supports four use cases on notarisation, diplomas, European self-sovereign identity, and trusted data sharing. The latter use case links to trade and supply chains as it aims to leverage blockchain technology to securely share data amongst customs and tax authorities in the EU. EBSI was added in 2020 as a building blocks to the Connecting Europe Facility[83], where it provides reusable software, specifications and services to support adoption by EU and Member State public administrations. In 2020, the EBP will select future use cases to be integrated in 2021. Current ideas are to develop a use case in the area of supply chain, for example on the topic of provenance. Sustainability and the role of ICT to achieve the Green Deal is another area of interest. The Digital Europe Programme will be the vehicle to continue the work on EBSI, focusing on deployment, in the next Multiannual Financial Framework.

A further initiative supported by the EU was the launch, in April 2019, of the International Association for Trusted Blockchain Applications (INATBA). The INATBA is a multi-stakeholder organisation that acts as a global forum which brings together developers and users of distributed ledger technology (DLT) with regulators and policy-makers from all over the world. Moreover, in November 2019, the Commission organised the 'Convergence Global Blockchain Congress' together with INATBA, the EU Blockchain Observatory and Forum and the non-profit association

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[81] The Commission has already invested more than EUR 80 million in projects supporting the use of blockchain in technical and societal areas and around EUR 300 million more are to be allocated to blockchain by 2020.

[82] For more information, see here: https://www.eublockchainforum.eu/reports.

[83] For more information, see here: https://ec.europa.eu/cefdigital/wiki/display/CEFDIGITAL/ebsi.

Alastria. The conference brought together industry and regulatory stakeholders to take stock and have an exchange on the current state of play of blockchain technology.

The Commission is also currently engaged in work to promote legal and regulatory aspects of blockchain-inspired technologies, for example by improving legal certainty in two areas related to blockchain, namely smart contracts and tokenisation[84]. In regard to smart contracts, there is a need to clarify mutual recognition across borders, while the use of tokens as a form of digital currency in the economy should also be clarified. Other issues such as using blockchain to implement digital identity, connecting to eSignatures and eSeals is being looked into more closely under the eIDAS regulation, but less relevant for trade and supply chains.

6.1.2. Legislation

Between 2017 and 2018 the European Parliament adopted a number of non-legislative resolutions on the subject of blockchain applied to different fields. Most notably, the 2018 Resolution on 'Blockchain: a forward-looking trade policy'[85], which specifically relates to the potential impacts of blockchain technology on the EU's approach to international trade. The report only examines the use of permissioned blockchains subject to authorisation. The aim of the resolution is to (i) highlight current non-optimal aspects in supply chains as well as in EU trade and customs procedures, (ii) identify possible benefits deriving from widespread application of blockchain technology and (iii) recommend strategic measures to the European Commission and the Member States to make use of the technology. To these ends, it explores blockchain's characteristics in relation to EU trade policy; the external aspects of customs and trade facilitation; cross-border data flows and data protection; SMEs; and the interoperability, scalability and interactions with related technologies. The following table reflects on the recommendations by the European Parliament and the European Commission's response, which was adopted in June 2019.

Table 24 - Responses of the European Commission to the 2018 resolution

Theme	The European Parliament recommends:	The European Commission:
General	Following developments on ongoing **pilots/ initiatives** in the international supply chain and external aspects of customs. Developing a set **of guiding principles** for blockchain applications to international trade, in order to provide industry and customs and authorities with sufficient legal certainty. Simplifying and enhancing the flow of information related to trade facilitation by adopting suitable communication technologies. Looking into how blockchain in trade could support the realisation of **Sustainable Development Goals**.	Will continue to **build on existing work**. In 2018 the European Blockchain Partnership (EBP) was created, committed to establish the European Blockchain Services Infrastructure (EBSI), supporting the delivery of cross-border digital public services. Is **reluctant to set up a new advisory group** with a proliferation of such groups and projects in this area.
Customs and trade facilitation	Maintaining and strengthening the WTO and its commitment to a rules-based trading system in order to ensure a level playing field and **enforce**	Has been looking into the potential application of blockchain solutions for a number of **trade-related aspects** (excise

[84] Tokenisation is usually understood as the process of replacing items of value (such as money, stocks, etc.) with tokens that reflect these values.

[85] Resolution 2018/2085(INI). The Committee on International Trade (INTA) was responsible for drawing up the resolution, which was adopted by the Parliament on 13 December 2018. The Commission adopted its response (SP(2019)355) on 12 June 2019.

	global trade rules as regards the Trade Facilitation Agreement.	duties, customs logistics, and traceability) through DG TAXUD. Has proposed (by DG TAXUD) a use case (**System of Exchange of Excise Data** – SEED) which has been prioritised by the EBP.
Cross-border data flows and data protection	Calling for provisions allowing for digital ecosystems and **cross-border data flows in FTAs**. Inviting the European Data Protection Board to issue **guidelines and recommendations** to ensure that technology is compliant with EU law.	Acknowledges the importance of simplifying and enhancing the flow of information related to trade facilitation and recognises the potential role of blockchain in this area. Recognises the need to ensure adequate data privacy. It is for this reason there has been a report from the European Blockchain Observatory (EBO) that specifically deals with blockchain and the GDPR, which found no fundamental issues that made blockchain non-compliant with GDPR.
SMEs	Recognising the need to ensure that the development of blockchain in international trade includes SMEs.	Nothing specific mentioned.
Interoperability, scalability and interactions with related technologies	Enhancing collaboration with ISO and other relevant standardisation bodies Further research into the applicability of blockchain technologies to the digital transformation and automation of international trade, in particular under the Digital Europe Programme. Assessing whether blockchain offers better solutions to existing technologies to deal with challenges in EU trade policy	The Commission organised a workshop on blockchain with **ETSI** in June 2018, and established a liaison with the newly established Industry Specifications Group on permissioned distributed ledgers. It has established a liaison with **ISO Technical Committee 307** and collaborates with **CEN**, which has set up a technical committee on blockchain to develop EU standards for EU law compliant reference implementations The EBO is liaising with the relevant stakeholders on an ongoing basis – an activity it hopes to continue and expand upon (paragraphs 44 and 45). Over 1500 stakeholders have joined the EBO working groups and forum. Interoperability between blockchain systems is a major focus in these discussions, but also scalability, sustainability, how to set up an eIDAS compliant blockchain implementation, and what the legal obstacles for blockchain systems deployment are.
Cooperation with Member States or International Organisations	Producing a horizontal strategy document involving relevant DGs on adoption blockchain technologies in trade-Set up an advisory group within DG Trade on blockchain Working with Member States to launch and supervise pilot projects in order to test its benefits. Collaborating with international organisations and feeding into current initiatives.	Acknowledges its potential to become a leading actor in the field of blockchain and international trade, and **looks forward to cooperating with a wide range of partners** – both in the public and private sector, at an international and national level – to ensure this is the case. Is **working closely with the Member States**, through the EBP and a broad set of stakeholders through the EBO.

Source: Ecorys, own adaption based on 2018/2085(INI)) and (SP(2019)355).

Other EU acts deal with blockchain technology from different angles. For example, the Resolution 'Distributed ledger technologies and blockchains: building trust with disintermediation'[86] explores DLT technology applications in the fields of energy and environment; transport, supply chains, healthcare, education, and creative industries; financial sector; digital identities and control of personal data to share; smart contracts; infrastructure security and public sector services. The 'European Agenda for the collaborative economy'[87] mentions blockchain and DLTs in the context of the rapid development and the increasing diffusion of innovative decentralised technologies and digital tools, stressing its potential to enable effective peer-to-peer transactions and connections in the collaborative economy, and allow the creation of independent markets or networks capable of replacing the role of intermediaries. More sector-specific is the resolution on 'FinTech: influence of technology on the future of the financial sector',[88] highlighting the potential of blockchain applications for cash and securities transfer and for smart contracts, simplifying complex commercial and financial contractual relationships.

6.1.3. Blockchain applications

Beside the broader focus of the non-legislative resolutions, the European Commission is also looking into a number of specific blockchain applications. From the perspective of **customs**, DG TAXUD has developed several proofs of concept (PoC). The **first PoC** was developed in collaboration with the ICC to test the potential benefits of blockchain's application to the notarisation and transaction of ATA carnets[89] in digital format.[90] The PoC was successfully concluded in mid-2018 demonstrating that blockchain technology could be used to ensure the integrity and traceability of ATA carnets. A **second PoC** tested the possibility to simplify a complex trans-European systems, such as excise goods movement monitoring in real-time by replacing the Excise Movement and Control System with a blockchain platform, in order to exchange information between custom authorities in Europe. The test showed significant efficiency gains, but also that challenges related to confidentiality and security remain. A **third PoC** is currently being implemented. It focuses on the potential use of blockchain technology for electronic registries on economic operators to replace the current centrally managed database.

The European Commission is also experimenting with solutions in areas not related to customs. A hands-on technological unit, the 'Blockchain Competence Centre', was established at DG DIGIT. Since financial stability requires a lot of coordination at European level, the 'European Financial Transparency Gateway'[91] was built on the initiative of DG FISMA as a PoC in 2017. Several Member States have joined since then and contributed data. Additional functions were added and a pilot was delivered in March 2019.[92] DG JUST, while not running any specific PoC, is looking into the use of smart contracts (e.g. for financial contracts) and centralised databases for justice systems. Finally, the aforementioned EBSI has four use cases in the areas of notarisation, diplomas, European self-sovereign identity, and trusted data sharing. The following table summarises the PoC and use case for blockchain-based solutions at EU level.

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[86] Resolution 2017/2772(RSP), adopted on 3 October 2018.

[87] Resolution 2017/2003(INI), adopted on 15 June 2017.

[88] Resolution 2016/2243(INI), adopted on 17 May 2017.

[89] An ATA carnet is an international customs document that permits the duty free temporary admission of most goods for up to one year. The Mercury II pilot project by the ICC aims to digitise this process (eATA) by providing worldwide electronic data exchange between countries or custom unions using the document.

[90] For more information go to: https://poc.webexpert.ch/ and https://mag.wcoomd.org/magazine/wco-news-87/digitization-ata-carnets/.

[91] Available at: https://eftg.eu/.

[92] For more information go to: https://steempeak.com/eftg/@sorin.lite/sorinlite-1562495321904-european-financial-transparency-gateway.

Table 25 - Overview over use case for blockchain-based solutions at EU level

Solution	Technology	Authorisation	Description
TAXUD PoC #1 in the field of temporary admission (eATA)	Ethereum	Private, permissionless blockchain, on a private network but anchored to the public Ethereum blockchain	In collaboration with ICC to add additional layer to ensure trust in a centralised solution (eATA) by anchoring and notarising data. Recording and storing of hashes for each transaction stage. Custom authorities could then compare these with the custom documents and thereby validate the documents.
TAXUD PoC #2 in the excise domain (EMCS)	Hyperledger Fabric	Private, permissioned, blockchain	End-to-end, transaction-oriented pattern: a system to exchange information and documents between custom authorities in Europe. No involvement of Member States or Traders in PoC.
TAXUD PoC #3 on electronical registries for economic operators	No information available	No information available	Blockchain-based registry to easily share information on economic operators. Only recently launched.
European Financial Transparency Gateway	Steem	Public, permissioned blockchain	Pilot project initiated by DG FISMA with funding from the EP. Provides unrestricted access to regulated financial information and the ability to search and compare while keeping data ownership at Member State level.
	EBSI Use Cases		
#1 Notarisation	Leveraging the power of blockchain to create trusted digital audit trails, automate compliance checks in time-sensitive processes and prove data integrity.		First wave of use cases will be launched beginning 2020 in their first versions and then continuously being upgraded. The second wave will follow end of 2020-21.
#2 Diplomas	Giving control back to citizens when managing their education credentials; significantly reducing verification costs and improving authenticity trust.		
#3 European Self-Sovereign Identity	Implementing a generic Self-Sovereign Identity capability, allowing users to create and control their own identity across borders without relying on centralised authorities.		
#4 Trusted data sharing	Leveraging blockchain technology to securely share data (e.g. IOSS VAT identification numbers and import one-stop-shop) amongst customs and tax authorities in the EU. Based on TAXUD PoC #2.		

6.2. Initiatives on blockchain at international level

To date, a significant number of initiatives and studies carried out by international organisations describe the technical, business and legal issues arising from the use of blockchain technology, with the aim to create an environment conducive to cooperation and research.

An active role is played by the Organisation for Economic Co-operation and Development (OECD), which provides a forum for constructive dialogue between stakeholders (for example in the context of the Blockchain Policy Forums which are held every year). The OECD also sets international standards, and helps building capacity in governments. In particular, the organisation is bringing its core competencies to the opportunities and challenges presented by blockchain and DLT. The organisation committed to help governments to find experts and practitioners to engage with, and to identify and share best practice for governments managing and using blockchain. In this context, the OECD Blockchain Primer provides an overview on blockchain technology, outlining some of its potential benefits as well as risks and challenges it poses, intending to help people better understand the growing impact of this emerging technology.

In addition, in 2019, following the 2018 Global Blockchain Policy Forum, the OECD established the Blockchain Policy Centre as a global reference point for policy-makers on blockchain which intends to support governments to address the challenges raised by DLT and their applications as well as to seize the opportunities it offers for achieving policy objectives. The OECD Blockchain Policy Centre builds on years of research and analysis carried by the OECD and considers the impact of DLT in different fields, exploring its interface with other emerging technologies such as artificial intelligence.

In regard to international trade specifically, the ICC, the Trade Financial Global and the WTO released in 2019 a white paper combining over 200 responses from banks, corporates, FinTechs and associations in the trade sector, as well as over 20 consortia, on the broader impact that DLT is having on the trade industry.

Also, a leading industry association for the blockchain technology ecosystem is the Global Blockchain Business Council, which was launched during the 2017 World Economic Forum. Its 2019 Annual Report mentions a number of successful use-cases in the field of supply chain.

Another example is the WCO, which has initiated work to identify possible case studies and uses of blockchain for customs and other border agencies with a view to improving compliance, trade facilitation, and fraud detection (including curbing of illicit trade through the misuse of blockchains and Bitcoins), while touching on associate adjustments in legal and regulatory frameworks.

6.3. Legislative framework at national level

Regulatory landscapes at the national level vary significantly from country to country. While some countries decided not to enact any new special regulations for blockchain for the time being, some others opted to update their existing laws to account for this new technology.

As a matter of example, in Europe, countries such as Poland, France and Luxembourg have chosen to adopt specific and tailored regulations to address specific applications of blockchain especially in the financial sector. In some other cases, such as in Switzerland, the government has proved keen on improving the existing legal framework to remove legal hurdles still holding up innovation based on blockchain, rather than enacting specific legislation. A proposed legislation is expected to be examined by the Swiss parliament in early 2020.

A progressive approach has been taken by Liechtenstein which, with the adoption of the Blockchain Act in 2019, has provided a holistic regulatory framework to govern the underlying concepts of blockchain, as opposed to its applications, thus becoming the first country in the world to adopt a legal basis for the Token Economy.

7. International trade documentation: challenges and envisaged solutions

The following sections introduce the issue of inefficiencies in trade, which are due to the amount of paper documentation required in international transactions. They hence present the current initiatives toward custom and trade digitalisation, which have been undertaken, both at EU and international level. However, despite these efforts, customs procedures remain somewhat burdensome and the implementation of e-customs and digital trade is slow.

Against this background, this chapter focuses on the blockchain's potential to simplify trade by reducing its reliance on paper documents, also providing an overview of the legislative framework and status quo on blockchain, with a description of the existing initiatives and legislation in the field. Finally, the final section presents some regulatory challenges that the use of such technology might entail.

7.1. Challenges related to international trade documentation

On average, for a trade deal of international sale of goods, about 36 original documents and 240 copies from as many as 27 parties are required.[93] International trade documents are indeed associated with every official procedure, from the contractual agreement to the delivery of goods. This large amount of paper documentation that needs to be exchanged leads to some inefficiency in terms of costs and time required for any transaction: according to the World Economic Forum, the costs of processing trade documents are as much as a fifth of those of shifting goods. These include the costs of coordinating trusted information about the provenance, ownership, and quality of goods for consumers, producers, and governments. In this context, EU and international regulators and policy-makers have sought to rationalise and simplify customs procedures, facilitating more efficient transactions in line with modern needs, in view of completing the shift to a paperless and fully electronic environment. However, while notable progress has been made, complete digitalisation of international trade has not yet been achieved.

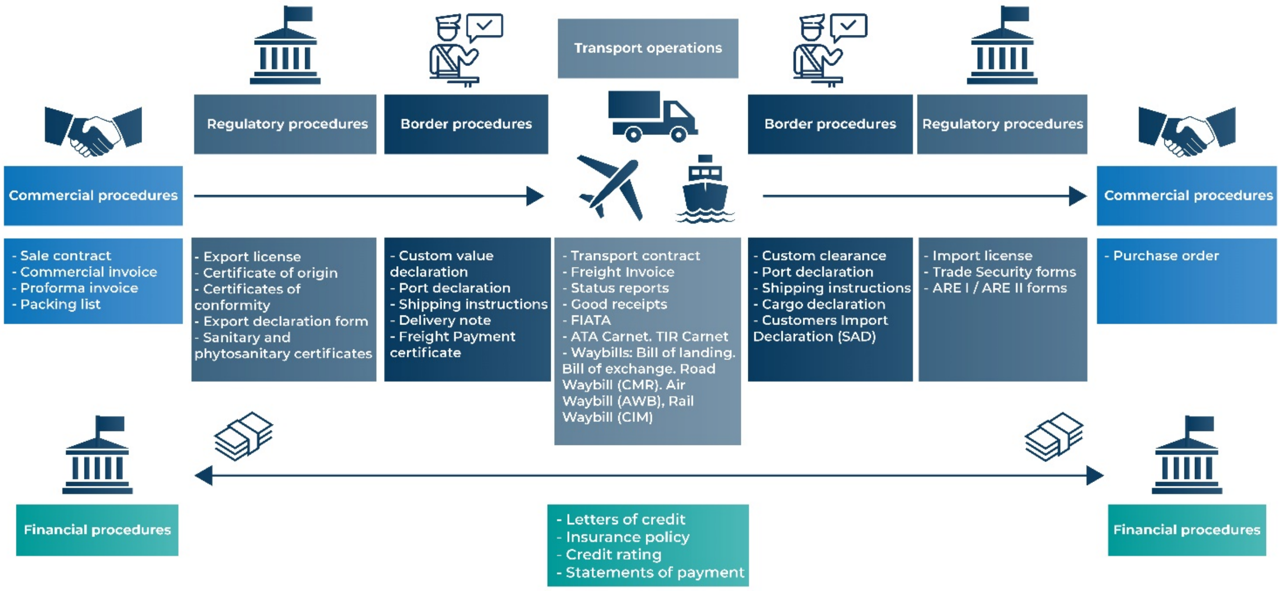
7.1.1. The issue of 'paper-heavy' trade

International trade documentation is a critical component of cross-border transactions. International trade supply chain consists of different steps and includes commercial, transport, regulatory and financial procedures. Any transaction inevitably involves a multitude of intermediaries, companies and government authorities, often located in different countries with different legislative frameworks. As a result, there is a great demand for information across the entire supply chain. Specific documents with diverse purposes are required to fulfil the requirements of any of these actors in the successive phases.

Considering the time gap that elapses between the delivery of goods by the exporter to the importer and the transfer of payment by the importer to exporter, it is crucial to draw up a number of documents to protect the interests of both. This is done by establishing when the goods, the charging of risks, the burdens relating to transport and the insurance costs pass from the responsibility of the seller to that of the buyer. Documents also serve to offer importers and exporters with an accounting record and shipping and logistics firms with instructions on freight. Other official papers are usually required to provide banks with instructions and accounting tools for processing payments, or to ensure compliance with the regulatory requirements in the countries of origin and destination.

[93] Kerstin Braun, president of Stenn Group.

Figure 18 - Documentation required for different trade procedures



Source: Grimaldi and Ecorys

The number of documents to be submitted can vary considerably across countries. The vast majority of documents are those required to satisfy regulatory obligations within different jurisdictions. In fact, as goods move across borders, they interact with a range of regulatory controls around market exchange. These regulatory burdens require extensive information about compliance (e.g. with rules on intellectual property and of origin, labour and environmental standards). To ensure the successful execution of international trade transactions, strict compliance with procedural formalities and requirements are always essential. Indeed, poorly completed documentation may result in a number of issues leading to delays and additional costs, e.g. in case of missing documents, delays in receiving payment or processing critical documents, charges for amending and costs for sending replacement documents. These problems occur more often where there is an extensive reliance on burdensome procedures and paper-heavy processes. For example, according to data from the World Bank's Doing Business surveys[94], time to export (i.e. time necessary to comply with all procedures required to export goods) vary in EU from a maximum of 19 days (Italy), to a minimum of 6 days (Estonia), while worldwide the country with the highest value is Afghanistan, with a time to export of up to 86 days.

7.1.2. Solutions proposed at EU level

For a long time, the EU has been showing interest in improving and facilitating the supply chain logistics and customs operations through the use of technology. In 2003, the Commission published a Communication[95] on creating **a simple and paperless environment for customs and trade**. Following that Communication, Decision No 70/2008/EC on a paperless environment for customs and trade[96] was adopted. The act aimed to review customs processes with a view to optimise their efficiency and effectiveness, by replacing paper-format customs procedures with EU-wide

[94] Calculations for the purpose of the survey are based on a number of assumptions, see https://www.indexmundi.com/facts/indicators/

[95] COM/2003/0452 final.

[96] Decision No 70/2008/EC of the European Parliament and of the Council of 15 January 2008 on a paperless environment for customs and trade, OJ L 23, 26.1.2008.

electronic ones and allowing the exchange of data between the customs administrations of EU countries, traders and the Commission.

Today, Regulation (EU) No 952/2013 lays down the Union Customs Code (UCC).[97] The UCC repeals and recast the Community Customs Code (Modernised Customs Code) of 2008, laying down the general rules and procedures that must be applied to goods imported into or exported out of the EU. The Code is part of the modernisation of customs and serves as the new framework regulation on the rules and procedures for customs throughout the EU. Compared with the previous Code, the UCC includes rules aimed at rationalising and simplifying customs legislation and procedures and facilitating more efficient customs transactions in line with modern needs, with a view of completing the shift by customs to a paperless and fully electronic environment. To this end, it stipulates that '*all exchanges of information, such as declarations, applications or decisions, between customs authorities and between economic operators and customs authorities, and the storage of such information, as required under the customs legislation, shall be made using electronic data-processing techniques*' (Article 6 UCC).

Implementing and delegated acts were adopted following the UCC to underpin the development of electronic systems.[98] According to these, all electronic systems required by the UCC were to be deployed no later than 31 December 2020. Nevertheless, due to challenges encountered in its implementation, the transitional use of means other than the electronic data-processing techniques was prolonged.[99] The transitional arrangements for the exchange and storage of customs information (i.e. existing electronic and paper-based systems) can hence continue to be used after 2020 for the customs procedures covered by the electronic systems that will not be operational by 2020. New deadlines are set for 31 December 2022[100] and 31 December 2025.[101] In addition, the Commission is required to submit an annual report to the European Parliament and to the Council on progress in developing those electronic systems until the date on which the electronic systems become fully operational. Considering the many challenges in changing to new data formats, it would be too difficult to change simultaneously also the technology used to share this data. In addition, Member States seem to prefer proven solutions instead of experimenting with new technologies such as blockchain.

7.1.3. Solutions proposed at international level

At the international level, customs digitalisation goes hand in hand with trade facilitation, simplification and harmonisation of customs procedures. These terms recur in all the main

[97] Regulation (EU) No 952/2013 of the European Parliament and the Council, laying down the Customs Code, OJ L-269, 10.10.2013.

[98] Commission Implementing Decision (EU) 2016/578 of 11 April 2016 establishing the Work Programme relating to the development and deployment of the electronic systems provided for in the Union Customs Code, OJ L 99, 15.4.2016; Commission Delegated Regulation (EU) 2016/341 supplementing Regulation (EU) No 952/2013 of the European Parliament and of the Council as regards transitional rules for certain provisions of the Union Customs Code where the relevant electronic systems are not yet operational, OJ L-69 15.3.2016; Commission Implementing Regulation (EU) 2015/2447 of 24 November 2015 laying down detailed rules for implementing certain provisions of Regulation (EU) No 952/2013 of the European Parliament and of the Council laying down the Union Customs Code, OJ L 343, 29.12.2015.

[99] Regulation (EU) 2019/632 of the European Parliament and of the Council of 17 April 2019 amending Regulation (EU) No 952/2013 to prolong the transitional use of means other than the electronic data-processing techniques provided for in the Union Customs Code, OJ L 111, 25.4.2019.

[100] For national electronic systems for the notification of the arrival, presentation, declaration, temporary storage and customs declaration of goods introduced into the customs territory of the Union.

[101] For (i) the three existing trans-European systems: the system dealing with Entry Summary Declarations; the system dealing with external and internal transit, and the system dealing with goods taken out of the customs territory of the Union; the National Export System (including the export component of the national Special Procedures System); (ii) the three new trans-European electronic systems (the systems concerning guarantees for potential or existing customs debts, the customs status of goods, and centralised clearance).

international legal instruments in the field, which have been adopted by the three leading rule-making institutions, namely the World Trade Organization (WTO), the World Customs Organization (WCO) and the United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT)[102].

It is worth noting that a key principle of international trade requires that any product that is moved from one country to another meets the requirements of the country of destination. Requirements for the product are traditionally divided into (i) mandatory (i.e. established by the legislation of the country), (ii) voluntary, and (iii) usually implicit without their documentary formalisation. The products' conformity to the relevant rules shall be attested by specific documents. The WTO devotes significant attention to good standardisation and regulatory practices so that standards, regulatory and conformity assessment procedure requirements do not become technical barriers to trade. To this end, efforts are made toward the simplification of customs clearance procedures for goods carried from country to country. This is achieved due to the electronic exchange of confirming compliance documents, electronic forms of payment for the required customs duties, and sharp reduction in time and in financial cost of inspection of goods and of implementation of export-import operations. Relevant agreements adopted at WTO level to this extent are:

- The Technical Barriers to Trade (TBT) Agreement, which aims to ensure that technical regulations, standards, and conformity assessment procedures are non-discriminatory and do not create unnecessary obstacles to trade.
- The Trade Facilitation (TFA) Agreement of 2017[103], which aims to reduce bureaucratic delays that pose a burden for traders in moving goods across borders. The agreement set multilateral rules that seek to address procedural hurdles to trade. Notably, it contains provisions on trade simplification, modernisation and harmonisation of export and import processes, including measures for effective cooperation between customs and other appropriate authorities on trade facilitation. Notably, Art. 10(e), Section I of the TFA provides that a Member, to whom information on import/export declaration have been requested, 'shall not be required to introduce paper documentation where electronic format has already been introduced', indicating a preference for paperless means.

In the context of the recent WTO Plurilateral Negotiations on Trade-Related Aspects of Electronic Commerce, the International Chamber of Commerce (ICC) has presented its Baseline Position for a High Standard Outcome, which sets out, under its pillar 2, a number of ideas that build on the landmark Trade Facilitation Agreement within the context of a fast-growing digital economy. Among these ideas a few suggested measures that could further facilitate trade through digitalisation stand out, i.e. provisions to enable electronic submission of customs documents prior to arrival to allow for an automated risk assessment and pre-arrival processing and immediate release/clearance and provisions to encourage the use of electronic payments for customs duties and other charges in multiple currencies, without mandatory currency conversion, in an account-based, periodic manner.

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[102] The United Nations Centre for Trade Facilitation and Electronic Business (UN/CEFACT) is a subsidiary, intergovernmental body of the United Nations Economic Commission for Europe (UNECE) which serves as a focal point within the United Nations Economic and Social Council for trade facilitation recommendations and electronic business standards. It has global membership and its members are experts from intergovernmental organizations, individual countries' authorities and also from the business community.

[103] World Trade Organization - PROTOCOL AMENDING THE MARRAKESH AGREEMENT ESTABLISHING THE WORLD TRADE ORGANIZATION – Decsion of 27 November 2014. Available at: https://docs.wto.org/dol2fe/Pages/SS/directdoc.aspx?filename=q:/WT/L/940.pdf.

Other institutional agreements relevant to the subject are:

- The United Nations Convention on the Use of Electronic Communications in International Contracts adopted in 2013[104], which aims at facilitating the use of electronic communications in international trade in order to remove obstacles arising from formal requirements contained in other international trade law treaties and to facilitate recognition of electronic documents.
- The World Customs Organization Kyoto Convention, which entered into force in 2006[105] and promotes trade facilitation and effective controls by providing for detailed application of simple yet efficient procedures. The revised Convention also contains new and obligatory rules for its application which all Contracting Parties must accept without reservation.
- The 2017 United Nations Commission on International Trade Law (UNCITRAL) Model Law on Electronic Transferable Records, adopted by the General Assembly on 7 December 2017. This instrument aims to widespread adoption of digitalised tradeand trade finance instruments. Important provisions worth mentioning are: Article 7: an electronic transferable record 'shall not be denied legal effect, validity or enforceability on the sole ground that it is in electronic form'; Articles 8–11: on the functional equivalence of electronic and manual records; and Article 12: on general reliability standards for verifying signatures, integrity and other aspects of electronic records.

Whereas the primary international instruments lay down general standards for efficient implementation of automated customs clearance, more detailed guidance for implementing the said principles is provided by soft law sources, such as recommendations and best practices generated by the WCO and the UN/CEFACT.

By way of example, the UNECE (CEFACT) Recommendation No. 33 proposes a special trade facilitation tool called Single Window system, whose implementation is encouraged by Art. 10.4 of the WTO TFA and further recommended by the ICC Custom Guidelines 2012 and the WCO developed guidelines on how to set up a Single Window.

Such a tool is described as '*a facility that allows parties involved in trade and transport to lodge standardised information and documents with a single entry point to fulfil all import, export, and transit-related regulatory requirement*' and the recommendation further says that '*If information is electronic, then individual data elements should only be submitted once*'.

The main feature of the Single Window system is to integrate the different stages of the specific functions of both state agencies and the involved private entities through paperless customs, regulatory Single Window, port Single Window, cross-border Single Window exchange platform, et cetera.[106]

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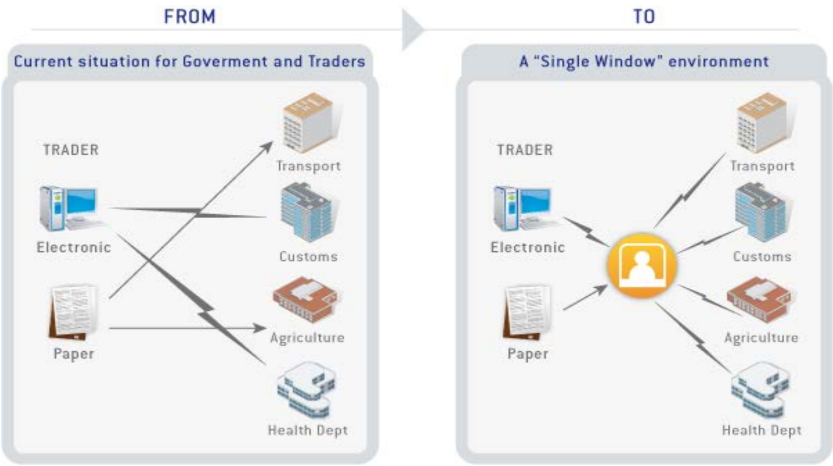
104 United Nations Convention on the Use of Electronic Communications in International Contracts (UNCITRAL), 2013. Available at: https://uncitral.un.org/sites/uncitral.un.org/files/media-documents/uncitral/en/06-57452_ebook.pdf.

105 International Convention on the Simplification and Harmonization of Customs Procedures, Available at: http://www.wcoomd.org/Topics/Facilitation/Instrument%20and%20Tools/Conventions/pf_revised_kyoto_conv/Kyoto_New.

106 Anastasiya Brachuk (2018), The international standards of single window system for the foreign trade, Lex Portus 1, no. 9, National University Odessa Law Academy.

Figure 19 – Moving to a Single Window environment



Source: UNECE –UN/CEFACT (UNECE Recommendation 33)

Thus far, the Republic of Korea and Singapore have successfully introduced the Single Window, having the former reported some 18 million USD in benefits in 2010 from the agency trade facilitation efforts and the latter's TradeNet brings together more than 35 border agencies since 1989, leading to large gains in government productivity.

7.1.4. Hurdles in the implementation of such solutions

While global trade is increasingly digitalised, many customs administrations around the world are still in the infancy of adopting new technologies, hence customs procedures still heavily rely on paper documents and on manual and inefficient processes, leading to delays and added costs.

The adoption of tools intended to boost digitalised trade has been in many cases very low. For example, a report of the ICC Working Group on e-Commerce[107] notes that only the Kingdom of Bahrain has enacted laws based on or influenced by the MLETR, despite its extensive negotiation and agreement.

According to the Global Express Association's Customs Capability Database, 46% of the annually measured countries do not electronically process the data required for release of shipments in advance of their arrival.

Interestingly, a 2017 study[108] estimated that, despite a major improvement in companies' annual revenue could be achieved by digitising the supply chain, the current digitalisation level is only 44% and only the 2% of the surveyed executives seemed willing to focus on digitalisation.

At EU level, there are a number of acts that explore the reasons why the deadline for the EU e-customs implementation has been missed. Already in 2016, the European Parliament called on the *Commission* and the Member States to come up with a coherent and ambitious strategy and timeline to stepping up efforts to create more uniform and interoperable electronic customs requirements at EU level within the time imparted by the UCC.[109] In its follow-up to the Parliament's resolution, the Commission highlighted that not all Member States share a common vision of how and when to use common electronic systems. In particular, some prefer a 'hybrid system architecture', which enables them to opt in to shared EU services or to maintain national solutions

[107] https://iccwbo.org/content/uploads/sites/3/2019/12/icc-issues-brief-3-facilitating-trade-through-digitalisation.pdf

[108] Bughin, J., LaBerg, L. and Melibye, A. (2017) 'The Case for Digital Reinvention'. McKinsey Quarterly.

[109] Resolution 2016/3024 of the European Parliament on tackling the challenges of the Union Customs Code implementation of 19 January 2017, (2016/3024(RSP)), OJ C 242, 10.7.2018.

on their own or in parallel. Furthermore, in an audit[110] the European Court of Auditors looked at whether the customs legislation was likely to deliver the new customs IT systems in the EU. It found that, despite the progress made, the implementation of these systems suffered a series of delays so that some of them will not be available at the 2020 deadline set in the UCC. According to the audit, the delays were due to several factors, including changing project scope, insufficient resources allocated by the EU and Member States, and a lengthy decision-making process due to the multi-layered governance structure.

7.2. Blockchain as an enabler for trade digitalisation

As observed in the previous paragraphs, despite the efforts to use new digital technologies to lower trade costs, international supply chain information remains stuck in manually administered and paper -based documentation. The latter requires significant t ime and attention to be manually filled in and physically transmitted when goods are delivered and is potentially error
to misinterpretation by different actors. In addition, it raises the potential of fraud and manipulation.

Against this background, it is observed that a number inefficiencies of the supply chain can be successfully addressed with the reduction of the amount of paperwork involved, thus improving the speed and efficiency of border procedures, making easier to clear and track goods, and guaranteeing trusted information.

Specifically, there is an important literature[111] and various initiatives about how blockchain-based technologies could apply to trade and customs operations, all of them being highly technical and go far beyond reproducing the current paper-like system. Blockchain seems to have potential for relieving high trade information costs by providing a digital record of transactions and creating a connected, transparent and data-rich environment.

In fact, through the technology, information contained in certificates held by the individual actors along the supply chain can be made accessible by decentralised dynamic ledgers of information about goods as they move. As a result, by tracking every step along the way, existing gaps in the exchange of information are bridged, the paper trail is streamlined and transparency between parties improved.

In terms of costs, it is noted that blockchain can provide comprehensive and readily available data on previous transactions, allowing interested parties to instantly see what is happening at each stage of the journey, such as what edits have been made to documents and by whom or when goods are boarded on the exporter ship or are picked up. Accordingly, as investors and banks are able to ascertain when the goods get closer to the importer, the risk assessment is facilitated and less collateral is needed. As a consequence, as risk falls, so too does the interest rate that is charged to the exporter or importer.

7.2.1. Regulatory challenges related to the use of blockchain-based technologies

Despite the potential of blockchain applications, the uptake of the new technology in global trade ultimately depends not only on the capacity of entrepreneurs to apply it, but also on the solution to

[110] European Court of Auditors' Special Report No 26/2018, of 10.10.2018.

[111] See e.g. Hanna C. Norberg, Unblocking the Bottlenecks and Making the Global Supply Chain Transparent: How blockchain technology can update global trade, SPP Briefing Paper. University of Calgary, The School of Public Policy, Canadian Global Affairs Institute, 2019.

existing and future regulatory challenges to be faced.[112] In principle, policy barriers of blockchain adoption stem from the inherent nature of trade as inter-jurisdictional. In fact, in the international context, where intermediate and final products often move across borders several times, transactions span a number of jurisdictions. Any technology that involves extensive data sharing and cross-jurisdiction transactions will arguably create legal challenges, for example around privacy, security, governance, regulatory recognition and interoperability. A careful eye should hence be cast on the need to ensure that blockchain is interoperable with the complex array existing regulations.

- Data localisation and privacy issues:

In the first place, given the borderless nature of blockchain, regulatory barriers are found in laws on data localisation and privacy. A growing number of jurisdictions are enacting data localisation laws which disrupt the movement of data aiming to keep citizens' data within the country's borders.[113] In particular, among the various forms which data localisation requirements can take, the measures of 'strict restrictions' - requiring data to be stored or processed locally or ban any cross-border data transfers - seem not likely to be compatible with blockchain. On the other hand, data privacy laws (such as the GDPR at EU level) usually apply conditions on data transfers ('conditional restrictions') which might raise some uncertainties in respect of compliance of blockchain-based technologies that process personal data. Notably, blockchain, as an immutable ledger where physical deletion of data is not possible, seems to contradict with the right to rectification and the right to be forgotten (as per Art. 16 and 17 GDPR) which allows individuals to obtain erasure of their personal data on request.[114]

- Applicable law and liability:

Another issue, which depends on the inter - jurisdictional and anonymous nature of the blockchain, is the identification of the applicable law and the allocation of liability in the event of a dispute or a fraud. This is especially relevant with permissionless blockchains. Uncertainties might occur, for instance, in cases data stored on the blockchain has a flaw, or its integrity is corrupted or hacked in transit between the parties, or an error in one party's code caused a breach of contract. In general terms, it is argued that (i) in permissioned blockchain where a provider can be identified there would be a centralised liability on such provider for the events occurring on the blockchain; while (ii) in permissionless blockchain there would be a disseminated contributory liability of all the participants to the blockchain. However, uncertainties arise from the fact that in a permissioned blockchain access control might not mean that there is full control on any event occurring on it; in a permissionless blockchain each user cannot be deemed liable for the actions of the whole blockchain that is out of its control. Given that every blockchain is different, liability issues should be addressed on a case by case basis, where there is no one-size-fits-all solution. While the issue could be specifically addressed in a specific contractual provision foreseeing a broad liability limitation, such clause might be deemed unfair in agreements with consumers.

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[112] As shown in a 2017 survey of experts in the logistics industry, regulatory uncertainty is deemed one of the most likely barriers for blockchain adoption in the logistics industry. See International policy coordination for blockchain supply chains. Darcy W.E. Allen et al., Asia & the Pacific Policy Studies 6, no. 3 (September 2019). p. 367–380.

[113] See among others Revolutionizing Global Supply Chains One Block at a Time: Growing International Trade with Blockchain: Are International Rules Up to the Task? Tracey Epps, Blake Carey, and Tess Upperton, Global Trade and Customs Journal 14, no. 14 (2019). p. 136–145.

[114] Further uncertainties relate e.g. to the possibility of identifying personal data among data recorded on a blockchain; the definition of the roles and responsibilities of the parties involved, in particular with reference to the identification of the data controller and the data processors, since blockchains are operated decentrally; lack of confidentiality due to the possibility to track and identify patterns and infer information; compliance with the principle of data minimisation.

- Legal recognition and validity of blockchain-based information:

A further issue pertains to the legal status of blockchain-based information.Different countries can have different statutory requirements which have to be met to comply with domestic regulations, including those related to the way the information is provided (i.e. a particular form is mandated). Blockchain application might then raise classification issues where information and contracts viewed as valid and enforceable by customs and courts are not technologically neutral. When information is conveyed through the blockchain instead of traditional documents, it is to be seen if, although not structured along the formal legal requirements, it is recognised as equally apt to attesting, for example, provenance, quality or ownership of goods, thus complying with domestic regulations.

- Interoperability and standardisation:

Finally, regulatory hurdles might result from the different existing data structures and following data standardisation requirements. In fact, rather than just digitising existing forms and processes, blockchain enables new structures of data. From a technical perspective, it is crucial that the data between different blockchain-platforms can interact. However, while this is primarily a technical issue, creating standards of data is also necessary from a regulatory perspective. In the context of trade and custom digitalisation, standards are needed in terms of data structure to comply with domestic requirements. Yet, achieving harmonisation on standards from different suppliers and governments might be arguably challenging.

8. Policy options for the European Parliament

'No doubt, blockchain opens interesting opportunities. But it also raises legal, regulatory and policy issues that deserve our attention — that deserve the attention of all stakeholders.', WTO Deputy Director-General Yi Xiaozhun at the Global Trade and Blockchain Forum.[115]

This chapter presents several policy options. These were developed based on the analysis of the legislative framework and status quo at European and international level. Based on these elements, we propose six 'themes' for further policy action. Under each of which policy options are presented for the consideration of the European Parliament.

8.1. Overview of policy options

Governments need to invest in building their knowledge of blockchain technology and explore its possible applications, because the technology has the potential to improve effectiveness, reduce friction between actors, reduce bureaucratic barriers, improve knowledge sharing, and foster automation through smart contracts.[116] Therefore, we looked at specific areas that require the attention of policy-makers. In the following sections, we present six overarching policy themes. These themes were chosen based on their impacts, but also the possibility for policy-makers to intervene. The themes are as follows:

- Theme 1 – Customs facilitation through blockchain;
- Theme 2 – Involvement of SMEs in the blockchain sphere;
- Theme 3 – Sustainable trade through blockchain;
- Theme 4 – Leadership in standardisation of blockchain technology;
- Theme 5 – Evidence-based policy-making in the area of blockchain;
- Theme 6 – Awareness raising for the use of blockchain.

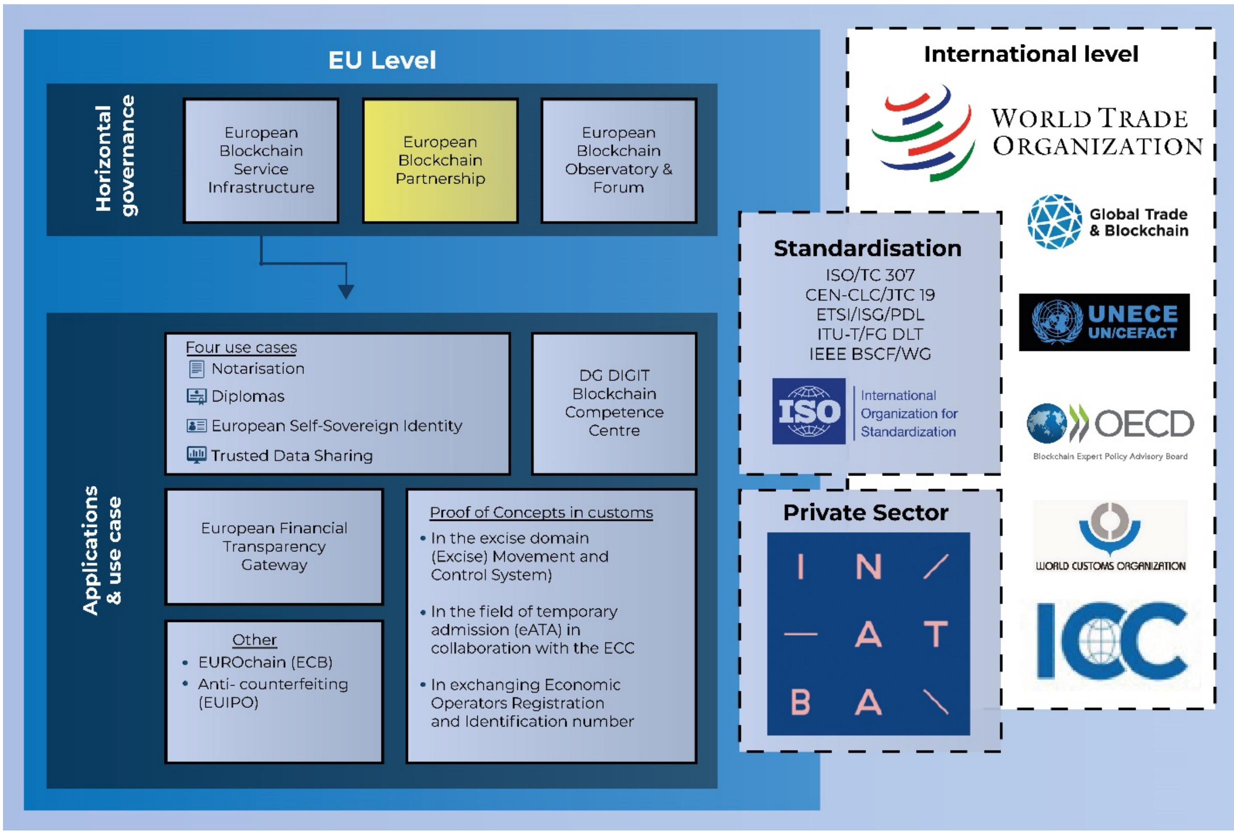
In elaborating these themes and the specific policy options we looked at how these fit into the current policy landscape for blockchain technology in trade and supply chains (see Figure 20). Furthermore, we look specifically at permissioned ledgers[117] as these are the most likely to be used in a public sector setting as well as in a setting where private actors exchange often sensitive information along supply chains.

[115] World Trade Organization: DDG Yi: Regulatory work needed to enhance trade impact of blockchain technologies – 2019 https://www.wto.org/english/news_e/news19_e/ddgyx_02dec19_e.htm

[116] Berryhill, J., T. Bourgery and A. Hanson (2018), 'Blockchains Unchained: Blockchain Technology and its Use in the Public Sector', OECD Working Papers on Public Governance, No. 28, OECD Publishing, Paris, https://doi.org/10.1787/3c32c429-en.

[117] Permissioned ledgers limit contributions to users who have been given permission. Access to view records can be restricted or public, depending on the settings of the ledger.

Figure 20 – Landscape for blockchain in trade and supply chains



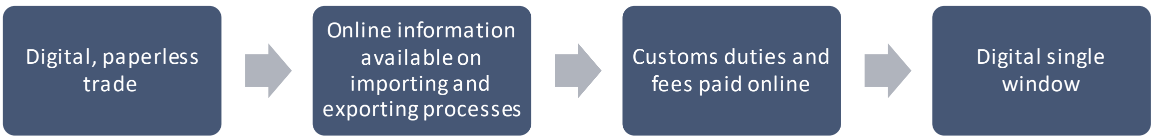
Source: Ecorys

Theme 1 – Customs facilitation through blockchain

'With the blockchain technology, Customs administrations and other border agencies would significantly improve their capacity for risk analysis and targeting, thus contributing to improved trade facilitation' - Yotaro Okazaki, World Customs Organisation

Some of the more relevant use cases this study has looked at—both in terms of potential impact as on the maturity of the applications—directly or indirectly involved customs. Many of the most burdensome document verification processes in international trade accumulate at the point of customs procedures. Work with Customs seems to be one of the more promising applications of blockchain in trade, due to the potential impacts of increased import processing timelines, increased transparency and the data that can be streamlined. Furthermore, Customs Authorities are used to having to work internationally and standardise processes, making the threshold lower for launching more large-scale DLT solutions than with other stakeholders.

Figure 21: Digital approaches to customs, from most globally adopted to least



Source: Ecorys, based on WEF's Windows of Opportunity

Efforts at making customs more efficient start with digital customs—which has been a major focus of the EU's Custom Union. As mentioned in chapter 2, the Union Customs Code (UCC), adopted in 2016, pushes for a paperless and fully electronic and interoperable environment, prioritising simplicity, service and speed in customs processes.[118] The Electronic Customs Multi-Annual Strategic Plan for Customs of 2019[119] underlines this commitment.

A 2018 research paper of the WCO[120] found that blockchain holds potential to collect accurate data, automatically detect fraud and collect taxes and duties. As part of its conclusions, it recommends that its WCO members continue making efforts in exploring the potential of blockchain and in researching their existing legal and technical constraints.

The importance of standardised information and documents with a single entry point to fulfil all import, export and transit-related regulatory requirements[121] has already been recognised on both a global as EU level. The EU Customs Single Window initiative enables economic operators to electronically lodge, all the information required by customs and non-customs legislation for EU cross-border movements of goods and launched its first pilot in 2014.[122] The European Commission has upheld this commitment—with a pilot that is currently operational in nine Member States, an approved business case for a new project, and a working group to develop a legal framework to implement the EU Single Window.

DG TAXUD has already completed two proof of concepts (PoC). One on the feasibility of using blockchain to facilitate and monitor the movement of 'excise goods' in real-time. The other one was in collaboration with the ICC on the **feasibility of a notarisation service for an international customs document (ATA carnet)** and its transaction via a blockchain. Given their proved practical potential, these PoCs are encouraging for actual deployment of solutions on standardising customs documents and procedures. While DG TAXUD does not intend to turn the PoCs into operational projects,[123] this could be picked up by other stakeholders interested in the digitisation of customs procedures.

1.1 The European Parliament could recommend that the European Commission act as a facilitator for EU customs authorities interested in employing DLT for the digitisation of custom to jointly develop further Proofs of Concept

National Customs Authorities have expressed a lack of trust of other solutions for the ATA carnet.[124] Mobilising these Customs Authorities around blockchain as a solution for these concerns could yield as a solution that is already co-developed across multiple stakeholders.

The ongoing efforts for the **EU Single Window** environment can also be used as a platform to further explore DLT-based Single Windows Solution. An EU Single Window Customs 2020 Project Group was set up in 2016 to study a possible frameworks to develop the EU Single Window environment for customs.[125] Guidelines for operationalising blockchain use-cases in Single Windows have already been developed by the WEF, from the establishment of a common vision and business case to steps for building the technology architecture and measuring its impact.

[118] European Commission - The Union Customs Code (UCC) – Introduction. Consulted at: https://ec.europa.eu/taxation_customs/business/union-customs-code/ucc-introduction_en.

[119] European Commission - Electronic customs - Consulted at: https://ec.europa.eu/taxation_customs/general-information-customs/electronic-customs_en.

[120] WCO Research P*aper, Unveiling the Potential of Blockchain for Customs, 2018

[121] United Nations Economic Commission for Europe recommendation No.33.

[122] European Commission – The EU Single Window environment for customs

[123] Digitization of ATA Carnets: how the Blockchain could enhance trust, Zahouani Saadaoui. Consulted at: https://mag.wcoomd.org/magazine/wco-news-87/digitization-ata-carnets/

[124] ibid.

[125] Ibid.

> *1.2 The European Parliament could recommend that established EU Single Window working groups run through the blockchain key questions to be addressed within the guidelines developed by the WEF through consultations with authorities, private sector groups and mixed focus groups to explore whether there is a business case for its development.*

These discussions should focus on the value added of DLT in terms of border clearance. Other issues (of standardisation, efficiency and data sharing) can and have been solved by digital processes and programmes which do not require the level of trust offered by DLT.

The EU has several **Mutual Recognition Agreements**[126] in place with key partners, and several negotiations ongoing. With partners such as China and the USA starting to implement their own solutions of border clearance using DLT, there is opportunity for collaboration on implementing MRAs through blockchain. The Inter-American Development Bank (IADB) is supporting the development of a DLT solution[127] which allows information on Authorised Economic Operators (AEOs) to be shared in an automatic and secure way.

> *1.3 The European Parliament could recommend that the European Commission look to its partners in Mutual Recognition Agreements to explore the possibility of a blockchain-based solution on sharing Authorised Economic Operator information.*

Theme 2 - Involvement of SMEs in the blockchain sphere

There has been a strong focus on SMEs creating innovative solutions through blockchain, however this has mostly placed them in the position of solution-providers rather than users. Small fin-tech companies have been experimenting with developing use cases to support supply chains—but are the SMEs in these supply chains able to use these? As discussed in the analysis of potential impacts, distributed ledger technologies can be used to address some issues that disproportionally affect SMEs.[128] However, the digital gap between SMEs and larger firms in the form of technical skills and adequate internet access can also widen the divide, creating new barriers if SMEs are unable to take advantage of new solutions. Furthermore, many of the potential advantages brought about by DLT solutions require critical mass, for which multiple users are required.

While users do not need to fully understand the technology underlying the solutions, it is important that blockchain does not act as a deterrent and intimidation when it could provide real benefit to EU SMEs.

> *2.1 The European Parliament could recommend for the European Commission to support SMEs to keep abreast of blockchain applications relevant for their particular role in the value chain to be able to make business decisions related to the technology.*

The most effective way to proceed is through regional and national organisations, as they are most familiar with the SME environment in their vicinity, their industries and their technological readiness. The Digital SME Alliance brings together a wide network of ICT SMEs. Work with these organisations should be encouraged to spread a similar understanding of the various types of DLT and their potential solutions across the board.

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[126] The Mutual Recognition of Authorised Economic Operators allows customs organisations to reduce security and safety related controls across various administrations.

[127] Called CADENA, the project has the IADB working with four LATAM customs authorities.

[128] This is particularly strong in access to credit and the high rejection rates for SMEs' request for trade finance, but can be seen in any point of the supply chain where inefficient set-ups create a disproportionally heavier burden for SMEs looking to trade internationally.

SMEs will need to increase their knowledge of the technology and keep abreast of its usage in their respective industries in order to effectively assess and make astute business decisions about the technology.

Furthermore, SMEs can be informed by involving them directly. The BLOCKCHERS[129] project incentivises collaboration between SMEs and DLT specialists as the technology providers. SMEs are able to best identify how the technology can provide solutions to existing problems. These types of consortia should be encouraged.

2.2. The European Parliament could make funds available for a call focussed on collaboration between SMEs as both suppliers of the solution and end users on global value chains.

In terms of practicalities, SMEs need to be informed and kept up-to-date about these opportunities. In this regard, one could make use of European, national and regional SME organisations as well as cluster organisations in order to better reach SMEs. The Digital Innovation Hubs (DIHs) are a potential channel for this. DIHs were launched in 2016 as part of the Digital Single Market package and they aim to create a network of hubs across Europe that act as one-stop-shops to help companies to become more competitive with regard to using digital technologies. For example, part of the network is the Port of Rotterdam's Blocklab, which aims to put blockchain technology into practice in order to test the sharing of logistical and contractual information.[130] In fact, the BLOCKCHERS project links their success in spreading relevant information to SMEs and startups to the DIHs.[131]

Theme 3 – Sustainable trade through blockchain

We need to change the way we produce, consume and trade. Preserving and restoring our ecosystem needs to guide all of our work. We must set new standards for biodiversity cutting across trade, industry, agriculture and economic policy. – President von der Leyen, 'My Agenda for Europe'

This study has focussed on blockchain use cases for sustainable trade, particularly in the tracking of ethical sourcing in terms of labour and the environment. The role of trade policy in supporting the EU's ecological transition was highlighted in the recently published Green Deal. This specifically related to ecological sourcing of products, for which several proofs of concept and use cases exist that propose ways to do this through blockchain technologies. As the ethical sourcing and consumption of materials, food and products becomes increasingly important for successfully implementing an ecological transition, further tools for empowering consumers to make these types of choices.

These types of tools designed to better inform consumers are currently being developed across the world. In 2018, the EC opened the European Innovation Council (EIC) Horizon Prize for Blockchains for Social Good, develop solutions to social innovation challenges using DLTs. One of the areas cited on the call as being a strong contender is the demonstration of the origin of raw materials or products and supporting fair trade.[132] A key aspect of these solutions is that they must be scalable, which is where the European Commission could step in to make these solutions be viable on a larger scale.

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[129] Blockchers – Portfolio – as of 2020. https://blockchers.eu/portfolio/

[130] Blockchain Havenbedrijf Rotterdam. For more information see: https://s3platform.jrc.ec.europa.eu/digital-innovation-hubs-tool/-/dih/1266/view AND http://blocklab.nl/.

[131] The Role of Digital Innovation Hubs in the Age of Blockchain. Available at: https://blockchers.eu/innovation-hubs-in-blockchain/.

[132] Blockchain allows the different participants in the supply chain to have access to immutable information—down to the consumer. A consumer or foundation can therefore access a ledger outlining the steps the product has undergone, from sourcing to processing to distribution.

3.1 The European Parliament could provide the European Commission with the budget to scale up the solutions being developed under Blockchain for Social Good, particularly those pertaining to the support of fair trade.

The Green Deal plans for more sustainable trade have been made even more explicit with the plans for an EU Carbon Border Tax, meant to act as a global incentive for firms to cut emissions. The objective goes beyond reducing greenhouse gas emissions at home and also cuts down on importing CO2 from abroad. This border tax is initially planned to be rolled out in a few sectors, and then slowly spread to more carbon-emitting sectors.

The use of DLT to measure and track carbon emission and so accurately identify where it is being generated across the supply chain is not new.[133] A formal EU Carbon Border Tax, however, would be, and immediately creates the need for a working system to be able to tax in an accurate, efficient and transparent manner.

3.2 The European Parliament could recommend the European Commission to include DLT solutions as a considerations for designing the practical aspects of an EU Carbon Border Tax.

Finally, it is important that the cure does not aggravate the problems which it is trying to solve. When potential new use cases of the technology are discussed, energy consumption and carbon footprint should be included in the consideration of the solution. Serious exercises must be carried out to benchmark different technologies against each other in terms of their environmental impacts, especially when there is the potential to deploy them on a global scale. The European Commission and especially DG DIGIT are already investigating energy efficient blockchain solutions. Moreover, permissioned blockchains are generally more energy efficient. Nevertheless, the European Parliament could engage the European Commission in taking the carbon footprint into consideration with the possibility of establishing guidelines for future use cases.

3.3 The European Parliament could remind the European Commission to consider energy efficiency and the carbon footprint when developing new use cases and could support the establishment of guidelines in this regard.

Theme 4 – Leadership in standardisation of blockchain technology

'Europe is well placed to take a global leadership position in the development of new trusted services and applications based on blockchain and distributed ledger technologies.', CEN-CENELEC (2018)

By warranting **interoperability and compatibility** of products and services, standards facilitate international trade. They benefit businesses and consumers by reducing costs, enhancing performance and improving safety. Blockchain provides an opportunity here, because the technology has the potential to incentivise firms and other actors to work together by adding external pressure to collaborate in trade, a field that has not seen much progress in standardisation. However, as discussed in section 5.1.2 it is also a challenge. It is a challenge because international trade involves a multitude of actors with different goals and in different legislative frameworks. The JRC recommends as part of its policy agenda for blockchain to support the development of international standards on security, privacy and governance and create certification process to ensure compliance of blockchain architectures with these standards.[134]

[133] White Paper Infosys: Re-engineering the Carbon Supply Chain with Blockchain Technology 2018

[134] Allessie D, Sobolewski M, Vaccari L, Pignatelli F (2019) Blockchain for digital government, EUR 29677 EN, Publications Office of the European Union, Luxembourg.

Interviewees proposed to promote interoperable standards, similar to the JRC's recommendation on developing international standards. It was mentioned too that governance between private actors is difficult to set up, solutions for public actors such as Customs should be easier to get on the same standards. The European Parliament also recognised the **importance of standards** in its resolution on blockchain in trade. In fact, the European Commission is already collaborating with ISO Technical Committee 307 and the technical committee on blockchain of CEN to develop EU standards. The Commission exchanged also with ETSI and its Industry Specifications Group on permissioned distributed ledgers as well as ITU. Bodies like the WCO and UN/CEFACT are working too on the standardisation of trade data. This collaboration needs to be continued and if possible intensified, because as noted in the CEN-CENELEC White Paper on Blockchain (2018), common standards contribute to avoiding market fragmentation and increase competition. Considering the abundance of private and public pilots, but also the various simultaneous standardisation efforts, especially the market fragmentation is a concern.

4.1 The European Parliament could recommend the European Commission to continue playing a leading role in the process of standardisation and to strive to provide a platform for the various actors working on pilots and standards to engage with each other in order to avoid fragmentation.

An overview over the ongoing standardisation work is presented in the table below.

Table 26 - Standardisation bodies and their working groups

Standardisation organisation	Status of work
ISO/TC 307 - Blockchain and distributed ledger technologies	• Published one standard: Overview of and interactions between smart contracts in blockchain; • Ten further standards are under development; • European Commission has established a liaison; • JRC researchers are participating in all of its study and working groups.
CEN/CLC/JTC 19 - Blockchain and Distributed Ledger Technologies	• No standards have been published yet; • Works in close contact with ISO/TC 307; • Focuses on specific European policy requirements, in support of the EU Digital Single Market; • A previous CEN-CENELEC Focus Group prepared a White Paper 'Recommendations for Successful Adoption in Europe of Emerging Technical Standards on Distributed Ledger/Blockchain Technologies'.
ETSI - Industry Specification Group (ISG) Permissioned Distributed Ledger (PDL)	• No standards have been published yet; • European Commission has established a liaison; • Investigates specifically permissioned distributed ledgers, which are according to ETSI better qualified to address the more business-oriented use cases that are of interest to industry and governmental institutions.
ITU - Focus Group on Application of Distributed Ledger Technology	• Published three sets of technical specifications and five technical reports; • European Commission has established a liaison; • The group established a liaison with ISO/TC 307 and vice versa; • UN/CEFACT, CEN-CENELEC, ETSI and European Commission presented their work on blockchain technologies and DLT to the Focus Group.

IEEE Standards Association	• Established a working group on blockchain in Supply Chain Finance (BSCF_WG).
UN/CEFACT	• Developing regulatory frameworks and international standards of emerging technologies including blockchain; • Including the exploration of how blockchain could support the SDGs; • Published a White Paper on Blockchain for trade facilitation.

Note: The National Institute on Science and Technology in the USA, the German Institute for Standardisation, and the Spanish Association for Standardisation have their own working groups on DLT-related standardisation.

In addition to the work of standardisation at international organisations, much work comes from **industry and community organisations**. Open source approaches facilitate collaboration and cross-industry applications. For example, Hyperledger (Linux Foundation) has a community of over 200 companies creating jointly a standard for enterprise blockchain platforms. Similarly, the Ethereum community continuously develops and maintains standards including the most known standard in use with ERC-20, which is used for smart contracts. Another interesting approach, is the Accord project, which provides an open ecosystem for building technology neutral smart agreements.[135] In addition, there are also sector specific efforts such as the Blockchain in Transport Alliance (BiTA), which combines freight, transportation, logistics and affiliated industries.

The amount of groups working on standardising the technology and the data needed for it is a good indication that this issue is taken seriously, however at some point this will also require harmonisation between initiatives and a governance structure that foster such cooperation. Standardisation organisation are already cooperating with each other as also showcased in the table above and the ITU – Focus Group on DLT recommended in its final report to maintain and build on existing relationships moving forward. However, one needs also to link up with private initiatives and should make use of existing bodies such as INATBA. In this regard, the Multistakeholder Platform on ICT Standardisation (MSP) already brings together the European Commission, Member States, standardisation bodies and stakeholder organisations from the industry. A recent joint working group of the MSP and the Digitising European Industry (DEI) identified blockchain and other DLTs as a standardisation need.[136]

4.2 The European Parliament could call on the European Commission to make use of the Multistakeholder Platform on ICT Standardisation (MSP) to further collaborate with the various stakeholders on standardisation of blockchain technology.

Next to facilitating exchange and providing a platform, the **EU should continue its leading role**. Competition between different standardisation approaches across countries (e.g. between the EU and the USA[137]) can lead to an international standard emerging that builds on one side, but neglects the needs of the other. Therefore, the cooperation and dialogue of European standardisation organisations with partners in the USA should continue.[138] Similarly, the EU needs to monitor efforts

[135] Accord Project, available online: https://www.accordproject.org/. as of 2019.

[136] Joint MSP/DEI Working Group on standardisation in support of Digitising European Industry (2018) Interim Report of the joint MSP/DEI WG.

[137] The American National Standards Institute (ANSI) has a very different approach to standardisation when compared with the European model. ANSI accredits US Standards Developing Organisations (SDOs), which are then likely to develop national standards for the US (referenced as ANS), while in Europe, CEN, CENELEC, and ETSI are developing European standards (referenced as ENs) themselves.

[138] CENELEC – Cooperation agreements, Informal cooperation with US available at : https://www.cencenelec.eu/intcoop/Agreements/Cooperation/Pages/USA.aspx. as of 2020.

in other third countries in order to avoid that competing standards are published that go contradictory to EU goals. Furthermore, Europe should aim to provide workable solutions. As shown under the Customs theme, the EU already connects in its Customs Union various economic operators and authorities, which provides a governance structure to test blockchain solutions and build standards. Moreover, while some industry-led efforts for interoperability between providers have been observed, it is clear that it is a very competitive field where the focus lies more on carving out market shares than work on international standards. In this regard, authorities can act as integrators, since government services often connect various actors at different levels.

4.3 Beyond dialogue with third countries on standardisation, the European Union could lead by example and set standards itself by introducing blockchain-based services for example in customs or financial transparency based on which private actors, third countries, and international standardisation organisations can orient themselves.

Overall, one needs to create a **comprehensive ecosystem that brings together all private and public actors** to establish a governance model that looks into legal, organisational, semantic and technological standards. The short term effect in defining standards is an increased cross-border and cross-pilot interoperability.[139] This will be critical to support wide-scale deployment and here the European Parliament can steer in the right direction, as well as provide support to the European Commission. In the longer term this should enable an ecosystem of public and private blockchains in international trade and supply chains that can communicate with each other either through standardised approaches and data formats or fitting application programming interfaces (APIs)[140].

4.4 The European Parliament could support the work of the European Blockchain Partnership and encourage its collaboration with the International Association for Trusted Blockchain Applications to work towards a comprehensive ecosystem of international supply chains connected through blockchain technology.

Theme 5 – Evidence-based policy-making in the area of blockchain and trade

'Without a clear understanding about what blockchains are, their potential public sector potential impact is sometimes misunderstood or, more often, ignored.', OECD (2018) Blockchains Unchained: Blockchain Technology and its Use in the Public Sector.

Research and innovation funding through EU programmes for blockchain-related projects amounted to EUR 83 million in 2018 and up to EUR 340 million could potentially be committed from 2018 to 2020[141]. Specifically, in area of international trade and supply chains there are many PoCs and pilots with blockchain technology. As the identified impacts of the use cases showed, their further development and application could have potentially strong impacts. However, currently these are at an early stage. Similar, none of the 39 blockchain projects analysed in the recently published WTO paper[142] are at a stage where they are considered as well established and live and running. Instead, many are only concepts and the average project is between its pilot phase and entering into early stages of production. Therefore, much is still in development.

[139] Allessie D, Sobolewski M, Vaccari L, Pignatelli F (2019) Blockchain for digital government, EUR 29677 EN, Publications Office of the European Union, Luxembourg.

[140] For example, The Port of Rotterdam's Blocklab has attempted this by building its own system which can be accessed or interfaced with via APIs.

[141] European Commission, Joint Research Centre (2019) Blockchain Now And Tomorrow: Assessing Multidimensional Impacts of Distributed Ledger Technologies.

[142] Ganne Emmanuelle and Patel Deepesh (2019) Blockchain & DLT In Trade: A Reality Check.

While over- or premature regulation must certainly be avoided, regulation should provide an enabling framework for using the technology in international trade. Policy-makers should inform themselves and **monitor the developments** closely in order to be ready to make good regulatory decision. There are already a few areas where future legislative actions might become necessary. For example, the lack of recognition of e-signatures, e-seals, and overall e-documents[143] internationally as well as the legal status of smart contracts and tokenisation are areas where more regulatory clarity would be needed. Technologies such as smart contracts are not a pre-condition for the use of blockchain, however specifically in the area of trade a main concern is the validation and verification of documents as well as the exchange thereof. For the latter blockchain technology alone is sufficient, however in order to really digitalise and automate trade procedure, one needs also supporting technologies such as smart contracts[144]. There has been work under the Connecting Europe Facility, where Member States worked on acknowledging eIDAS[145] based digital identities and e-signatures. The eIDAS regulation has been fully applicable since July 2016. It opened numerous new possibilities for the trustworthy digitalisation of administrative and business processes. Another issue is privacy and the GDPR regulation due to a conflict between the immutability of data on a blockchain with the right to be forgotten. Though, in the case of trade and supply chains, one generally does not need personal data, making it less of a concern.

Regarding regulatory certainty, the WTO also notes that policy action may be needed to provide a predictable regulatory environment, since blockchain can only accelerate the digitalisation of international trade if the legislative framework allows for transactions to be carried out through digital means and if those transactions are recognised as legal and valid.[146] Organisations such as the EU Blockchain Observatory and Forum (EBO), but also international organisations such as the ITU already provide research on the regulatory aspects of the technology.[147] For example, DG CNECT recently tendered a study on blockchain and its legal, governance and interoperability aspects.[148] In terms of practicalities, the European Parliament could setup regular interaction with their counterparts at the European Commission and at Member States. This could be achieved by for example having an observing role in the European Blockchain Partnership (EBP) or by regularly inviting relevant European Commission DGs (e.g. CNECT, TAXUD, FISMA, TRADE, DIGIT) to the European Parliament.

5.1 Considering the large amount of work already happening at EU level in regard to blockchain technology and international trade, the European Parliament could consider to engage more actively in the work by observing relevant organisations such as the European Blockchain Partnership or asking for regular updates on their work from the European Commission.

Current EU legislations such as the eIDAS regulation are technology agnostic, meaning the technology used to comply with them does not matter. Other regulations such as the UCC actively aim at updating and digitalising processes. The aforementioned unclarities therefore are challenges, but should not turn into problems if regulators are aware and informed about them. As stated in the

[143] There have been international efforts to improve their recognition, for example the WTO launched its e-commerce Joint Statement Initiative in December 2017.

[144] Smart contracts are self-executing contracts where the terms are written directly in software code on the blockchain. Each smart contract is an automated 'if/then' scenario that executed when a specific trigger occurs.

[145] The EU's eIDAS regulation is one of the examples worldwide of electronic and digital signatures being actively regulated, however also some courts such as China's Supreme Court have already recognised blockchain-based proofs, See: ITU-T FG DLT (2019) Technical Report FG DLT D4.1 Distributed ledger technology regulatory framework.

[146] Deputy Director-General Yi Xiaozhun at the Global Trade and Blockchain Forum.

[147] For example, see the EBOF's thematic report on *Legal and regulatory framework of blockchains and smart contracts* or the ITU's report on Distributed ledger technology regulatory framework.

[148] Smart 2018/0038

EBO's recent report on smart contracts, regulators should create simple and usable definitions of the technology as well as harmonise the law and interpretations of it.

In the future though, new issues might arise. In addition, it will be necessary to stay informed about already existing issues. Established organisations such as the EBO and the EBP already exist to **exchange of knowledge across the European Union** similar organisations such as UN/CEFACT and WTO's Global Blockchain Forum exist **at international level**. Here the European Parliament should aim to stay closely involved but also support further research and the sharing of best practices.

5.2 The European Parliament could promote networks such as the European Blockchain Partnership, the Observatory, and others. To this end the European Parliament could also promote research results as well as approve and supporting the funding of further research in the area such as a mapping of regulatory readiness in the EU, its Member States and international partners

Given the embryonic stage of most initiatives in this field, many claims on impact and results thus far go unsubstantiated—and understandingly so. While proofs of concept show strong potential impact, these do not provide concrete numbers to back up the claims on efficiency gains. However, estimates of these impacts are a key input for the policy debate.

New technologies are often categorised as 'hype' and the way to differentiate that from core capability is to focus on experimentation and limited-scope initiatives that deliver lessons.[149] Importantly, these lessons should then feed into the wider landscape of blockchain solutions. Further developments should have impact measurement as one of the priorities. The supported use cases of SMEs should be tied to monitoring and evaluation standards, which needs to feed back into studies. It is time for blockchain proofs of concept to materialise and generate results indicators that will help assert whether the technology has the potential to materialise the studied potential impacts.

5.3 The European Parliament should highlight to the European Commission that calls for innovative solutions should include reporting indicators and specific plans on how results will be measured, communicated and developed into lessons learned.

Theoretical research alone is, however, not enough. A practical approach should be taken that **applies and test the technology** in a well-regulated environment. As mentioned in previously, DG TAXUD has already completed two PoCs. One on the feasibility of using blockchain to facilitate and monitor the movement of 'excise goods' in real-time. The other one was in collaboration with the ICC on the feasibility of a notarisation service for an international customs document (ATA carnet) and its transaction via a blockchain. A third one has been launched that looks into the potential implementation of blockchain technology into electronic registries of economic operators.

Similarly, the European Blockchain Service Infrastructure (EBSI) supports four use cases: on notarisation, diplomas, European self-sovereign identity, and trusted data sharing.[150] The latter aims at customs services by leveraging blockchain technology to securely share data amongst customs and tax authorities in the EU. In 2020, EBSI will become a CEF Building Block, providing reusable software, specifications and services to support adoption by EU institutions and European public administrations. A second wave of use cases will be selected in 2020 by the EPB.

[149] More information at: https://www.gartner.com/en/newsroom/press-releases/2019-05-07-gartner-predicts-90--of-blockchain-based-supply-chain, on estimations that 90% of blockchain-based supply chain initiatives will suffer Blockchain Fatigue by 2023.

[150] https://ec.europa.eu/cefdigital/wiki/display/CEFDIGITAL/EBSI

[151] These will possibly include further use cases in the area of supply chains. For example, on the topic of provenance and sustainability. The Digital Europe Programme will be the vehicle to continue the work on EBSI, focusing on deployment, in the next Multiannual Financial Framework. Here **the EU has the chance to become a forerunner** in applying blockchain technology to government services by creating building blocks that connect services using blockchain technologies across the Member States. Potentially, this should lead to the focused development of pilots, the sharing of best practices, and the faster uptake of pilots by Member States.

5.4 Having regard of the work already being done in piloting blockchain at EU level, the European Parliament could monitor closely their progress as well as support the set-up of future use cases and pilots under EBSI and the CEF.

At EU level, the EBP supports collaboration, while **among private actors** cooperation is organised in the International Association of Trusted Blockchain Applications (INATBA). INATBA support delivery of cross-border digital public services and develop interoperability guidelines. In addition, as shown in the use cases we analysed but also in a recent publication by the WTO[152] there exist a large amount of privately run proofs of concepts and pilots. These are run by private Consortia working in fields such as finance or logistics and often involve large players collaborating with small innovative start-ups. Relating back to the theme on SMEs, it would be beneficial to continue supporting European solution providers through grants or loans.[153] Resources should be used to foster not only public solutions but also support the innovation climate surrounding private consortia.

5.5 Considering the early development stages of many blockchain related projects in trade and supply chain, the European Parliament could support and strengthen the EU's efforts through funding schemes for researchers and businesses in the area.

Next to supporting public and private pilots, one need to also consider how to bridge these efforts. **Public-private partnerships** (PPP) in areas of joint interest (e.g. custom procedures, tracking of dangerous or sensitive goods, provenance checking) could trigger fruitful cooperation and the setting-up of public-private blockchain-based infrastructures in the area of supply chains and international trade. Overall, blockchain is more collaborative than competitive as shown in the many private Consortia that have formed. Examples of PPPs already exist, the Dutch Blockchain Coalition is a joint venture between partners from the government, knowledge institutions and industry. Similar to EBSI, they are developing blockchain building blocks and aims to implement use cases on

[151] Next to the use cases at EU level, there are also some at national and local level. A recent JRC report presents a selection of use cases in the areas of notarisation, smart contract, and shared databases: Exonum land title registry (Georgia), Blockcerts academic credentials (Malta), Chromaway property transactions (Sweden), uPort decentralised identity (Zug, Switzerland), Infrachain governance framework (Luxembourg), Penstion infrastructure (Netherlands), Stadjerspas smart vouchers (Groningen, Netherlands). Source: Allessie D, Sobolewski M, Vaccari L, Pignatelli F (2019) Blockchain for digital government, EUR 29677 EN, Publications Office of the European Union, Luxembourg. Further use cases can be found in Berryhill, J., T. Bourgery and A. Hanson (2018), 'Blockchains Unchained: Blockchain Technology and its Use in the Public Sector', OECD Working Papers on Public Governance, No. 28, OECD Publishing, Paris, https://doi.org/10.1787/3c32c429-en.

[152] Ganne Emmanuelle and Patel Deepesh (2019) Blockchain & DLT In Trade: A Reality Check.

[153] For example, In 2018, DG GROW launched a call on 'Blockchain and Distributed Ledger Technologies for SMEs' (INNOSUP-03-2018)21. The winning project, BLOCKCHERS (https://blockchers.eu/), will implement a two-phase funding scheme and support SMEs. One of its goals is to foster matchmaking among traditional SMEs and potential DLT specialists, as technology providers, and sensitise stakeholders about the benefits and opportunities around DLTs to implement real-use-case scenarios.

self-sovereign identity, logistics and other.[154]. The European Commission has also taken a first step towards PPP in the area of blockchain by supporting the creation of INATBA.

5.6 Having regard of the creation of INATBA, the European Parliament could support and encourage the European Commission in establishing a Public-private partnership in the area of blockchain in trade and supply chains.

Theme 6 – Awareness raising for the use of blockchain

One challenge mentioned throughout interviews is the **challenge of scalability**. Scalability and energy consumption are often flagged as a barrier to using blockchain technology. However, for government blockchain implementations this is less relevant as the issue applies to inefficient proof of work consensus mechanisms used on permissionless blockchains.[155] In the case of permissioned blockchains, the challenge of scalability relates not to technological barriers, but to a general misunderstanding of the technology, its use, and potential applications beyond well-known examples such as Bitcoin.

In the end, to benefit from most of the identified impacts, one needs to go beyond isolated pilots towards an interconnected system of blockchain-based platforms in trade and supply chains. The problem here is that currently the technology's benefits are often not recognised among business communities and even less so among the wider public. The technology is currently more associated with negative aspects and topics, such as cryptocurrencies and the darknet. Indeed, a recent publication by the OECD on blockchain and its use in the public sector, notes that the inherent distrust as well as the lack of understanding about the technology is one of its largest barriers. It is recommended that instead of explaining the technology it is important to focus on the benefits it can bring. [156]

Blockchain is in need of **enhanced recognition**. Despite the hype, many still do not understand it. One interviewee remarked that we have all seen graphics and read explanations but struggle to visualise how such an application would look like in real life. Therefore, after becoming informed policy-makers can support the use of blockchain by explaining how it can improve current processes. The European Parliament does not need to become a partisan of blockchain-led solutions nor an expert on it, but could highlight the technology's benefits in advancing EU values such as transparency, fair trade, as well as social and environmental responsibility. One could also highlight the efficiency gains and the potential reduction of administrative burden for example in custom procedures.

6.1 Having regard of the potential blockchain technology has in improving efficiency and in supporting EU values such as transparency, fair trade, social and environmental responsibility, the European Parliament together with the European Commission and Member States could promote recognition of the technology and its use in trade and supply chains.

Awareness building can best be channelled through existing bodies such as the EBP, the EBO and among private actors in INATBA. Alternatively, the European Parliament could provide a platform itself by inviting relevant speakers or organising a conference on the topic of blockchain technology

[154] Another example is the ID2020 initiative (UN agencies, companies such as Microsoft Accenture), which seeks to provide formal identities to individuals who lack one, including refugees.

[155] Of course there are still other barriers to the scalability of blockchain technology. Specifically, blockchain is designed for small amounts of data. If data storage is needed, blockchain may not be a good fit, or a hybrid solution may be needed (e.g. only the transactions are recorded, while actual documents are stored separately).

[156] Berryhill, J., T. Bourgery and A. Hanson (2018), 'Blockchains Unchained: Blockchain Technology and its Use in the Public Sector', OECD Working Papers on Public Governance, No. 28, OECD Publishing, Paris, https://doi.org/10.1787/3c32c429-en.

in international trade. Of course as discussed under Sustainable trade theme any advocacy should go beyond highlighting the positive aspects of blockchain technology in trade and supply chains. The European Parliament could also use its competencies in terms of **scrutiny** and EU budget decisions to push towards the active use of the technology to forward EU values by for example making funding for blockchain projects dependable on their consideration of these values.

For support and uptake of the technology, blockchain solutions also need to be more tangible. As discussed, distrust as well as the lack of understanding are a barrier to overcome. Therefore, when promoting the use of blockchain technology for trade and supply chain, it is helpful to highlight already successful pilots such as the European Financial Transparency Gateway (EFTG)[157] or the proofs of concept run by DG TAXUD as well as pilots by private Consortia. The goal should be to get more Member States or other actors (e.g. Chambers of Commerce, economic operators, international organisations) informed about and involved in these pilots. Highlighting such platforms would be another way to separate the theoretical explanations from what it actually does for business, government and citizens, thereby getting actors interested to participate.

6.2 In order to increase familiarity among stakeholders with the technology and its uptake, the European Parliament could promote successful proof of concepts, pilots and the available building blocks on the Connecting Europe Facility platform among Member States, private stakeholders and citizens.

Finally, the scalability also needs to look across borders. Right now there is a focus on EU legislation. The Connected Europe Facility, the eIDAS regulation, and the UCC have Member States working on a EU framework for blockchain technology, however at **international level** efforts are slow. Organisations such as the WTO, WCO, and UN/CEFACT work on facilitating and digitalising trade (e.g. through the Trade Facilitation Agreement or through standardisation of data models that are related to trade), but progress on issues such as the recognition electronic signatures or smart contracts is slow[158].This lack of recognition of e-signatures and e-documents around the world remains a barrier to the digitalisation of trade. Here the European Union as a member in many of these international organisations, could raise further awareness about the potential benefits from using blockchain technology and move the topic higher up in the agendas.

6.3 The European Parliament could recommend to the European Commission and Member States to make use of their roles as members in international organisations such as the WTO, WCO and UN/CEFACT to promote trade digitalisation and the use of blockchain technology.

8.2. Conclusions

In the past sections, we presented various policy options for the consideration of the European Parliament. While there is no imminent need for action, our research has shown the promising impacts blockchain technology can have on international trade and supply chain. The European Union, international organisations, and private actors are currently engaged in exploring the use of blockchain technology in areas such as customs, trade finance, and more. The European Parliament does not need to be at the forefront of this, however, it should be aware of developments and use

[157] The goal of the EFTG Pilot Project consists of developing a Blockchain platform infrastructure, technically enabling citizens and investors by giving them increased access to public regulated information provided by the participating Officially Appointed Mechanisms in Member States. The pilot project is running in six Member States and the European Commission.

[158] For example, a United Nations model law on electronic signatures has only been adopted in some 30 jurisdictions, and only 12 parties ratified the Convention on the Use of Electronic Communications in International Contracts, while only two have ratified the UNCITRAL Model Law on Electronic Transferable Records from 2017.

its competencies to steer these in the right direction in order to maximise benefits from blockchain technology while respecting core EU values.

The suggestions for consideration of the European Parliament are summarised below. The table below provides an overview of policy options per theme, the actors that would be involved, and a ranking in term of their feasibility or the ease in implementing them.

Table 27 - Overview over the proposed policy options for the European Parliament

#	Policy options	Other actors	Feasibility
	1. Customs facilitation through blockchain		
1.1	Recommend that the European Commission act as a facilitator for customs authorities interested in employing DLT for the digitisation of custom to jointly develop further Proofs of Concept	European Commission, National Customs Authorities	Requires substantial efforts in coordinating between authorities, however tests could be started with a smaller set of authorities.
1.2	Recommend that established EU Single Window working groups run through the blockchain key questions to be addressed within the guidelines developed by the WEF through consultations with authorities, private sector groups and mixed focus groups to explore whether there is a business case for its development.	Customs 2020 working group, European Commission, National Customs Authorities, Business Associations	Depends on coordination and exchange between different groups.
1.3	Recommend that the European Commission look to its partners in Mutual Recognition Agreements to explore the possibility of a blockchain-based solution on sharing Authorised Economic Operator information.	European Commission, National customs Authorities, National Accreditation Bodies	Requires substantial resources to establish working groups with third countries
	2. SMEs involvement in the blockchain landscape		
2.1	Recommend the European Commission to support SMEs to keep abreast of blockchain applications relevant for their particular role in the value chain to be able to make business decisions related to the technology.	European Commission, SMEs, DIHs	Requires effort to make use of existing fora to inform SMEs.
2.2	Make funds available for a call focussed on collaboration between SMEs as both suppliers of the solution and end users on global value chains.	European Commission, Council of the EU, SMEs, DIHs	Depends on agreements in the Multiannual Financial Framework with the Council and Commission.
	3. Sustainable trade through blockchain		
3.1	Provide the European Commission with the budget to scale up the solutions being developed under Blockchain for Social Good, particularly those pertaining to the support of fair trade.	European Commission, Council of the EU	Depends on agreements in the Multiannual Financial Framework with the Council and Commission.

3.2	Recommend the European Commission to include DLT solutions as a considerations for designing the practical aspects of an EU Carbon Border Tax.	European Commission, Member States	Already a contentious and complex topic, would require considerable coordination
3.3.	Remind the European Commission to consider energy efficiency and the carbon footprint when developing new use cases and could support the establishment of guidelines in this regard.	European Commission, EBP	Requires effort in providing guidelines for the EBP
4. Leadership in standardisation of blockchain technology			
4.1	Recommend to the European Commission to continue playing a leading role in the process of standardisation and to strive to provide a platform for the various actors working on pilots and standards to engage with each other in order to avoid fragmentation.	European & international Standardisation organisations	Requires continuation of current efforts
4.2	Call on the European Commission to make use of the Multistakeholder Platform on ICT Standardisation (MSP) to further collaborate with the various stakeholders on standardisation of blockchain technology.	European Commission, MSP, INATBA	Requires establishing flanking measures for current efforts
4.3	Beyond dialogue with third countries on standardisation, the European Union could lead by example and set standards itself by introducing blockchain-based services for example in customs or financial transparency based on which private actors, third countries, and international standardisation organisations can orient themselves.	European Commission, Member States, Third countries	Requires considerable effort in turning current use cases and PoCs into actual pilots.
4.4	Support the work of the European Blockchain Partnership and encourage collaboration with the International Association for Trusted Blockchain Applications to work towards a comprehensive ecosystem of international supply chains connected through blockchain technology.	EBP (European Commission, Member States), INATBA	Requires to intensify collaboration with and in between the EBP and INATBA.
5. Evidence-based policy-making in the area of blockchain			
5.1	Consider to engage more actively in the work by observing relevant organisations such as the European Blockchain Partnership or asking for regular updates on their work from the European Commission.	European Commission, EBP	Requires some resources for monitoring and information exchange.
5.2	Promote networks such as the European Blockchain Partnership, the Observatory, and others. To this end the European Parliament could also promote research results as well as approve and support the funding of further research in the area such as a mapping of regulatory readiness in the EU, its Member States and international partners.	EBP, EBO	Requires to devote some of the EBO's resources to this research.
5.3	Highlight to the European Commission that calls for innovative solutions should include reporting indicators and specific plans on how results will be measured, communicated and developed into lessons learned.	European Commission	Requires substantial resources in monitoring and evaluating use cases.

5.4	Having regard of the work already being done in piloting blockchain at EU level, the European Parliament could monitor closely their progress as well as support the set-up of future use cases and pilots under EBSI and the CEF.	EBP, European Commission, Member States	Requires some resources for monitoring and information exchange.
5.5	Considering the early development stages of many blockchain related projects in trade and supply chain, the European Parliament could support the European Commissions' efforts through funding schemes for research and business in the area.	European Commission, Council of the EU	Depends on agreements in the Multiannual Financial Framework with the Council and Commission.
5.6	Having regard of the creation of INATBA, the European Parliament could support and encourage the European Commission in establishing a Public-private partnership in the area of blockchain in trade and supply chains.	European Commission, INATBA	Requires substantial resources in coordinating, setting up and financing such a PPP.
6. Awareness raising for the use of blockchain			
6.1	Having regard of the potential blockchain technology has in improving efficiency and in supporting EU values such as transparency, fair trade, social and environmental responsibility, the European Parliament together with the European Commission and Member States could promote recognition of the technology and its use in trade and supply chains.	European Commission, Member States, Stakeholders	Requires some efforts in promoting blockchain.
6.2	Promote successful proof of concepts, pilots and the available building blocks on the Connecting Europe Facility platform among Member States, private stakeholders and citizens in order to increase familiarity among stakeholders with the technology and its uptake	None	Requires some efforts in promoting blockchain use cases.
6.3	Recommend to the European Commission and Member States to make use of their roles as members in international organisations such as the WTO, WCO and UN/CEFACT to promote trade digitalisation and the use of blockchain technology.	European Commission, Member States, WCO, WTO, UN/CEFACT	Requires some efforts in making use of existing forums.

[1] Feasibility: 1 = easy to implement, 2 = requires some effort; 3 = requires constant effort and follow-up.

Annex 1 – Study process and methodology

In this section, we present a brief overview of the overall study process and the methodology used, which will clarify the context of this report and point to additional sources for information (this report being voluntarily synthetic). The study was conducted in 3 phases:

Phase 1: review and explanation.

In this phase, we introduced the key concepts of blockchain in international trade. The phase 1 report initially presents the key concepts of blockchain technology, provides a review of the main technological options available, and an assessment of the potential limitation of the technology and of the technological questions that remain open.

An assessment was conducted of the potential elements in the international trade process, which could benefit from the use of blockchain. This led to the definition of 12 potential use cases, spread along the trade and supply chain, from the onset of a commercial transaction, to trade finance, regulatory and custom issues, logistics or traceability and transparency issues.

Finally the phase 1 report provides an analysis of the potential future development of blockchain in trade, through an analysis of the market drivers and barriers and a first vision of potential impacts.

Phase 2: case study and impact

The analysis of use cases carried out in phase 1 served as a basis for a more in depth look at 8 specific cases (which can be understood as future scenarios for the use of blockchain in international trade). The 8 case studies were selected to ensure a full coverage of the supply chain, while providing a good balance between their level of development, potential impact and scope.

In order to investigate these cases in more detail, the study conducted interviews, targeting both stakeholders directly involved in the case (companies and experimenters developing proof of concepts or commercial services based on the use case) and external blockchain and trade expert providing a more 'horizontal' view on a specific impact dimension of multiple use cases.

The phase 2 report then synthetised the potential impacts of blockchain in international trade over 8 dimension of impact: Economic, Trade, Social, Technological, Security, Environmental, Data protection, Transparency.

Phase 3: reflections and options

The study was concluded by providing further reflections on the use of blockchain in international trade, the potential impacts and concrete ideas of policy options for the European Parliament. In particular, the research team provided:

- a review of blockchain, its added-value in international trade and an analysis of potential alternatives.
- an overview of the existing legislative framework that applies to blockchain in international trade.
- And finally, an analysis of potential policy options and elaborates based on the status quo on potential needs and solutions.

This work in drafting policy options is based on the previous work in identifying impacts of blockchain technology in trade and supply chains, as well as on targeted interviews with stakeholders and additional literature review. The policy options were developed in consultation with the European Parliament as well as European Commission services that work on blockchain and trade. The following organisations were interviewed:

- World Trade Organization;
- Directorate-General for Communications Networks, Content and Technology (DG CNECT);
- Directorate-General for Taxation and Customs Union (DG TAXUD);
- Directorate-General for Trade (DG TRADE);
- Directorate-General for Justice and Consumers (DG JUST);
- Directorate-General for Informatics (DG DIGIT);
- European Parliament Panel for the Future of Science and Technology (STOA).

In addition to interviews, various policy relevant literature sources on blockchain and trade were also consulted. These include for examples, reports form the EU Blockchain Observatory and Forum, from the JRC, from the European Parliament as well as from international organisations such as the OECD, WTO, WCO, WEF, and more.

Annex 2 – Additional definition and context

We present in this section additional considerations regarding blockchain technologies that complement the element presented in section 1.

Technical background

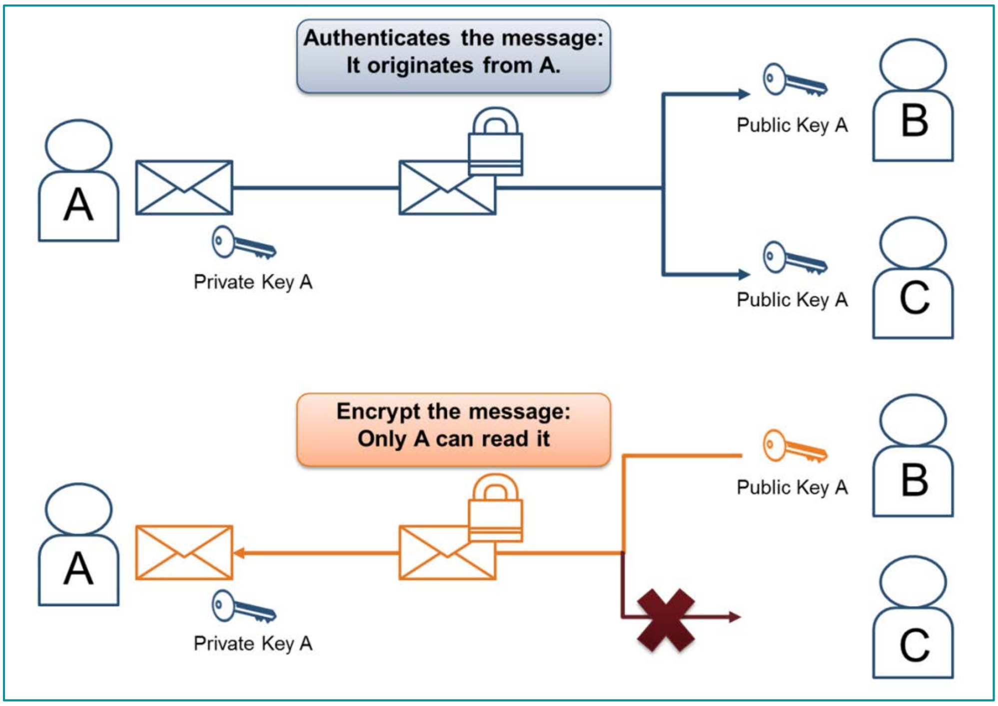
The two following technologies are important components of most blockchain implementation and we present here a basic overview of their behaviour. Without diving too deep into the algorithmic and mathematic foundations of these technologies, a basic understanding can help navigate discussions regarding blockchain technologies.

Asymmetric cryptography

The process of authenticating the blockchain's transactions is based on the principle of asymmetric cryptography. This system uses pairs of keys: a private key that the user must keep absolutely secret, and a public key that must be disseminated openly.

A message encrypted with a private key can only be decoded with the public key and vice-versa.

Figure 22: Asymmetric cryptography



Source: IDATE DigiWorld, *blockchain,* October 2016

This system ensures both the authentication and the secrecy of the interactions:

- By using a private key to encrypt a message, and publishing their public key, a user proves that they are the author of the message – which other users can use the public key to verify.
- By using the recipient's public key to encrypt a message, the recipient can use their private key to decipher it (ensuring that only the recipient is able to open the message).

In a blockchain, the private key is used to sign the transactions and the public key is used to identify the users.

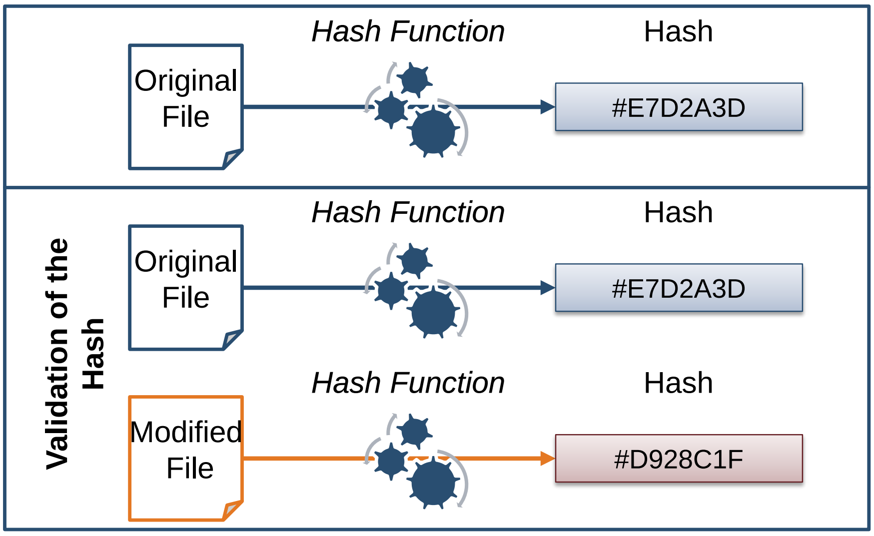
Hashing

A hash function is a mathematical function that makes it possible to detect even the most minute alteration to a file.

This mathematical function takes an input of random size or length and produces a fixed length output. This output number must be such that it is impossible to guess or reconstruct the input value.

Any alteration, regardless of how small, of the input produces a significant and unpredictable variation of the output. The function's input and output values are thus linked in a clear and unique fashion. This is the mechanism used to link a debit card with its visual cryptogram on the back.

Figure 23: Hash function



Source: IDATE DigiWorld, *blockchain,* October 2016

This principle is used in numerous blockchain related applications. For instance, in the proof of work algorithm, this function is used like a mathematical puzzle for validating a block. The network nodes create a hash using the input block (or a ledger of transactions), a link to the previous block in the chain and a random number (nonce). The result of the hash for this set must be lower than a predefined number (therein lies the difficulty of the puzzle).

It is impossible to predict which random number (nonce) must be used to obtain the right output from the hash function, so they need to be tried one by one. Once the solution is found, however, it is very easy to verify that the output is right by applying the hash function.

Examples of use of blockchains in other domains

The global value proposition of the blockchain (as presented in section 1) can be applied to numerous ecosystems and applications in various industries. The following are common examples of scenarios where the utilisation of blockchain concepts is either under development or considered.

Cryptocurrencies

Initially thought as a decentralised means for payment in day-to-day business transactions, cryptocurrencies have however turned out to be mostly instruments of speculation or suitable set-up for countries facing uncertainties around their currency. In the wake of Bitcoin several other cryptocurrencies have emerged, each building its own blockchain with slightly different positioning and technology. In the case of cryptocurrencies, blockchains are used as a ledger, securely recording every transaction thereby preventing the 'double spend problem[159]' and being used as a monetary creation tool through the process of validation of transactions (called 'mining'[160]).

Blockchain in finance

Blockchain has also been adopted by the financial sector as a back office infrastructure solution for facilitating data exchange between financial institutions and reducing the need for intermediaries and/or state supervision. The aim of the provided solutions is to serve as a backbone that can help reduce financial institutions' cost structures (international interbank payment, ledgers, and automated shareholder agreements), intermediary numbers and transaction times, especially for international fund transfers.

Blockchain in insurance

Blockchain implementation in the insurance industry is optimising business processes by sharing data in a secure, efficient and transparent way. Insurance companies are examining the possibilities offered by blockchain, especially for 'smart contracts' to automate payments (see smart-contract in section 1.1.3).

Blockchain for public services

Blockchain offers the potential for digital public services to be provided in a manner that is more secure, decentralised and open, to both citizens and corporations. Blockchain technology implementation is considered or implemented as proof of concepts in public services such as land registry, to authenticate land ownership. There is a range of possible applications from creating property registers or ownership records (such as a land registry) to replacing personal ID documents, or providing a proof of existence and ownership of a document (when trying to prove ownership or origin).

Other potential uses

Beyond the above utilisation scenarios, many other industries are considering the use of blockchain in various applications. This can range from energy trading systems; to media and entertainment micropayment and management solutions for digital rights; health information exchange; and of course numerous applications in trade and logistics as presented further in section 2.

Other blockchain implementations

In this section other noteworthy implementations that - while being less adopted than the ones presented above - bring additional capabilities to the blockchain concept are presented.

The sidechain concept: Lisk

Purpose and key features

Lisk was the first cryptocurrency to introduce sidechain capabilities. A sidechain is a blockchain that is linked with another existing blockchain that is used as a second repository to archive the state of the 'sidechain'. Several sidechains might be associated to one parent blockchain. At the same time, sidechains are independent of the main blockchain, meaning that everything happening on a sidechain will have no effect on the parent blockchain regardless of the number of transactions. Lisk offers a platform that helps organisations create white-label sidechains. Applications created on

[159] https://en.bitcoinwiki.org/wiki/Double-spending

[160] https://en.bitcoinwiki.org/wiki/Mining

separate sidechains are connected to the so-called mainchain – the main blockchain. The major use cases envisioned are gaming, supply chain, healthcare, real estate, legal and even autonomous cars.

Key advantages

Lisk offers high flexibility in a decentralised application development context due to the use of sidechains. The platform is oriented towards developers and simplifies the development process. Moreover, Lisk has chosen JavaScript as its programming language opening up to a large community of developers. Another strong point of Lisk is its delegated proof of stake (DPoS) concept instead of using common proof of work and proof of stake approaches. In this consensus mechanism (DPoS), blockchain base currency holders can vote for validators. Validators with the most votes become delegates who validate transactions. In Lisk, there should be 101 delegates at any point of time. Such a system is supposed to be more democratic and decentralised.

Main limitations

However, the DPoS consensus has also an important weakness - critics say that the protocol allows to organise an attack by a group of delegates more easily.

Internet of Things oriented blockchain: IOTA

Purpose and key features

IOTA is a distributed permissionless ledger designed for Internet of Things (IoT) to perform 'feeless microtransactions' IOTA positions itself as a solution to public blockchain inefficiencies such as 'sluggish transaction times and skyrocketing fees'.[161]

The main element in IOTA is its Tangle – a Directed Acyclic Graph (DAG). The main difference in comparison to traditional blockchains is the way transactions are stored - contrary to traditional blockchains, they are not grouped into blocks within a sequential chain but are rather presented as a 'stream of individual transactions entangled together'[162] Another difference is that there are no transaction fees in Tangle. Finally, Tangle users initiating transactions also validate them and perform a sort of proof-of-work which is not the case in legacy blockchain.

Key advantages

According to Lisk, the fact that the process of making and validating transactions is coupled makes the system fully decentralised and increases scalability of the system.

Another advantage comparing with popular blockchains like Bitcoin is the absence of transaction fees, which constitutes a key factor enabling microtransactions in a network of interconnected IoT devices. Another benefit of Tangle comparing to legacy blockchain is its 'quantum resistance', i.e. the supposed increased protection against quantum computer attacks in the future.

Main limitations

One important limitation of IOTA is the lack of smart contracts which are needed, so that developers can easily build decentralised applications (DApps) on the platform. Another aspect that needs to be verified is the supposed 'quantum resistance'.

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[161] IOTA official website; 2019. www.iota.org/get-started/what-is-iota

[162] Ibid.

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This study provides an analysis of blockchain technology in the context of international trade. It analyses the potential impacts of blockchain development and applications in eight supply chain and international trade case studies. It also provides an analysis of the current legislative framework and existing initiatives.

Based on this analysis, and following a broad consultation of relevant organisations, the study identifies several challenges in international trade documentation and processes, and presents a range of policy options for the European Parliament.

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