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The *Foresight Brief* is a publication from the European Trade Union Institute (ETUI) focused on strategic thinking about the future challenges for the world of work. It is produced by the ETUI's Foresight Unit, whose work concentrates on two priority areas: climate change adaptation and new technologies. The *Foresight Brief* is also available in French under the title *Notes de prospective*.

Foresight Brief
Special issue

Blockchain in the world of work: hype or hope?

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Among the many disruptive new technologies that have emerged recently, blockchain is the one that has the most potential to profoundly revolutionise society and the labour market. For blockchain to be socially acceptable, however, accountability and transparency in the governance of its architecture is necessary – as is giving all actors, including workers, the ability to become co-creators in its technological development and to shape its implementation. This Foresight Brief describes blockchain technology and analyses its implications for the world of work and possible uses in certain sectors, including value chains. On a more experimental basis, it discusses whether blockchain can help to manage trade union organisations, including membership aspects, without establishing a specific 'use case'. The publication finally highlights one (r)evolution for which society needs to be prepared, namely the way blockchain and artificial intelligence will increasingly be combined in the future. It outlines four important areas that need to be considered if these technologies are to be more widely adopted: data quality; privacy and data protection; environmental sustainability; and solving issues related to 'smart contracts' and 'decentralised autonomous organisations'.

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Foreword

Technological innovation is at the centre of major transformations currently taking place in the world of work. While workers and their unions are not new to negotiating on issues related to technological change through social dialogue and collective bargaining, the depth and scope of the 'fourth industrial revolution' are profound and unprecedented. Trade unions are also conscious that technology is being deployed in two different ways: changes in the actual composition of jobs on the one hand, and the use of technology to re-cast employment relationships (the 'Uber business model') on the other.

Trade unions are thus campaigning and advocating for policy and regulatory measures to shape the technological transition in a way which maximises the benefits for working people and society at large. At the same time, their organising and bargaining strategies are becoming increasingly responsive to current and future challenges.

One area which trade unions need to deepen their understanding of and incorporate into their strategies concerns the development and deployment of distributed ledger technologies, or 'blockchain'. Most people who have heard of blockchain probably associate it with cryptocurrencies, but as this report shows, the implications of blockchain go well beyond Bitcoin and its equivalents, and indeed beyond the finance sector alone.

This ETUI report is a major contribution to helping unions to appreciate the potential (or perhaps, given the level of hype around blockchain, the lack of potential) of distributed ledgers to transform how businesses and public sector bodies work, and indeed the possibility of completely new forms of enterprise. To take one striking example from the report, in Estonia the whole population lives in a blockchained environment.

As with any other innovation, it is not the technology itself that will determine outcomes. The impact that distributed ledgers will have is a matter of choice and, with appropriate regulations, policies and systems to support dialogue and negotiation, the upsides can be maximised and the downsides mitigated or avoided altogether.

There are still more questions than answers about blockchain. Are cryptocurrencies the way of the future? How can the huge energy footprint of distributed ledgers be made carbon-neutral? What are the employment and privacy implications? Can the immutable blockchain record satisfy the 'right to be forgotten' that is enshrined in the GDPR? And what happens when the integration of blockchain and artificial intelligence really takes off?

The following pages canvass these issues and more, looking at the possible changes and pathways that unions will need to understand and shape in the world of work and the wider social and economic landscape.

At the same time, this report provides a framework through which trade unions can consider the possible uses for distributed ledger applications in their own structures and activities, something which some unions are now contemplating.

One of the strongest points of this report is the way in which it provides a dispassionate analysis of crucial blockchain issues, without succumbing to either the hype of blockchain evangelists or the dystopian projections of critics. It also describes the distributed ledger concept in a way that is accessible and understandable.

The ETUI has produced a provocative and informative report which provides a basis for unions, in Europe and elsewhere, to begin or further their journey into understanding blockchain and formulating strategies.

— *Tim Noonan*
Director, Campaigns and Communications
International Trade Union Confederation
Brussels

Introduction
Blockchain: why should trade unions care?

> 'How can we accelerate the human transformation required to keep pace with accelerating technological innovation and disruption? How can we avoid massive social dislocation, or worse? Lest we be accused of being technology determinists or utopians, may we propose that it's time for a new social contract for the digital age.'
>
> **D. Tapscott and A. Tapscott, 2016, 'Blockchain Revolution'**

Today, blockchain is still primarily known as the backbone technology for cryptocurrencies (namely Bitcoin, Ether, Tether, Litecoin and the 2,857 other cryptocurrencies currently traded in the world[1]), which is why its potential to disrupt and revolutionise the way societies operate remains largely invisible. Despite this, and although it is still an immature technology which has not yet resolved certain key challenges related to scalability, security and mass adoption (International Finance Corporation 2018), its disruptive potential is undeniable. Trade unions must start looking into this technology, which has the capacity to transform the way financial transactions happen but also, more importantly, to revolutionise the way almost all human transactions (understood as any interaction between two parties which involves an exchange of goods, services or the entering into any commitment) take place, including labour and employment relations.

Blockchain technology has the potential to disrupt and revolutionise the transactional architecture of whole nations. Some have already started on this journey. Estonians, for example, are already living in a blockchained environment and have a digital identity, for which other citizens or companies of the world can apply. According to e-estonia.com, Estonia is the first country that, using blockchain technology, has set up an e-governance system able to provide almost all public services online: 90% of all state-related operations – except marriage, divorce and real estate transactions – can now be carried out digitally. Since 2012, Estonia's registries dealing with national health, judicial, legislative, security and commercial code systems are operated through blockchain.

Blockchain has principally been used to exchange cryptocurrencies but has increasingly become the backbone technology for other applications, such as financial inclusion (for example, giving access to bank accounts to people excluded from the financial system), energy exchange, transparent voting or management of healthcare data. To take one example: land ownership registration, when inadequately recorded, can cause problems for governments and individuals. Several countries, including Estonia, Georgia, Ghana, Ukraine and Sweden, are following Estonia's lead and using blockchain to carry out and record property transactions and land registration. They consider blockchain to be a good technology for securing data, ensuring transparency and making it more difficult to question the ownership of a property (Ponce del Castillo 2018).

Moving closer to the world of employment, some actors, mainly in the consultancy industry, suggest that using blockchain solutions could benefit

1. At the time of writing, in January 2020, the website https://www.investing.com/crypto/currencies lists 2,857 cryptocurrencies. This number is regularly updated.

the HR transformation of organisations, in particular the hiring process and even the way workers engage in an organisation (Wallace 2018; Wiles 2019). The idea behind this is that candidates can bundle together their degrees, work experience and certifications, effectively creating a 'block' out of their CVs that can then be attached to a blockchain and made available to recruiting agencies or directly to employers. This approach can indeed have possible benefits for applicants, whose work history would then come from one single source. However, caution is necessary in the handling of personal data (related to life outside the workplace, or to medical and performance evaluations), and specific permissions need to be in place so that workers have genuine control of their data.

This publication first describes in simple terms how blockchain technology works, including how it is used for cryptocurrency trading. It then addresses blockchain's impact on work and employment, looking in particular at supply chain traceability and how trade unions can use blockchain (both as a tool for internal organisation and as a tool for organising members). It then describes five requirements which have to be met for blockchain to be effective and beneficial, rather than detrimental, to the world of work.

To produce this study, multiple sources have been explored, using methods such as document analysis, active participation in blockchain conferences, and conversations with various trade union and non-trade union actors. The reasons for producing this work are: (1) the need to look into technologies that can radically change or disrupt employment, working conditions and labour relations; (2) there have been informal questions from trade union organisations about blockchain in general and the possibility of using it internally, in particular for membership communication, internal finances and management; (3) some trade unions in Europe are looking into the possibility of developing projects to further explore how blockchain can improve the functioning of and working conditions in various supply chains.

It is worth pointing out that this publication does not establish a case for the use of blockchain. It outlines important issues to consider before possibly choosing to implement a technology that can radically disrupt work and labour relations (again, blockchain has many uses beyond cryptocurrencies). It invites trade unions to take notice of and increase their awareness about a technology that is still flying under their radar. Indeed, trade unions would benefit from deepening their knowledge about all new technologies impacting society and enhancing their critical understanding of both the technologies themselves and the ecosystem around them. Some may also find value in reflecting about whether a blockchain framework could be a cost-effective tool to improve their internal functioning and better organise their members.

1. Understanding blockchain technology

Blockchain, or 'distributed ledger technology', first appeared several years ago and became known to the wider public when the trade in Bitcoin and other cryptocurrencies began to emerge. Despite the Bitcoin hype, blockchain is still an immature technology (De Filippi and Loveluck 2016; Fink 2019). However, it is one that is developing very rapidly and in a disruptive way, across many industrial sectors and services. Its potential nevertheless remains difficult to grasp because it is still relatively invisible and restricted to certain sectors of society, and also because it converges with other technologies through the use of big data generated by AI, the 'internet of things', machine learning or robotics.

1.1 How does blockchain work?

Blockchain technology can be defined as an 'evolution of database technology'. Firstly, it is a shared database that records and stores the history of transactions, which can be understood as any interaction between humans that needs to be recorded, such as financial transactions or service provision. The database, or ledger, however, is not stored in any single location but hosted by a peer-to-peer network of interconnected computers, or 'nodes', which each hold a copy of the ledger.

Secondly, it is a verification system in which nodes ratify the validity of every transaction, which eliminates the need to go through a trusted third party. The ledger or database of transactions is continually updated and verified; it is not just decentralised (in terms of control) but also distributed (in terms of location), immutable and secure (Corrales et al. 2019). The power, authority and control over the transactions is not entrusted to a single central entity but to many nodes, located around the world, independent from each other and not controlled by anyone, which is how safe and fast transactions can be guaranteed. This is where the true disruptive dimension of the technology lies: blockchain obviates the need for a trusted central authority, since trust and verification are established in real time by a multiplicity of actors. In addition, blockchain is an open source technology: its creators' intention was to serve the common good by giving 'the power to the people'.

> Blockchain's potential remains difficult to grasp because it is still relatively invisible and restricted to certain sectors.

To explain in very practical and simple terms how blockchain technology works, let us imagine a room with 50 people. Four of them start to play cards for money. The other 46 are watching. The result of each hand played is recorded by everyone in the room, hand after hand.

Let us assume that Hand 1 is won by Player A and that he wins three euros. This 'transaction' is written down by everyone in the room:

	Player A	Player B	Player C	Player D
Hand 1	+3	− 1	− 1	− 1

The game continues and more transactions or results are added to the scoresheet. At the end of the night, 600 hands have been played. The scoresheet looks like this:

	Player A	Player B	Player C	Player D
Hand 1	+3	− 1	− 1	− 1
Hand 2	− 2	− 2	+6	− 2
Hand 3	+3	− 1	− 1	− 1
Hand 4	− 3	− 3	− 3	+9
Hand 36	− 1	+3	− 1	− 1
Hand 120	− 2	− 2	+6	− 2
Hand 455	+3	− 1	− 1	− 1
Hand 566	+9	− 3	− 3	− 3
Hand 600	− 2	− 2	+6	− 2

The scoresheet is a blockchain, made up of blocks of data (the score of each hand), linked to each other to create a chain (the scoresheet). This particular blockchain is a decentralised database. Nobody in the room owns it alone and no central authority (a referee or game master) has control over it. All card players and spectators have access to the data and all have an identical copy of the chain of transactions and the blocks. In such a system (or 'distributed database'), no one can override the consensus of the network, and trust is thus intrinsically built into the architecture of the system.

Anyone can become a node involved in a blockchain. Practically speaking, the requisites are to have a computer with enough power and space to host a copy of the blockchain, to have an internet connection, and to keep the computer running for long periods of time. The nodes are located throughout the world and each one of them has a copy of the particular blockchain it is a part of, making it decentralised. The more nodes there are, the more decentralised the network is. There is no intermediary holding any power, no central 'referee' (i.e. there are fifty scoresheets, not one), no hierarchy and no fee is paid for the recording of the transactions. The network is distributed (peer-to-peer), with all nodes equal in importance. The tasks of nodes are: (1) when a 'miner' (see below) wants to add a block to the blockchain, to verify whether it is valid or not; (2) to store blocks of transactions added to the blockchain; and (3) to disseminate the history of transactions to other nodes.

Section 2, below, describes one use of blockchain technology that is very visible but sometimes misunderstood: cryptocurrency trading.

1.2 Blockchain and cryptocurrency trading

In the specific case of blockchain technology applied to cryptocurrency trading, like Bitcoin or Ethereum, transactions are inputted into the network by generating a unique encrypted code called a 'hash' (or hash value). This is done by an algorithm, which converts any content (for example, a series of transactions stored in a block, or a series of letters or numbers) into a hash value. For example, when the SHA-256 algorithm is applied to any content, it will encrypt it into a unique string of 64 digits, which will look something like this '*f5038662e2a6e20e94a397d5a113d28e7288c165489ccc8ef557d912 49282ed1*'[2].

Such a hash is unique; no two strings are ever equal and any slight change in the content will produce a different hash. Any content, of any length, can be hashed: Baudelaire's poem 'L'Albatros', after hash encryption (using SHA-256), becomes: '*a8f883ab0cfafcd3de73dc38e453294020718e770fbcaf 3b0d67e3a7caf297c3*'.

Adding blocks to the blockchain is done by individuals called 'miners'. They compete with each other, the winner being the first one who generates a hash output that is considered as valid, meaning that it meets the target established by the Bitcoin network. In the case of Bitcoin, the target hash will be one that starts with a certain number of consecutive zeroes.

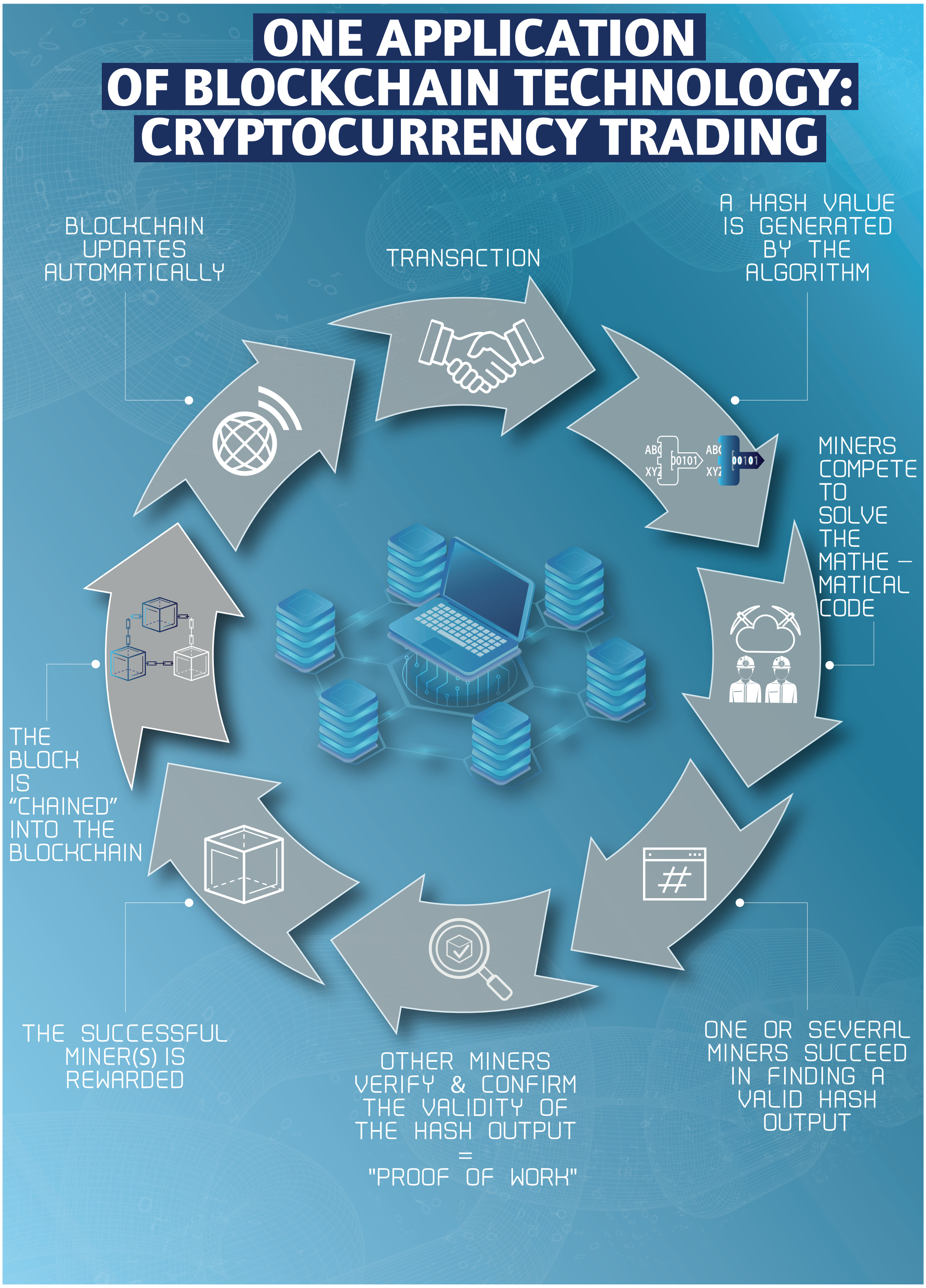
The block the miners want to add to the blockchain contains several types of content: sender address, receiver address, amount, block number, content of the block (transactions), hash value of the previous block in the chain, and an arbitrary number called 'nonce' (an abbreviation of 'number only used once'), which can be freely chosen by the miners. What takes place is essentially a process of trial and error: the miners generate hash outputs one after the other, keeping all the content identical except for the nonce, which they will change at every attempt, in order to produce a different hash value at every single try.

Eventually, a particular nonce will produce a hash output string that meets the set target, meaning it starts with the correct number of zeros. Based on the current target of January 2020, the probability that a random hash will be valid is 0.00000000000000000003%. This means that the probability of coming up with a nonce that generates a valid hash for the block is 0.00000000000000000003%. This explains why so much computational power (and therefore electricity) is involved in Bitcoin mining. Miners are using extremely high-powered computers and one of them will always, eventually, succeed in finding a nonce that meets the target.

When that happens, the successful miner will announce to all other miners that he has successfully generated a valid hash. Other miners will verify the hash and, when they agree, will confirm its validity. This process is called 'proof of work' (or 'proof of stake' in some blockchains). Once all miners agree, they decide that a block can be added to the blockchain, which ensures consensus and thus prevents manipulation of the system. The successful miner receives a financial reward for generating a valid hash output. The blockchain now contains a new block and will update itself automatically every ten minutes on all the nodes.

2. To decode this hash value, the reader can use the encryption machine available here: https://md5hashing.net/hash.

Figure 1 **One application of blockchain technology: cryptocurrency trading**



1.3 Key characteristics of blockchain

Blockchain is immutable and irrevocable as it cannot be changed, reversed or deleted once validated. If a mistake is made or incorrect information enters the blockchain, it will remain there practically forever. It is cryptographically sealed and permanently recorded – every transaction is chained to another. Experts sometimes say that absolute immutability does not exist and that a change in a transaction means the creation of a completely new hash. Yet while transactions can indeed be reversed, it is only in very specific circumstances, when the nodes agree to do so and if this is backed by a contract.

> Data accuracy is key, particularly if the blockchain is to be used for socially related data or transactions.

For that reason, the 'garbage in, garbage out' challenge is a very real issue in blockchain. If incorrect data is entered in a block, the wrong output will be produced, as the system is not made to assess whether the data entered is accurate, valid, correct or true. For that reason, data accuracy is key, particularly if the blockchain is to be used for socially related data or transactions.

Blockchain is also global, available to everyone, and transparent, since transactions can be seen by everyone.

Security is ensured through cryptography and by updating (every 10 minutes) all the data on all the computers of the chain participants (just like in the earlier card game example, where scores were updated by all 50 participants after every hand). This, together with the use of mathematics, makes the whole system almost impossible to hack, as a hacker would have to hack all the computers almost simultaneously.

1.4 Private versus public blockchains

One key feature of a blockchain is its private or public nature. Both types are decentralised networks but private blockchains are established and maintained by a private actor who has the sole authority to decide who is allowed access to the chain. A public network can be joined by anyone and usually encourages participation by awarding some type of reward to peers, as is the case in cryptocurrency trading. It is open to read and write, with a ledger that is distributed, immutable and secure due to the mining (Ellervee et al. 2017; Massessi 2018), but the huge computational power needed to maintain a public network and the openness itself of the chain are two of the drawbacks which have prompted some actors, particularly private corporations, to establish their own private blockchains.

Whether they are private or permissioned, though, these blockchains are still decentralised, peer-to-peer systems, which guarantee the immutability of the data. Participants are allowed to read data, create transactions, validate blocks or create new ones. The benefits are a central or permissioned control, faster transactions as there are fewer nodes, better scalability and less use of energy.

The future of blockchain may be found in 'hybrid blockchains', which are made up of a public blockchain and a private network, accessible only upon invitation by a centralised body. Large enterprises, regulated companies and governments are particularly interested in hybrid solutions, which suit the highly regulated environment they operate in and also allow them to differentiate more easily between the data they need to keep private and the data they share publicly (Freuden 2018).

2. Blockchain in society and the world of work

This publication takes as a starting point Winner's (1980) work on the politics of technologies, the way they can be used to enhance the political power of some actors in society over others, and their influence on how workers will work and perform their tasks. Technology is not neutral, and this publication considers that these questions are particularly relevant in the case of blockchain, which is likely to disrupt society and, more specifically, the world of work and employment in which, by definition, the distribution of power is unequal and where 'technological ownership' is in the hands of only a few actors.

According to Winner (and other authors), science and technology, when they impact society, should not be in the hands of a limited number of experts. Instead, the majority should have the ability to shape them, precisely *because* of their impact on society (Kline and Pinch 2010, Nowotny et al. 2001, Winner 1980). This is true for end users but even more so for workers, who are active users of technology, work with it on a daily basis and develop a specific but quite real expertise in it. If this is not the case, there is a real risk of social inequalities, precariousness and undesirable political consequences. Other actors, including trade unions, labour inspectors and public authorities, should also be involved. They should be co-creators in the development of technology and have a say in assessing the possible inequalities related to its development, design and deployment, and access to it.

Again, this publication suggests looking beyond the technocratic narrative: when any new and disruptive technology is implemented, it should be assessed not only in terms of its business value but also its long-term social, ethical and legal impact. In other words, the question is whether blockchain can have a social function and possibly benefit society by bringing about stronger democracies, better working conditions and a more sustainable environment.

Based on the work done by the author for a public hearing organised by the European Economic and Social Committee on 'Blockchain for the social economy 4.0' (2019), this paper argues that blockchain can be most effective and beneficial for society when it is made widely available, including to those with limited means. Some concrete initiatives prove it can contribute to the social economy: for example, blockchain solutions have already been successfully adopted by cooperatives in the field of sustainable mobility. Scity.coop, in France, has developed dematerialised carpooling vouchers that companies can use to encourage their employees to commute differently. Thanks to blockchain technology, the vouchers can be used with different operators and the scheme offers cooperative governance involving all project stakeholders (transport operators, institutions, local authorities, etc).

Blockchain can also benefit civil society actors, including trade unions. As a transactional technology, blockchain has a natural appeal in the world of work, where transactions of all types take place: beyond purely commercial transactions, blockchain may be used to facilitate fairer interactions between economic actors, to improve product traceability in the supply chain, to improve auditing, and to establish employment relationships. In doing so, it can revolutionise the way society exchanges goods and services and organises work, and disrupt the collective dimension of work. This is why it needs to be on the radar of trade unions, both as potential users and actors of blockchain applications (Ponce del Castillo 2018).

The following section presents two possible uses of blockchain in the world of work.

2.1 Verification and traceability of the supply chain

Supply chains are often urged to increase their transparency and become less opaque (Badzar 2016, Egels-Zandén et al., 2014, New 2010). The main issues include inconsistent, missing or fraudulent data; the lack of interoperability of data systems; limited information on product traceability; a lack of transparency regarding the actors involved; a lack of financing for due diligence activities; abusive or unsafe working conditions; and environmental damage (Boucher 2017; OECD 2019b). Fung (2013) suggests that increased transparency should be assessed according to the availability of information, its accessibility, and also the ability of individuals and organisations to act on that information to protect themselves from, as well as influence, powerful organisations. This is particularly important when child labour, migrant labour, poor working conditions, long working hours and low wages are all issues in play, and sometimes omitted in factory audits. Supply chains should be transformed in order to better incorporate workers' participation and that of other actors in their design, implementation and monitoring (Egels-Zandén et al., 2014; Lund-Thomsen 2008), which could help in building an architecture of accountability.

What are the opportunities for the world of work?

There are hopes that blockchain could contribute to this by allowing a product to be followed or tracked in real time, from its origin to its final destination (Boucher 2017, Su 2018). This would allow actors in the supply chain, including suppliers, vendors, transporters or buyers, to have access to the terms of the recorded transactions, which would thus be open to inspection, by everyone or by authorised auditors (Boucher 2017).

Some initiatives along these lines are already in preparation. According to a December 2019 press release, ALROSA, the world's largest diamond producer, and tech company Everledger will launch a pilot program which will use blockchain to allow consumers to purchase diamonds with full transparency about their origin, characteristics and ownership history, ensuring full traceability from mine to consumer (www.everledger.io).

Similarly, some industrial players have set up a pilot project to explore the responsible sourcing of industrially mined cobalt using blockchain (IBM

News Room 2019). As Kohler and Mpufane (2018) report in their study about the case of cobalt and blockchain, setting up a traceable and verifiable digital record of cobalt from its origin in the mines of the Democratic Republic of Congo through to its installation in the battery of a car would enable anyone to know and monitor exactly when and in which mine – and potentially even by which miners – the cobalt in a particular battery was produced and ensure that it has not been produced by child labour.

Similar approaches could be applied to other sectors. An interesting idea is for labour inspectors, who are in charge of ensuring the application of labour legislation in the workplace, to have access to information related to the supply chain and registered in the blockchain to help them carry out their inspection missions and better supervise working conditions.

Another avenue worth exploring is using blockchain systems to record the presence of ingredients that leave no physical, chemical or 'nano' trace in a finished industrial item, or when a trace is left but is too costly to detect, as is the case with nanomaterials. This would fill a gap, as nanomaterials[3] do not have to be mentioned in the list of ingredients of a particular manufactured product (except in cosmetics and biocides) nor appear on safety data sheets, which means that their presence may go totally unnoticed.

Blockchain could also be used as a tool to prevent fraud in the garment industry supply chain, particularly to prevent the duplication of certificates (Zibell 2019). An interesting project will be launched in 2020 by the United Nations Economic Commission for Europe (UNECE). Entitled 'Enhancing Transparency and Traceability of Sustainable Value Chains in the Garment and Footwear Sector', it will aim at developing a technical standard for full traceability of the value chain in the industry and include a blockchain pilot for the cotton industry.

In addition to the transparency and traceability of supply chains, blockchain systems could be used to further develop the circular economy. For the European trade union IndustriAll (2016), keeping track (and trace) of information related to the life cycle of a product is crucial, and particularly 'recovering it in machine-readable format, (which) is immensely more efficient than attempting to re-construct it post hoc'. Such information could be a product's material composition, its diagnostics, or the instructions for testing and disassembling it, in order to facilitate automated maintenance and repair operations; the history of all operations performed on the item (in manufacturing, but also at a later stage in maintenance, repair, upgrade and recycling), in order to support sustainability claims regarding re-used or recycled items; or even liability for repair, maintenance, or upgrade operations (Zibell 2019). Here, blockchain can provide a concrete, innovative and practical way to make information transparent and able to be pulled out, validated or scrutinised when necessary.

However, despite the real opportunities offered by blockchain, particularly in improving the transparency of the supply chain, major feasibility issues still have to be resolved. In the case of cobalt mining, Kohler and Mpufane (2018) mention issues such as geopolitical boundaries and the real participatory capacity of artisanal miners as nodes in the blockchain. One of the core characteristics of the system, namely its immutability, can also be a problem: if data is improperly inputted at the very beginning of the chain,

3. Nanomaterials are made of extremely small particles and manufactured at a very small scale, usually between 1 to 100 nanometers.

it will remain wrong or invalid in the rest of the process, which could be an cause for concern in social audits. Privacy is another issue, particularly when the right to be forgotten or the right to object are invoked. As Kohler and Mpufane (2018) report, ensuring genuine traceability of the value chain in the cobalt industry involves dealing with social, cultural, environmental, political and economic concerns that cannot be fixed by technology alone.

2.2 Assessment framework for developing a trade union blockchain protocol

Across the world, trade unions are organised in many different ways. At national level, a trade union is usually structured around one or several confederation(s), the peak of the structure. In the EU, some Member States have a single union confederation, while in others multiple confederations exist, organised primarily along occupational or educational lines (Fulton 2015). A number of departments or offices then make it possible to cover the national territory and the different economic sectors; these provide services to their members, who are workers in different workplaces.

This setup means that members are organised in a variety of conventional database structures which are difficult to standardise. Blockchain could help to bring together this diverse galaxy of structures, should this be considered useful. According to the International Transport Workers' Federation (2018), blockchain could also be used to collect membership fees (using cryptocurrencies), to transfer funds to organisers in countries that suffer from union hostility, or in union elections.

Some believe blockchain could even lead to new forms of collective representation of workers (Bridgers 2017; Mannan 2018). However, these commentators overlook the fact that trade unions are not just organisations that bring together members for collective representation, but are also heavily involved in training, research, lobbying, collective bargaining, etc. Blockchain could possibly facilitate the work of trade unions and help them to be more effective by increasing their coverage, but this needs to be founded on a strong use case (a methodology used in system analysis to identify how a system is used) and methodical testing before any financial or non-financial investments are made.

In order to assess whether trade unions can use blockchain to improve the way they work, conversations were held with several trade unions and related think tanks that are currently exploring technological solutions: Unions 21 (United Kingdom), HK Lab (Denmark), Futurion (Sweden), IndustriAll Europe and the International Trade Union Confederation. The conversations explored the possible uses of blockchain technology in trade unions. Using these conversations and further research as a base, below is a first attempt to establish an assessment framework for the development of a trade union blockchain protocol.

Clarifying the purpose behind the use of the technology is the first step, as blockchain may not be useful for everyone. Trade unions need to look at the specific use case, the actors involved and their interests, and the technology and the rules behind it, including data quality, rules for data sharing, the maintenance of those rules and the way they can be managed. Blockchain can disrupt social relations in ways that we do not yet know, so caution is required.

The use case should identify, clarify and define the specific use of the blockchain system, the goal(s) to be achieved, the requirements that the technology needs to fulfil, and the way users and members will interact with it. This overview should be done in a way that highlights the added value of blockchain compared to other technologies.

This publication considers that trade unions interested in exploring the possible uses of blockchain should focus their efforts on the following specific purposes: data management, data sharing, verifiable voting, and financial management. The table below lists these possible uses and outlines the potential opportunities and challenges to overcome.

To ascertain whether a blockchain protocol can be developed, four other aspects need to be taken into account:

Agents: In a trade union blockchain platform, involved actors (users, administrators, developers, trade union representatives, employees, employers, etc) would have different interests, roles and responsibilities. These need to be clarified for liability and jurisdictional purposes. Questions such as who writes the code and who can make changes to it also need to be answered.

Equally important is to avoid what could be called a 'vacuum scenario', in which the blockchain is supposed to operate through scientifically or technically self-executing codes.

Data: Trade unions process huge amounts of personal and sensitive data about their members, including pay rights, qualifications, gender, family status, health information, etc. Here, the General Data Protection Regulation (GDPR) applies to enforce the rights of data subjects.

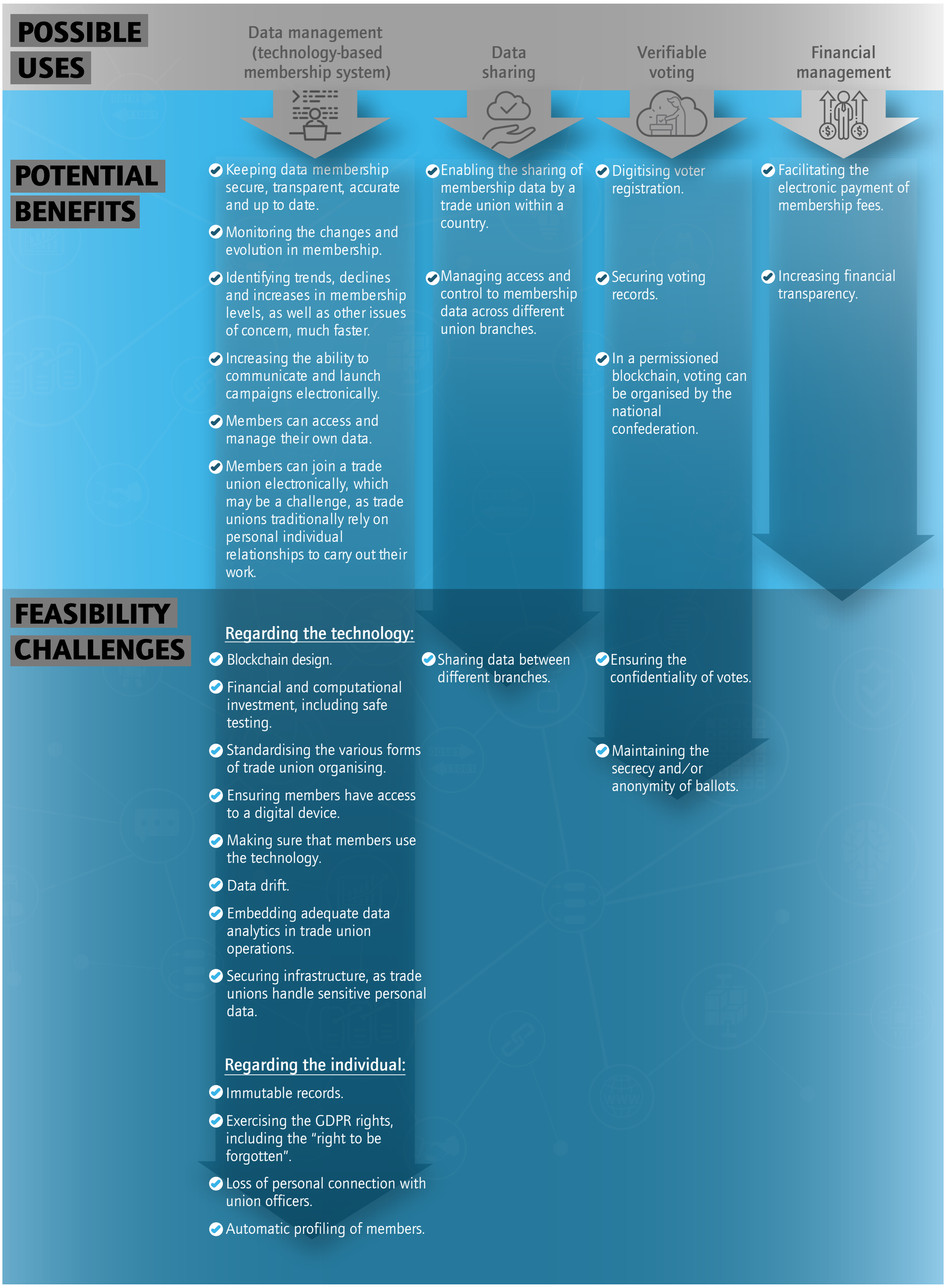
The data in question is highly valuable, particularly because it enables trade unions to provide their members with assistance and representation in individual and collective cases. There is an open question on how to address this in a blockchain system where data might not be easy to modify nor to anonymise. It is also important to protect the identity and the rights of individuals, such as the right to data portability, to rectification, to object or to be forgotten.

Technology: the technological backbone of a blockchain platform, together with its internal architecture, need to be well defined and developed. Numerous blockchain protocols exist that can be adapted for use by trade unions, without having to develop a brand new one from scratch.

A technical assessment needs to be carried out before implementation. This entails describing the risks in adopting blockchain (technical, operational, data confidentiality, regulatory, information security, interoperability, etc), their possible consequences and how they can be managed. This would concern in particular individuals whose privacy may be at risk.

Security: As trade unions manage highly sensitive data related to their members (such as membership, employment conditions and health) and potentially to companies, any blockchain they establish needs to be secure. This means measures must be in place to prevent anyone from accessing sensitive information, to prevent illicit attempts to change data and to carefully guard encryption keys. This may involve developing unique digital identity certificates that determine people's access to the information and the exact permission for each participant.

Figure 2 **Potential uses of blockchain by trade unions: an assessment framework**



3. Making blockchain work for the world of work: four key requirements and one (r)evolution we need to be prepared for

A central question is how blockchain systems can be developed in full respect of individuals' human, labour and privacy rights, as well as the environment, which are all prominent concerns for trade unions. This publication identifies four requirements to make blockchain-based systems beneficial for society and the world of work, and one (r)evolution that we need to be prepared to face.

3.1 Ensuring the quality, veracity and integrity of data

In essence, blockchain technology has been designed to record data in a trustworthy manner and to ensure its integrity – not to verify it or ensure its accuracy. For blockchain solutions to be beneficial to society, data must therefore be correct and valid from the start of the process. Incorrect, false or poor-quality input will produce an invalid or faulty output. This is particularly important as data, once on the blockchain, becomes indelible and mistakes cannot easily be corrected. In this sort of situation, the 'garbage in, garbage out' principle becomes a real issue.

When applying blockchain to the supply chain, establishing a certification scheme that proves that all the information in the blockchain is 100% valid and true all along the supply chain would be a valuable approach, and trade unions should be involved and invited to play a role in this regard (Zibell, 2019). This blockchain-based scheme would mimic initiatives such as the Clean Clothes Campaign (https://cleanclothes.org/), in which companies must use blockchain to guarantee that their clothes are 'clean'. Such a mechanism could help to improve working conditions for workers along the supply chain.

Blockchain needs to be developed in full respect of individuals' human, labour and privacy rights.

Such a certification scheme could also be used to fight slavery and clandestine subcontracting. Moreover, it could help in implementing global framework agreements such as the 'Bangladesh Accord', a legally binding agreement between brands and trade unions that aims at working towards a safe and healthy garment and textile industry in Bangladesh, with a focus on better working conditions and collective bargaining.

3.2 Complying with data protection laws

In a world that is increasingly interconnected, privacy matters – and this is relevant to blockchain. Recent laws, such as GDPR, have enhanced privacy and data protection for individuals and businesses in the EU and EEA and this has direct implications when blockchain is used.

Europe has adopted a strong position on data privacy and wants to export its regulatory approach to the international community. Right after GDPR came into force, other jurisdictions started adopting similar regulatory approaches and implementing similar provisions, such as Brazil, Japan, South Korea, Thailand and the State of California in the United States.

Despite this regulatory achievement, legal scholars are of the opinion that some fundamental issues remain to be solved in order for blockchain to comply with GDPR:

1. **Protection of digital identity, including the de-identification of the data subject.** This paper understands digital identity as an intrinsic component of an individual's identity. As data on the blockchain is immutable, one possibility is to explore the use of pseudo-identifiers to prevent direct 'linkability' between data subjects and their original identity (Niessi et al. 2017). According to guidance provided by the 'Article 29 Working Party' (2014), de-identification should ensure that: (a) it is not possible to single out an individual; (b) it is not possible to link records relating to an individual; and (c) no information concerning an individual can be inferred. This is particularly relevant for workers who are sharing their data and accessing other data sources in interconnected workplaces and environments.

> Fundamental issues remain to be solved in order for blockchain to comply with GDPR.

2. **Definition of roles and responsibilities.** In the case of blockchain, it is sometimes difficult to determine who is the controller of the data, who is the processor, and whether there might be cases of joint controllership. Here, experts disagree: some classify all the nodes as controllers; others consider that data subjects are controllers; others consider that the distinction between controllers and processors depends on the use of the blockchain. Here, useful guidelines have been produced by the French Commission Nationale Informatique et Libertés (2018), which considers that where a group collectively decides to use blockchain, the data controller should be defined from the inception. The advantage of this approach is that it allows data subjects to identify the entity they need to contact to enforce their rights and provides a single point of contact for data protection authorities.
3. **Application of the core principles of data protection laws in a system that can register personal data forever.** This refers to the ability of blockchain systems to respect the seven GDPR principles: lawfulness, fairness and transparency; purpose limitation; data minimisation, accuracy; storage limitation; integrity and confidentiality; and accountability.
4. **Respecting the right to rectification and erasure.** Article 17 of GDPR provides the data subject with the right to obtain the erasure of personal data under certain circumstances.
   By definition, this contradicts one of blockchain's key features, namely its immutability. Experts looking into this issue are currently exploring a possible solution: given the impossibility of deleting personal data

once it is in the blockchain, data would first be encrypted, and only then stored in the blockchain. It is the encryption key that would be destroyed whenever a data erasure request is received.
Article 16 of GDPR provides the data subject with the right to obtain from the datacontroller the rectification of inaccurate personal data. Here, a possible solution would be to first erase the inaccurate data (by deleting the encryption key) and then to input the accurate data into the blockchain.

5. **Data drift and security.** This is very important for companies and for workers, particularly when data is shared or transferred to environments that are located outside of the EU and the EEA and offer lower or no labour protection, or to fiscal paradises which might not provide sufficient protection.

Finding ways to ensure that blockchain fully complies with GDPR is far from obvious. Guidance from the European Data Protection Supervisor and national data protection authorities is urgently needed.

3.3 Reducing energy and environmental costs

Today, the energy footprint of running some public blockchains is very high. This is particularly true for cryptocurrency trading because of the proof-of-work process used to reach a consensus. As the mathematical puzzles miners try to solve become gradually more complex, more processing power is needed. Findings from the International Energy Agency (IEA, 2019) show that running Bitcoin's proof-of-work algorithm consumes huge amounts of energy: it is estimated that the electricity use of Bitcoin miners is around 0.1 to 0.3% of global electricity use. According to the Bitcoin Energy Consumption Index of *Digiconomist*, the annualised carbon footprint of Bitcoin is 34.75 metric tons of carbon dioxide (Mt CO_2) (comparable to the carbon footprint of Denmark) and the electrical energy consumed is 73.17 terawatt hours (TWh) (comparable to the consumption of Austria). A single transaction has a carbon footprint equivalent to that of 758,908 VISA transactions or 50,594 hours of watching YouTube. In 2018, *The Guardian* reported that in Iceland, where intense cryptocurrency mining takes place, server farms burn more electricity than the whole population (2018).

Proof-of-work is costly but useful when participants are anonymous and involved in a public blockchain. It is less necessary in private or permissioned blockchains, where all participants are known. These have lower maintenance requirements and consume less energy. Furthermore, other consensus algorithms, such as proof of stake, are much more energy-efficient than proof of work: instead of consuming electricity to produce countless hashes until stumbling on a valid one, which is the basis of proof-of-work, validators are selected on the basis of their stake in the network.

The problem can be addressed from three different perspectives: the energy source (switching to renewables), the energy requirements (changing the equipment, namely the hardware) and the mining techniques (replacing proof-of-work by another type of consensus algorithm) (Jackson 2018).

Some companies are also investigating the possibility of using unused storage space on computers, so as to reduce the necessary processing power. Others are developing 'green' cryptocurrencies, understood as currencies mined with renewable energy only.

3.4 Clarifying the impact of smart contracts and decentralised autonomous organisations (DAOs)

Another important piece in the blockchain ecosystem is the 'smart contract'. These are self-executing agreements written in programming code that define how certain tasks should be carried out and the consequences of doing or not doing certain things (using 'if-then' instructions), just like a legal contract defines the relationship between contracting parties. Some forms of smart contracts are already used in the field of financial services (such as the transfer of money and securities, insurance claims and micro-insurance), healthcare or the media. As an example, the music industry is increasingly turning to smart contracts to streamline royalty payments, create a centralised information system about and for musicians, and trace music streaming.

In the blockchain community, it is often said that smart contracts are neither smart nor contracts. Legal scholars define them as agreements whose facilitation and execution is both automatable (being executed by one or more computers in a blockchain) and enforceable without human control: once a smart contract has been initiated, it must be executed (Raskin 2017; Clack et al. 2016).

The crucial problem with smart contracts is that no one has control over their execution. The execution is recorded by the nodes in the network and later monitored for compliance (De Filippi and Hassan 2016). An example of a smart contract that is relevant to the world of work would be a call centre where the smart contract executes rules and allocates working-time slots and schedules to workers. In such a situation, workers risk losing the ability to interact with a line manager to request and confirm their work schedule, since everything is done automatically, following pre-defined rules.

In addition, De Filippi and Hassan (2016) explain that sets of smart contracts can be set up so that multiple parties – smart contracts or human beings – interact with each other. This completely new business model is called a decentralised autonomous organisation (DAO). In simple terms, DAOs are companies which are solely ruled, organised and governed by smart contracts.

A study by the Scientific Foresight Service (STOA) of the European Parliament defines DAOs as 'bundles of smart contracts, culminating in a set of governance rules that are automatically enforced and executed through blockchains' (Boucher 2017). In the physical world, it is a company with no leader, CEO or human employer, governed by shareholders who vote (with identity verification) directly on the key issues of the company. The best-known example of such a company was 'The DAO'. Established in 2016, it operated as an investment fund and raised around 150 million USD through crowdfunding but crashed after a few months of existence, the victim of a cyber-attack that found a security loophole in the code and drained a sizeable part of the funds.

DAOs are ground-breaking innovations but can have harmful consequences for workers: they can lead to dematerialised factories, where machines and workers in fixed pools are rented on demand for very short periods of time, by virtual, ad-hoc companies set up to produce one single batch of industrial items and which dissolve thereafter, with no employee nor any legal existence (Zibell, 2019).

Building on Zibell's observations (2019), the use of smart contracts raises the following questions for work and employment:

1. **Turning code into law**: computer programming code is used to either support or replace legal contracts, which challenges the legal system and the effectiveness of regulation. As De Filippi and Hassan (2016) stress, smart contracts can be used to emulate the function of legal contracts through technology, hence effectively turning code into law. Transposing legal rules into technical rules is a delicate process that can have a significant impact on the legal system. An illegal clause in a contract can be reverted via a legal process, whereas in a blockchain the registration of a transaction is irreversible, thus contradicting the principle of the primacy of law.
2. **Dissolution of employment relations or labour law**: If there is no company as we know it, then there is no employer, no employment contract nor any employee, just people 'freely' associating to perform tasks in common. In such a context, labour law becomes irrelevant. This is compounded by the fact that participants in a DAO can reside in completely different jurisdictions, making the determination of the applicable law, and the relevant court, almost impossible.
3. **Future possibilities**: If the concept is pushed to the next level, self-owning and autonomous economic entities could come into existence, for instance a self-owned autonomous car serving as a taxi: it works 24 hours a day, collects fees from customers, pays for its energy, maintenance and liability insurance – and all this without any human intervention. This is still impossible today as autonomous cars are not a reality yet, but automotive manufacturers and telecommunications operators are doing considerable research and investing in this field, and they anticipate that autonomous cars could become a reality in the first half of the 2020s. Even more realistically, self-owned automated factories or 3D-printing workshops could soon be a reality. Potentially, such a self-owned economic entity could even ultimately employ people, thereby inverting the hierarchy between humans and machines.

However, if DAOs become a reality, they might present some interesting opportunities to trade unions, which deserve further consideration and research:

1. **Full transparency**: in a DAO environment, every single shareholder and stakeholder can participate in the decision-making and voting process. This would ensure the transparency of operations, as all 'secrets' would be open to everyone, including trade unions, thus marking the end of confidential business information.

2. **Fairer rules for all actors**: the rules implemented in the code of smart contracts can be made truly democratic, although the opposite (centralised, authoritarian and unequal rules) is also possible. In such a landscape, trade unions would have the same power as other actors and the ability to shape the features of smart contracts in a direction that they consider desirable.
3. **Fairer collective agreements**: some of the rules that workers are subject to in their working life, including those laid out in collective agreements, could be negotiated and implemented through smart contracts. In this case, workers would be better protected and submitted to the same standards everywhere. This would have the advantage of eliminating the risk of arbitrary decisions taken by managers in a specific location and of contributing to more equal working conditions, and possibly better wages.

3.5 The next (r)evolution: combining blockchain and artificial intelligence

Blockchain is still perceived by many as a very new technology, but the next stage in its development is already looming and will come from combining blockchain and artificial intelligence (AI). According to recent market research by Tractica, the global AI industry is due to grow from just under 10 billion USD in 2019 to almost 120 billion USD by 2025. PwC goes further, predicting that by 2030 AI will add close to 16 trillion USD to the global economy. At the same time, Deloitte's Global Blockchain Survey revealed that 53% of all professionals considered blockchain as their organisations' primary focus in 2019 (Leewayhertz 2019).

The rationale behind combining both technologies is that they can complement each other and eliminate their respective limitations. Blockchain enables the secure storage and sharing of data, but is still very resource-intensive, particularly because of its reliance on consensus mechanisms such as proof-of-work. Other consensus mechanisms such as proof-of-stake require less energy and could be run more effectively using artificial intelligence.

Artificial intelligence applications, in turn, require seamless access to large quantities of data, usually stored in a single location, with all the security risks this entails. Decentralising the data through blockchain would reduce this risk to almost zero.

Several companies are already combining AI and blockchain, in sectors such as coffee production (crop analysis, supply chain management and payment) and health (records-based medical diagnosis and sharing of data for scientific studies) (Daley, 2019).

This evolution is presented by industrial actors as the ideal approach, one which makes the most out of both worlds. However, bringing together two powerful technologies that still present numerous uncertainties also raises concerns, in particular related to data privacy, algorithmic accountability and transparency. The power that will result from combining AI and blockchain will be of such magnitude that adequate safeguarding mechanisms, namely well-targeted regulation and sectoral legislation, will be urgently needed.

4. Conclusion

For trade unions and the general public, blockchain is still an immature technology that has a limited presence outside of the world of cryptocurrencies. However, while it still faces big issues related to scalability, security and mass adoption, its disruptive capability is very real. Because of this, society, including trade unions, would benefit from a better understanding of its workings and stand to gain by anticipating the possible impact it can have on the world.

When blockchain impacts human transactions, including labour and employment relations (as in the case of smart contracts), it is essential to ensure that individuals' rights are protected and that real accountability and liability mechanisms are in place.

If trade unions ever consider using blockchain for their internal management, it will be important for them to build on uses already tested in similar value-driven organisations, to assess how the potential benefits and feasibility challenges described here can impact them, and to then decide whether blockchain is desirable, feasible and cost-effective.

Finally, it would be a mistake to treat blockchain as an isolated new technology. Its development coincides with the emergence of several other technologies, in particular artificial intelligence. In a not so distant future, these two powerful technologies will combine, with AI systems able to use blockchain and operate with little or no human intervention. When that happens, key questions will have to be answered: who is the decision-maker regarding the machine's operations, who is responsible for the technology, and how and to whom are the benefits distributed? It is not just the developers or owners of the technology but the whole of society, including workers and trade unions, who will have to answer these essential questions. Only then will it be possible to build a governance framework that can fairly and transparently regulate these powerful technologies, and in doing so shape a common future in which they will thrive: not at the expense of human beings, but as tools in their service.

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References

Arnorld M. (2017) Five ways banks are using blockchain, Financial Times, 16 October 2017. https://www.ft.com/content/615b3bd8-97a9-11e7-a652-cde3f882dd7b

Article 29 Data Protection Working Party (2014) Opinion 05/2014 on Anonymisation Techniques. https://ec.europa.eu/newsroom/article29/news-overview.cfm

Badzar A. (2016) Blockchain for securing sustainable transport contracts and supply chain transparency: an explorative study of blockchain technology in logistics, Master's thesis, Lund University. http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=8880383&fileOId=8880390

Banafa A. (2019) Blockchain and AI: a perfect match? https://www.bbvaopenmind.com/en/technology/artificial-intelligence/blockchain-and-ai-a-perfect-match/

Boucher P. (2017) How blockchain technology could change our lives: in-depth analysis, Brussels, European Parliament Research Service (STOA). https://www.europarl.europa.eu/RegData/etudes/IDAN/2017/581948/EPRS_IDA(2017)581948_EN.pdf

Bridgers A. (2017) Will workplaces be going off the rails on the blockchain?, Journal of Internet Law, 20 (11), 3-6.

Commission Nationale Informatique et Libertés (2018) Premiers éléments d'analyse de la CNIL: blockchain. https://www.cnil.fr/sites/default/files/atoms/files/la_blockchain.pdf

Corrales M., Fenwick M. and Haapio H. (2019) Digital technologies, legal design and the future of the legal profession, in Corrales M., Fenwick M. and Haapio H. (eds.) Legal Tech, Smart Contracts and Blockchain, Singapore, Springer, 1-15.

Daley S. (2019) Tastier coffee, hurricane prediction and fighting the opioid crisis: 31 ways blockchain & AI make a powerful pair. https://builtin.com/artificial-intelligence/blockchain-ai-examples

De Filippi P. (2014) Bitcoin: a regulatory nightmare to a libertarian dream, Internet Policy Review, 3 (2). DOI: 10.14763/2014.2.286

De Filippi P. and Hassan S. (2016) Blockchain technology as a regulatory technology: from code is law to law is code, First Monday, 21 (12). DOI: 10.5210/fm.v21i12.7113

De Filippi P. and Loveluck B. (2016) The invisible politics of bitcoin: governance crisis of a decentralized infrastructure, Internet Policy Review, 5 (4). DOI: 10.14763/2016.3.427

De Filippi P. and Wright A. (2018) Blockchain and the law: the rule of code, Cambridge, Harvard University Press. DOI: 10.2307/j.ctv2867sp

Deloitte Legal (2018) Blockchain: legal implications, questions, opportunities and risks. https://www2.deloitte.com/content/dam/Deloitte/be/Documents/legal/Blockchain%20Booklet%20March2018.pdf

Digiconomist (2020) Bitcoin Energy Consumption Index. https://digiconomist.net/bitcoin-energy-consumption

Egels-Zandén N., Hulthén K. and Wulff G. (2014) Trade-offs in supply chain transparency: the case of Nudie Jeans Co, Journal of Cleaner Production, 107, 95-104. DOI: 10.1016/j.jclepro.2014.04.074

Ellervee A., Matulevicius R. and Mayer N. (2017) A comprehensive reference model for blockchain-based distributed ledger technology, in Cabanillas C., España S. and Farshidi S. (eds.) Proceeding of the ER Forum 2017 and the ER 2017 Demo track, Valencia, 6-7 November 2017, 306-319. http://ceur-ws.org/Vol-1979/paper-09.pdf

European Economic and Social Committee (2019) Public hearing Blockchain: technology for the social economy 4.0, Public Hearing, 29 May 2019. https://www.eesc.europa.eu/en/agenda/our-events/events/blockchain-technology-social-economy-40

Fink M. (2019) Blockchain and the General Data Protection Regulation: can distributed ledgers be squared with European data protection law?, Brussels, European Parliamentary Research Service (STOA). DOI: 10.2861/535

Firica O. (2017) Blockchain technology: promises and realities of the year 2017, Quality-Access to Success, 18 (S3), 51-58.

Freuden D. (2018) Hybrid blockchains: the best of both public and private. https://bravenewcoin.com/insights/hybrid-blockchains-the-best-of-both-public-and-private

Fulton L. (2013) Worker representation in Europe, Labour Research Department and ETUI, Produced with the assistance of the SEEurope Network. http://www.worker-participation.eu/index.php/National-Industrial-Relations/Across-Europe/European-level-Representation

Fulton L. (2015) Trade Unions. Union structures. http://www.worker-participation.eu/National-Industrial-Relations/Across-Europe/Trade-Unions2

Fung A. (2013) Infotopia unleashing the democratic power of transparency, Politics & Society, 41 (2), 183-212. DOI: 10.1177/0032329213483107

Global Legal Insights (2019) Blockchain and cryptocurrency regulations 2019: the regulation of blockchain technology. https://www.globallegalinsights.com/practice-areas/blockchain-laws-and-regulations/15-the-regulation-of-blockchain-technology

IBM News room (2019) Ford Motor Company, Huayou Cobalt, IBM, LG Chem and RCS Global launch blockchain pilot to address concerns in strategic mineral supply chains. https://newsroom.ibm.com/2019-01-16-Ford-Motor-Company-Huayou-Cobalt-IBM-LG-Chem-and-RCS-Global-Launch-Blockchain-Pilot-to-Address-Concerns-in-Strategic-Mineral-Supply-Chains?cm_mmc=OSocial_Blog-_-Blockchain+and+Watson+Financial+Services_Blockchain-_-WW_WW-_-Blockchain+for+the+mining+industry+Ethical+cobalt+production+In+Text+IBM+Newsroom&cm_mmca1=000020YK&cm_mmca2=10005803

IndustriAll (2016) An industrialised circular economy: an ambition for industrial trade unions in Europe, Policy Brief 2016-03 v3. https://news.industriall-europe.eu/content/documents/upload/2018/9/636718239534547822_Circular%20Economy%20Policy%202016-03_EN_v3%20checked_CLEAN.pdf

International Energy Agency (2019) Bitcoin energy use - mined the gap. 15 July. https://www.iea.org/commentaries/bitcoin-energy-use-mined-the-gap

Jackson T. (2018) Environmental implications of blockchain. https://insideecology.com/2018/06/15/blockchain-and-the-environment/

Kline R. and Pinch T. (2010) The social construction of technology, in MacKenzie D. and Wajcman J. (eds.) The social shaping of technology, Maidenhead, Open University Press, 113-115.

Koene A. et at. (2019) A governance framework for algorithmic accountability and transparency, Brussels, European Parliamentary Research Service (STOA). DOI:10.2861/59990

Kohler B. and Mpufane G. (2018) Will blockchains verify virtue in the value chain? The case of cobalt, Global Worker, 2, 5-8. http://www.industriall-union.org/welcome-to-global-worker-2

Leewayhertz (2019) Blockchain and AI: towards the ‘Fourth Industrial Revolution’. https://www.leewayhertz.com/blockchain-and-ai/
Lehdonvirta V. and Ali R. (2016) Governance and regulation, in Walport M. (ed.) Distributed ledger technology: beyond blockchain, London, UK Government Office for Science, 40-45. http://vili.lehdonvirta.com/wp-content/uploads/2016/05/Lehdonvirta-Ali-2016-Distributed-ledger-governance-regulation.pdf
Lund-Thomsen P. (2008) The global sourcing and codes of conduct debate: five myths and five recommendations, Development and Change, 39 (6), 1005-1018.
Lyons T., Courcelas L. and Timsit L. (2018) Blockchain and the GDPR: a thematic report prepared by the European Union Blockchain Observatory and Forum. https://www.eublockchainforum.eu/reports
Mannan M. (2018) Fostering worker cooperatives with blockchain technology: lessons from the Colony Project, Erasmus Law Review, 11 (3), 190-203.Marr B. (2018) Artificial intelligence and blockchain: 3 major benefits of combining these two mega-trends. https://www.forbes.com/sites/bernardmarr/2018/03/02/artificial-intelligence-and-blockchain-3-major-benefits-of-combining-these-two-mega-trends/
Massessi D. (2018) Public vs private blockchain in a nutshell. https://medium.com/coinmonks/public-vs-private-blockchain-in-a-nutshell-c9fe284fa39f
Microsoft (2018) Data mining algorithms: analysis services - data mining. https://docs.microsoft.com/en-us/sql/analysis-services/data-mining/data-mining-algorithms-analysis-services-data-mining?view=sql-server-2017
Nascimento S. et al. (eds.) (2019) Blockchain now and tomorrow: assessing multidimensional impacts of distributed ledger technologies, Luxembourg, Publications Office of the European Union. DOI: 10.2760/901029
Nguyen G.T. and Kim K. (2018) A survey about consensus algorithms used in blockchain, Journal of Information Processing Systems, 14 (1), 101-128. DOI: 10.3745/JIPS.01.0024
Neisse R., Steri G. and Nai Fovino I. (2017) A blockchain-based approach for data accountability and provenance tracking. https://doi.org/10.1145/3098954.3098958
New S. (2010) The transparent supply chain, Harvard business Review, 88, 1-5. https://hbr.org/2010/10/the-transparent-supply-chain
Niforos M. (2018) Blockchain governance and regulation as an enabler for market creation in emerging markets, EMCompass 57, Washington, DC, World Bank Group. http://documents.worldbank.org/curated/en/636421540530725523/Blockchain-Governance-and-Regulation-as-an-Enabler-for-Market-Creation-in-Emerging-Markets
Nowotny H., Scott P. and Gibbons M. (2001) Re-thinking science: knowledge and the public in an age of uncertainty, Cambridge, Polity Press.
OECD (2019) Blockchain technologies as a digital enabler for sustainable infrastructure, OECD Environment Policy Papers 16, Paris, OECD Publishing. https://doi.org/10.1787/0ec26947-en
OECD (2019b) Is there a role for blockchain in responsible supply chains? http://mneguidelines.oecd.org/Is-there-a-role-for-blockchain-in-responsible-supply-chains.pdf
Ponce Del Castillo A. (2018) Three ways in which blockchain is changing the world of work. https://www.equaltimes.org/three-ways-in-which-blockchain-is#.XcKnQDNKiUk

Pratap M. (2018) Everything you need to know about smart contracts: a beginner's guide: introducing smart contracts and its features in an efficient way. https://hackernoon.com/everything-you-need-to-know-about-smart-contracts-a-beginners-guide-c13cc138378a

Reed A. (2017) The environmental impacts of bitcoin. https://medium.com/wolverineblockchain/the-environmental-impacts-of-bitcoin-b01592b8c848

Su E. (2018) Top 5 most compelling use cases for blockchain technology. https://medium.com/bitfwd/top-5-most-compelling-use-cases-for-blockchain-technology-d198e500e3d3

The Guardian (2018) How Iceland became the bitcoin miners' paradise, The Guardian, 13 February 2018. https://www.theguardian.com/world/2018/feb/13/how-iceland-became-the-bitcoin-miners-paradise

UNBIAS (2020) Awareness cards. https://unbias.wp.horizon.ac.uk/fairness-toolkit/

Wallace A. (2018) Accenture HR transformation. https://www.accenture.com/_acnmedia/PDF-24/Accenture-HR-Transformation-video-transcript.pdf

Wiles J. (2019) 5 ways blockchain will affect HR. https://www.gartner.com/smarterwithgartner/5-ways-blockchain-will-affect-hr/

Winner L. (1980) Do artifacts have politics?, Daedalus, 109 (1), 121-136.

Yeung K. (2017) Algorithmic regulation: a critical interrogation, Regulation & Governance, 12 (4), 505-523. DOI: 10.1111/rego.12158

Zibell L. (2019) Participation in the European Economic and Social Committee public hearing 'Blockchain and the EU single market: what next?', Brussels, 24 June 2019. https://www.eesc.europa.eu/en/agenda/our-events/events/blockchain-and-eu-single-market-what-next

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