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Fundamental Elements of a Blockchain-Based Tax System – When to Use Blockchain for Tax?

This article aims to explore the fundamental elements of a blockchain-based tax system by approaching the research question of when to use blockchain for tax. The authors, after introducing the basics of blockchain technology, address the conceptual theoretical perspective by identifying the preconditions under which blockchain can concretely represent a valuable opportunity for tax. In this respect, the analysis starts from the systematic literature review and also covers the different points of view from which to consider the development of a blockchain-based tax system, including the tax administration's perspective, the taxpayer's perspective, and the ecosystem perspective. Furthermore, the article addresses the empirical analysis of the current blockchain pilot projects in the tax domain; in this respect, the objective is to verify whether and how each use case concretely addresses the above preconditions. The authors also discuss some future possibilities for more blockchain-based use cases having regard to revenue sourcing rules under the OECD Pillar One proposal and transfer pricing control. In the conclusions, the authors argue that, to comply with the principle of tax efficiency, blockchain-based use cases for tax should always comply with the preconditions identified under the present study.

Contents

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1. Introduction

Over the last years the increasing digitalization of the economy and society in general is opening up new possibilities to enhance the effectiveness and the efficiency of tax administrations and processes across the globe. The extensive use of digital tools, advanced communication channels and large data sources suggests a major shift in the current approach to tax assessment and collection.

In this respect, the Organisation for Economic Co-operation and Development (OECD) is supporting a new "Tax Administration 3.0" model[1] in which technology is intended to make tax processes more seamless and frictionless over time with significant reductions in administrative burdens. Experts see the potential of this digital transformation to replace burdensome voluntary compliance activities by taxpayers, as well as resource-intensive investigations and audits by tax authorities. The ultimate objective is to improve tax compliance by overcoming several persistent tax gaps and moving taxation closer to taxable events (real-time taxation).

This journey towards Tax Administration 3.0 requires a great deal of effort. Tax administrations are called upon to develop the building blocks of this digital transformation with high-level standards for data collection, sharing and processing.

1. *See* OECD, *Tax Administration 3.0: The Digital Transformation of Tax Administration* (OECD 2020), available at http://www.oecd.org/tax/forum-on-tax-administration/publications-and-products/tax-administration-3-0-the-digital-transformation-of-tax-administration.htm (accessed 30 May 2022). *See also* D.R. Post, *Digital Tax Administration 4.0: Towards a Distributed Tax System*, in *Tax Law and Digitization, The New Frontier for Government and Business, Principles, Use Cases and Outlook*, pp. 39-60 (J. Owens & R. Risse eds., Kluwer Law International 2021).

In this new context, blockchain is often referred to as a disruptive technology that holds the potential to revolutionize the entire tax administration and collection process.[2] There are already several studies exploring the interplay between blockchain and the tax domain. The authors of these studies often use an enthusiastic tone assuming blockchain technology to be the perfect solution to solve several tax challenges. Basically, they focus on the idea of a shared ledger updated in real time to justify a major shift towards the use of blockchain for tax.

However, on closer analysis, these ideas around the potential of blockchain for tax in most but not all instances tend to remain at a general level, without a systematic approach or a deep investigation including the empirical perspective. In particular, the conclusions are often not adequately supported by an overall evaluation of the pros and cons of blockchain compared to other existing technologies. The missing point is the awareness that blockchain technology, despite its broad benefits, is far from being the perfect solution and presents, as any disruptive technology, advantages and disadvantages as for its implementation. Furthermore, most scholars seem to focus on the upside potential of what blockchain technology may contribute to tax processes (e.g. transparency, more robust data and tax processes) without taking a step back to consider whether blockchain technology actually is a suitable solution or enabler.

Starting from these considerations, this work aims to provide a comprehensive answer to the research question of when to use blockchain for tax. For this purpose, the authors will explore the topic from a more systematic angle covering both the technology and tax law aspects. This is the first step to define the fundamentals of a blockchain-based tax system; the goal is to concretely identify the preconditions under which there can be a favourable environment to implement blockchain technology. In other words, the authors want to identify in which tax scenarios the use of blockchain can make the difference for tax administrations and taxpayers, providing further guidance and perhaps a new pillar for the Tax Administration 3.0 model.

To answer this main research question, the methodology used in this article is based on the conceptual analysis from both the theoretical perspective and the empirical perspective. As for the theoretical perspective, the authors will start with a systematic literature review and then identify a series of preconditions under which the application of blockchain technology can in principle provide benefits based on the principle of tax efficiency. As for the empirical perspective, starting from the conversion of such preconditions into specific research sub-questions, the authors will explore how these are addressed in the practical experience by analysing the use cases across the globe where blockchain technology is already applied to tax.

Accordingly, the structure of this contribution is developed as follows. After this first section containing the introduction, section 2. focuses on the basics of blockchain technology by introducing the essential knowledge to approach the design of a blockchain-based tax system. In section 3., starting from a systematic literature review, the conceptual theoretical perspective is considered to explore the opportunity of blockchain technology for tax and consequently identify in which tax scenarios and under which preconditions the use of

2. Despite the fact the blockchain technology is hardly mentioned in the OECD report (*see* OECD, *supra* n. 1), with only minor references on pp. 47 and 54 of the report. *See also* sec. 3.

blockchain technology is a potential good fit. Section 4. is dedicated to the empirical perspective with the analysis of the current pilot projects in the blockchain and tax domain. The subsequent discussion in section 5. aims to measure the remaining space for more blockchain-based use cases for tax based on the results of the analysis process carried out in the previous sections. Finally, in section 6. the conclusions of this work are presented.

This article represents the outcome of the first part of a comprehensive research on the fundamental elements of a blockchain-based tax system. It will generally focus on when to consider blockchain for tax.

2. The Basics of Blockchain Technology

To explore the possibilities of blockchain in the tax field, it is first necessary to elaborate on the basics of the technology. For this purpose, the present section aims to introduce a series of key concepts and features to provide the essential tech knowledge to approach the design of a blockchain-based tax system. Accordingly, it starts by clarifying the relationship between blockchain and distributed ledger technologies (DLT). Then, the different types of blockchain networks will be presented based on the choices concerning the permitted users and the consensus process. Next, the main features of blockchain will be described with respect to immutability, transparency and real-time information. Finally, the overview will include some insights on the main tools that are commonly associated with a blockchain network, such as smart contracts, tokens, oracles, artificial intelligence (AI) and data analytics.

Suffice to state that this section will only scratch the surface of the general aspects necessary to understand the key concepts around blockchain and DLT. In the second part of this research, the aim will be to further explore some of the elements of these technologies as deemed appropriate for a blockchain-based tax system.

2.1. Blockchain versus DLT

The systematic approach to blockchain first requires identifying the main field within which the technology has been developed. In this respect, it is necessary to introduce the concept of DLT and explain the differences and similarities with blockchain.

A distributed ledger is merely a database that is distributed across several nodes.[3] These nodes are devices that participate in the same network and communicate in a peer-to-peer (P2P) manner to ensure the most accurate update of the information stored in that database. Within this system, no data is stored in a centralized server; on the contrary, all nodes in the network record, share and synchronize the same information in their respective electronic ledgers. Consequently, DLT always involves the use of a decentralized database where no hierarchy or central administration exists.[4]

3. H. Anwar, *Blockchain vs. Distributed Ledger Technology* (101Blockchains 2019), available at https://101blockchains.com/blockchain-vs-distributed-ledger-technology/ (accessed 30 May 2022).
4. A. Singh, *Distributed Ledger vs Blockchain Technology: Do You Know the Difference?* (Brandlitic 2021), available at https://medium.com/brandlitic/difference-between-distributed-ledger-and-blockchain-vs-dlt-7969f3837ded (accessed 30 May 2022).

Every node can request an update to the ledger; as this happens, the other nodes vote on that update to ensure that the majority agrees with the corresponding action. This voting process with respect to a certain copy of the ledger is called "consensus mechanism" and is conducted automatically by the implementation of an algorithm.[5] As soon as the consensus is achieved, the distributed ledger is updated and the latest agreed-upon version of the ledger is saved on each node of the network.[6] This means that each update to the ledger is replicated across the entire network, thus creating a system where each node has a full identical copy of the entire ledger at any time.[7]

Based on these characteristics, the concept of DLT is sufficiently broad to assume the form of a main category including the blockchain itself. In the case of a distributed ledger, the key features of the system exclusively deal with the absence of central administration and the circumstance that the same ledger is shared by all the nodes participating in the network.

Differently, regarding the concept of blockchain, such basic features are enriched with a series of additional functionalities that make it possible to identify blockchain as a subset of the main domain of DLT.[8]

The first additional functionality of blockchain regards the specific organizational structure; in fact, differently from a merely distributed ledger, a blockchain is necessarily organized in a sequence of blocks.[9] These blocks are linked to one another using cryptography; as a new transaction progresses, more blocks are added by creating a chain.[10] Due to the structure of this chain, altering or deleting previously entered data on earlier blocks is not possible. New additions to the database are possible when one node creates a new block of data, for example including information on a given transaction.[11] The same information is then shared across the entire network and all the nodes of the network collectively determine the block's validity according to a predefined consensus mechanism based on an algorithmic validation method. Once the consensus process is positively concluded, all the nodes add the new block of data to their respective ledgers.[12]

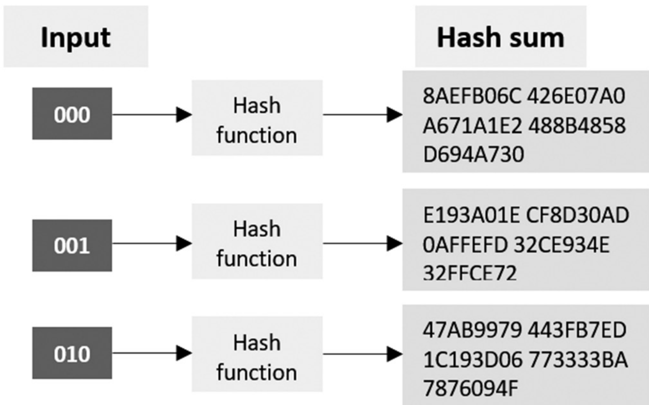
The second significant difference between blockchain and DLT concerns the use of cryptography;[13] in this sense, hashing, asymmetric-key cryptography and digital signatures constitute the basic foundations of any blockchain network.[14]

5. The concept of consensus mechanisms will be explained in more detail in sec. 2.2.
6. Marco Polo Network, *Difference Blockchain and DLT* (Marco Polo Network 2018), available at https://www.marcopolonetwork.com/articles/distributed-ledger-technology/ (accessed 30 May 2022).
7. S. Ray, *The Difference Between Blockchains & Distributed Ledger Technology* (Medium 2018), available at https://towardsdatascience.com/the-difference-between-blockchains-distributed-ledger-technology-42715a0fa92 (accessed 30 May 2022).
8. I-SCOOP, *Blockchain technology and distributed ledger technology (DLT) in business* (I-SCOOP 2018), available at https://www.i-scoop.eu/blockchain-distributed-ledger-technology/ (accessed 30 May 2022); Anwar, *supra* n. 3; Marco Polo Network, *supra* n. 6; S.K. Krause, H. Natarajan & H.L. Gradstein, *Distributed Ledger Technology (DLT) and Blockchain* (World Bank Group 2017), available at https://openknowledge.worldbank.org/bitstream/handle/10986/29053/WP-PUBLIC-Distributed-Ledger-Technology-and-Blockchain-Fintech-Notes.pdf?sequence=5&isAllowed=y (accessed 30 May 2022).
9. Anwar, *supra* n. 3.
10. I-SCOOP, *supra* n. 8.
11. Krause, Natarajan & Gradstein, *supra* n. 8.
12. Singh, *supra* n. 4.
13. Id.
14. Id.

The most commonly known hash function uses the Secure Hash Algorithm (SHA) 256 to generate a hash value of a fixed length from the plaintext.[15] This way, every input has always the same output if processed through the hash function, while reverse engineering is not possible; this means that it is nearly impossible to generate the input based on the output and the hash function. Hash functions play a fundamental role in linking the blocks to one another and in maintaining the integrity of the data stored inside the block.[16] In fact, any alteration in the block data determines a difference in hash value and can consequently lead to the invalidity of the blockchain. In cryptography, this property of the hash function is known as the "avalanche effect".[17]

As illustrated in Figure 1, when the function input changes, then the output becomes completely different.

Figure 1 – Avalanche effect in the hash function



Asymmetric-key cryptography makes it possible to generate a private and a public key. The public key is used to encrypt data and it is calculated by executing an irreversible algorithm; differently, the private key is used for data decryption, and it is generally produced by a random number algorithm.[18] The use of this feature is fundamental for the blockchain environment: it allows users to transfer data through the network in a safe manner.[19] In this regard, also digital signatures play a major role by ensuring the integrity of all the processes as they are easily verifiable and cannot be corrupted.[20]

In summary, it is possible to conclude that blockchain is a subset of the main category of DLTs. Blockchains, in fact, while they share all the basic features of DLT, also present

15. Id.; G. Iredale, *Blockchain Cryptography Explained* (101Blockchains 2021), available at https://101blockchains.com/blockchain-cryptography/ (accessed 30 May 2022). For example, bitcoin uses this algorithm.
16. Singh, *supra* n. 4; Ray, *supra* n. 7.
17. For an explanation of the avalanche effect, *see* H. Feistel, *Cryptography and Computer Privacy*, 228 Scientific American 5, pp. 15-23 (1973).
18. M. Sahu, *Cryptography in Blockchain: Types & Applications* (upGrad 2021), available at https://www.upgrad.com/blog/cryptography-in-blockchain/ (accessed 30 May 2022).
19. S. Zhai, Y. Yang, J. Li, C. Qiu & J. Zhao, *Research on the Application of Cryptography on the Blockchain*, 1168 Journal of Physics: Conference Series 3 (2019), available at https://iopscience.iop.org/article/10.1088/1742-6596/1168/3/032077/meta (accessed 30 May 2022).
20. Sahu, *supra* n. 18.

additional features concerning their block-based structure and the extensive use of cryptography. Generally speaking, all blockchains are distributed ledgers, but not all distributed ledgers are blockchains.

2.2. Types of blockchain networks

Based on the permissions granted to the nodes and the different consensus mechanisms, it is possible to make a distinction between public blockchains, private blockchains and hybrid blockchains.

In a public blockchain, also known as "permissionless blockchain", generally all the nodes connected to the network have access to the data stored on the distributed ledger with the right to read and validate transactions. In this case, the consensus process provides that all the nodes need to authorize and validate a transaction according to a consensus mechanism. These mechanisms are usually based on an algorithm with an incentive structure rewarding participants who contribute to the network. For example, the proof-of-work (PoW) consensus mechanism uses the so-called "miners" to validate and authenticate the blocks to be added to the chain. These miners are required to solve a mathematical puzzle to prove that a sufficient amount of computation has been performed to determine a correct value for the solution of the puzzle. The incentive for miners who solve the puzzle is an award consisting of an amount of cryptocurrency for their correct computation. When a miner correctly solves this challenge, the data of the new block is transmitted to all the other nodes of the network who consequently validate the block, thus successfully adding it to the blockchain.[21] Other consensus mechanisms used in public blockchains include proof-of-stake (PoS), proof-of-capacity, and proof-of-elapsed-time. Public blockchains ensure full decentralization and high data integrity.[22] However, the related consensus mechanisms typically have lower speed compared to other methods and are currently very computationally expensive and power consuming.[23]

Furthermore, a weak point of public blockchains is related to the privacy issue due to their inherent nature; for example, as each node can write on the ledger, in case of an upload of sensitive information there is no way to change such an action.[24] Simultaneously, additional technological developments like the use of so-called zero-knowledge-proof (ZKP) technology can facilitate the transfer of sensitive and confidential information without sharing this information beyond the parties they wish to disclose to on a public blockchain.[25]

21. M. Cash & M. Bassiouni, *Two-tier permission-ed and permission-less blockchain for secure data sharing*, in 2018 IEEE International Conference on Smart Cloud, p. 140 (IEEE 2018).
22. M. Liu, K. Wu & J.J. Xu, *How will blockchain technology impact auditing and accounting: Permissionless versus permissioned blockchain*, 13 Current Issues in Auditing 2 (2019).
23. Id.; R. Yang, R. Wakefield, S. Lyu, S. Jayasuriya, F. Han, X. Yi, & S. Chen, *Public and private blockchain in construction business process and information integration*, 118 Automation in construction, pp. 1-21 (2020).
24. Yang et al., *supra* n. 23, at p. 2.
25. Zero-knowledge-proof technology comes is various shapes and forms. The present article does not go into this technology any further other than stating that this privacy-preserving technology may become very relevant as part of a blockchain-based tax system. For a more detailed description of the technology, *see* N. Narula, W. Vasquez & M. Virza, *zkLedger: Privacy-Preserving Auditing for Distributed Ledgers*, available at https://static1.squarespace.com/static/59aae5e9a803bb10bedeb03e/t/5aa1b35ce4966bd538d3f1d2/1520546653653/zkledger.pdf (accessed 30 May 2022).

In a private blockchain, also known as "permissioned blockchain", only selected nodes have the access to the data stored on the ledger and the right to verify and validate transactions. In this case, one sole owner is controlling the access to the network and granting different rights and permissions to a group of selected users. Therefore, private blockchains are not fully decentralized systems as they are based on a hierarchy with respect to the control over the network.[26] The nodes have different rights and permissions; accordingly, the consensus process is controlled by a preselected set of nodes without the use of mining, PoW, or remuneration.[27] Here, the consensus mechanism is generally achieved based on a process called "selective endorsement" where nodes can validate transactions only when they have been selected as validators according to the governance rules of the network.[28] By eliminating incentives, the validators are not repeatedly performing power-consuming computational operations to validate blocks. Therefore, a shorter time is required to get the consensus for the network, and transactions can be processed at high speed.[29] Private blockchains ensure high data privacy because any change on the ledger can only be done by an action of a trusted node.[30] However, as private blockchains have fewer nodes, the risk of data manipulation is higher compared with public blockchains.[31] For this reason, critics have argued that private blockchains do not scale.[32]

Hybrid blockchains – also known as "federated blockchains" or "consortium blockchains" – combine the features of private and public blockchains.[33] This is a partially decentralized blockchain that is managed by a group of organizations and not by a single entity.[34] This way, a hybrid blockchain eliminates the risks that are inherent to a private blockchain where only one entity has full control over the network.[35] This approach is often used in a network of multiple organizations that require a common ground on which to carry out transactions or relay information. Also, in this case, only preselected nodes have the right to oversee the consensus process and authorize transactions as validators (i.e. write mode). Other nodes of the network usually have more limited rights (i.e. read-only mode).

2.3. Key features

The blockchain architecture involves some key features focused on immutability, transparency and real-time information.

As for immutability, once a block of data is added to the ledger, the information becomes tamper-proof or immutable, which means that in principle it cannot be modified or

26. Liu, Wu & Xu, *supra* n. 22.
27. D. Guegan, *Public Blockchain versus Private blockchain* (2017), available at https://econpapers.repec.org/paper/msecesdoc/17020.htm (accessed 30 May 2022).
28. Cash & Bassiouni, *supra* n. 21, at p. 141.
29. Yang et al., *supra* n. 23, at p. 2.
30. Id.
31. Liu, Wu & Xu, *supra* n. 22; Cash & Bassiouni, *supra* n. 21, at p. 140.
32. *See* P. Brody, *Why enterprises should build on public blockchains* (Coindesk 2021), available at https://www.coindesk.com/markets/2021/08/09/why-enterprises-should-build-on-public-blockchains/ (accessed 30 May 2022).
33. Yang et al., *supra* n. 23, at p. 2.
34. T.K. Sharma, *Types of Blockchain in the Market: Which One Is Better?* (Blockchain Council 2021), available at https://www.blockchain-council.org/blockchain/types-of-blockchain-in-the-market-which-one-is-better/ (accessed 30 May 2022).
35. C. Parizo, *What are the 4 different types of blockchain technology?* (TechTarget 2021), available at https://searchcio.techtarget.com/feature/What-are-the-4-different-types-of-blockchain-technology (accessed 30 May 2022).

altered.[36] In this case, the use of hashing ensures the link between blocks in chronological order and the irreversible character of recorded data. Therefore, as long as a transaction is confirmed based on the consensus mechanism, a single node in the network cannot modify the ledger because that new block is linked to all the previous blocks of data.[37]

As for the different types of blockchains, it is worth noting that immutability is fully ensured only in a public blockchain since a potentially unlimited number of users can operate there as nodes to validate transactions. Differently, in private and hybrid blockchains, immutability generally is more dependent on the honesty of the users allowed to operate as validating nodes.[38]

The second key feature of blockchain is related to the transparency of the data stored on the distributed ledger.[39] According to some authors, blockchain technology would be a "trustless technology" since it eliminates the need for any centralized trusted authority by replacing it with a system of publicly verifiable proofs.[40] In this sense, blockchain technology would enable a "shift from trusting people to trusting math"[41] by maximizing the degree of confidence in the system based on mathematical knowledge and cryptographic rules.[42] This way, transparency would become a fundamental tool to overcome the lack of trust between the parties.[43]

However, these statements are not true in all situations since transparency assumes different levels of effectiveness according to the type of blockchain network used. In a public blockchain, transparency is ensured as data recorded on the ledger is fully accessible to all the nodes of the network.[44] However, as far as private and hybrid blockchains are concerned, the network does not offer absolute transparency; in this case, the master copy of transaction records may not be distributed to all participants such as when data is fully visible only for a predefined group of users of the network;[45] furthermore, differently from a public blockchain, transactions could be rolled back by a centralized agency with override authority.

36. F. Hofmann, S. Wurster, E. Ron & M. Böhmecke-Schwafert, *The immutability concept of blockchains and benefits of early standardization*, in *2017 ITU Kaleidoscope: Challenges for a Data-Driven Society*, pp. 1-8 (IEEE 2018), available at https://ieeexplore.ieee.org/document/8247004 (accessed 30 May 2022).
37. In other words, if one node tries to alter a block, the attempt is immediately recognized by the other participants and, consequently, the consensus is denied. Nonetheless, the immutability feature does not impede the creation of a countervailing transaction to annul a disputed transaction; as this is the case, immutability only means that the original record remains.
38. For the concept of immutability with regard to blockchain, *see also* E. Landerreche & M. Stevens, *On Immutability of Blockchains*, 2 Reports of the European Society for Socially Embedded Technologies 7 (2018), available at https://dl.eusset.eu/bitstream/20.500.12015/3160/1/blockchain2018_04.pdf (accessed 30 May 2022).
39. I-SCOOP, *supra* n. 8.
40. K. Werbach, *Trust, But Verify: Why the Blockchain Needs the Law*, 33 Berkeley Tech. L.J. 489 (2018); D. Tapscott & A. Tapscott, B*lockchain Revolution: How the Technology behind Bitcoin Is Changing Money, Business, and the World* (Penguin 2016).
41. A. Antonopoulos, *Bitcoin Security Model: Trust by Computation* (O'Reilly Radar 2014), available at http://radar.oreilly.com/2014/02/bitcoin-security-model-trust-by-computation.html (accessed 30 May 2022).
42. P. De Filippi, M. Mannan & W. Reijers, *Blockchain as a confidence machine: The problem of trust & challenges of governance*, 62 Technology in Society (2020), available at https://www.sciencedirect.com/science/article/pii/S0160791X20303067 (accessed 30 May 2022).
43. S. Webber, W. Owen & R. Koborsi, *INSIGHT, Blockchain and Distributed Ledgers – Another Wave of Challenge to Tax and Transfer Pricing from the Digital Economy* (Bloomberg Tax 2019), available at https://news.bloombergtax.com/daily-tax-report/insight-blockchain-and-distributed-ledgers-another-wave-of-challenges-to-tax-and-transfer-pricing-from-the-digital-economy (accessed 30 May 2022).
44. Yang et al., *supra* n. 23.
45. Liu, Wu & Xu, *supra* n. 22.

This means that the "trustlessness" of a private or hybrid blockchain relies on the credibility of its controlling owners and the architecture of the consensus protocol.[46]

The third and last key feature of blockchain deals with the availability of (near) real-time information. All the information recorded in the distributed ledger is available on a (near) real-time basis to all the nodes of the network. Therefore, any time a new block of data is added to the blockchain, the distributed ledger is updated in real-time for all the participants through the automatic P2P transmission between the nodes connected to the blockchain. This way, each participant having full access to the blockchain shares the same version of the ledger, which ultimately represents the real-time truth for all the nodes connected to the network. Consequently, there is no need for data verification and reconciliation between different parties considering the absence of a centralized server.[47] In other words, blockchain technology allows the participants of the network to have the possibility to share the same version of the truth and not merely exchange information originally recorded in a centralized server, thereby tackling the "double-spending problem".[48] It is also for this reason that blockchain technology is also referred to as the "internet of value".

2.4. Associated tools and functionalities

Extensive use of blockchain technology for tax purposes requires the implementation of a series of additional tools and functionalities to be stored as computer programs on the distributed ledger. The following subsections describe the most common of these tools and functionalities including smart contracts, tokens, oracles, AI and data analytics.

2.4.1. Smart contracts

Blockchain transactions occur on the basis of computational logic by codifying instructions into programs to be recorded on the ledger. According to this logic, the network makes use of algorithms representing a set of rules that automatically trigger transactions between nodes as long as specific predefined events occur.

Based on these principles, the encoding of standardized contractual terms into software gives birth to the so-called "smart contracts"; in this case, the clauses of an agreement, including for example payment or delivery terms or the transfer of a token, are coded into computer language and become self-executing upon the fulfilment of certain conditions.[49] This way, it is possible to ensure the automatic execution of operations and payments[50] when

46. For transparency and blockchain, *see also* F. Rizal Batubara, J. Ubacht, & M. Janssen, *Unraveling transparency and accountability in blockchain*, in Proceedings of the 20th Annual International Conference on Digital Government Research, pp. 204-213 (2019).
47. *See* T. Sim, J, Owens, R. Petruzzi, R.J.S. Tavares & C. Migai, *Blockchain, Transfer Pricing, Customs Valuations, and Indirect Taxes: Transforming the Global Tax Environment*, 26 Transfer Pricing Report, pp. 209-217 (Bloomberg BNA 2017).
48. The double-spending problem can essentially be described as the situation whereby a digital item of value (e.g. a digital token) can be spent more than once.
49. *See* B. Mohanta, S. Panda & D. Jena, *An overview of smart contract and use cases in blockchain technology*, in 9th International Conference on Computing, Communication and Networking Technologies, pp. 1-4 (IEEE 2018); V. Shermin, D*isrupting governance with blockchains and smart contracts*, 26 Strategic Change 5, pp. 499-509 (2017); L.F. Neto, *The Blockchain Revolution for Transfer Pricing Documentation: If Not in 2020, Then When?*, in *Taxing the Digital Economy: the EU Proposals and Other insights*, pp. 307-334 (P. Pistone & D. Weber eds., IBFD 2019).
50. For an overview of the main characteristics of smart contracts *see* Mohanta, Panda & Jena, *supra* n. 49; Shermin, *supra* n. 49; Neto, *supra* n. 49; N. Szabo, *Smart Contracts* (1994), available at https://www.fon.

predefined conditions are met according to the logic of "if this … then that", where "this" and "that" are predetermined by the smart contract's author.[51]

As far as the dynamic perspective is concerned, smart contracts can be scrutinized by describing their life cycle stages. The first life cycle stage of a smart contract is the coding process. When a conventional contract is signed,[52] the coding process begins with the conversion of (some elements of) the clauses into an executable computer program (i.e. the smart contract).[53] At this stage, software engineers assume a fundamental role in the coding process by converting (part of) an agreement written in traditional language into a smart contract written in computer language.[54] Therefore, while lawyers maintain the domain over the drafting process of the conventional contract, software engineers and data scientists become the main actors as far as the coding process is concerned. For instance, software engineers have exclusive responsibility for the choice of specific computer languages or specific smart contract compilers that can generate the computer code to be stored and deployed on the distributed ledger. This particular element only already highlights the interdisciplinary nature of the use of blockchain technology.

After coding, the second life cycle stage of a smart contract is the deployment process. As soon as the conventional contract is coded into a smart contract, the deployment process starts following the storage of data on the distributed ledger. At this stage, the same data that contains the smart contract is replicated through the validating nodes in a P2P manner without the use of a centralized server.[55] This way, smart contracts, once deployed on the ledger, inherit all the blockchain's main characteristics including immutability, transparency, and real-time information.

The third stage is the execution of the smart contract. In this regard, it is worth noting that a smart contract consists of a certain number of declarative statements with logical connections. When a condition is triggered, the corresponding statement is automatically executed; in other words, as soon as a certain condition is fulfilled, the smart contract enables the automatic execution of a corresponding action. Accordingly, transactions are

hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart.contracts.html (accessed 30 May 2022); N. Szabo, *Formalizing and Securing Relationships on Public Networks*, 9 First Monday 2 (1997), available at https://doi.org/10.5210/fm.v2i9.548 (accessed 30 May 2022); N. Szabo, *Secure Property Titles with Owner Authority* (1998), available at https://nakamotoinstitute.org/secure-property-titles/ (accessed 30 May 2022); M.S. Iller, Computer Security as the Future of Law (1997), available at www.caplet.com/security/futurelaw (accessed 30 May 2022); N.S. Szabo, *Smart Contracts: Building Blocks for Digital Markets* (1996), available at https://www.fon.hum.uva.nl/rob/Courses/InformationInSpeech/CDROM/Literature/LOTwinterschool2006/szabo.best.vwh.net/smart_contracts_2.html (accessed 30 May 2022).

51. R. De Caria, *The Legal Meaning of Smart Contracts*, 26 European Review of Private Law 6, p. 737 (2018).
52. The pre-existence of a conventional signed contract is not a necessary requirement for having a smart contract running on a blockchain network. Smart contracts are computer programs that automate the enforcement of terms; consequently, the software code may exist regardless of the previous drafting of a conventional contract. From a legal perspective, a still open question is whether a smart contract has the same legal value as a conventional contract. This may differ from country to country, depending on the underlying law system (common law versus civil law).
53. Z. Zibin, X. Shaoan, D. Hong-Ning, C. Weili, C. Xiangping, W. Jian, & I. Muhammad, *An Overview on Smart Contracts: Challenges, Advances and Platforms*, 105 Future Generation Computer Systems, pp. 475-491 (2020), available at https://arxiv.org/pdf/1912.10370.pdf (accessed 30 May 2022).
54. F. Idelberger, G. Governatori, R. Riveret & G. Sartor, *Evaluation of logic-based smart contracts for blockchain systems*, in International Symposium on Rules and Rule Markup Languages for the Semantic Web (RuleML), pp. 167-183 (Springer 2016).
55. Zibin et al., *supra* n. 53.

automatically executed and validated by the nodes operating on the blockchain network.[56] The execution stage also involves that the validated transaction is finally added to the list of stored transactions within a new block.[57]

The fourth and last stage is the completion. Once a smart contract is entirely executed, there is an automatic update of the states of all of the involved parties. Accordingly, the transactions during the execution of the smart contract and the updated states are safely stored in the blockchain. In this respect, it should, however, be noted that smart contracts in some instances may never be completed, for example if the underlying logic embedded in the smart contract is dependent on subsequent transactions which may occur indefinitely.

2.4.2. Tokens

The tokenization process represents a form of digitalization of value in tradeable units of account, called tokens. In principle, a token may represent anything of value from the real world (then often also referred to as a digital twin) but also something completely digital like digital memorabilia or non-fungible tokens (NFTs).[58]

The main literature generally distinguishes between payment tokens (cryptocurrencies), utility tokens and asset tokens.[59] Payment tokens refer to any cryptographically secured digital representation of value that is used or intended to be used as a medium of exchange; thus, they are a means of value transfer and include blockchain native cryptocurrencies like Bitcoin[60] or Ethereum. Utility tokens are intended to provide digital access to an application or service through a blockchain-based infrastructure. Asset tokens – also called "security tokens" – are assets, such as a debt or equity claim on the issuer; in terms of their economic function, therefore, these tokens are analogous to equities, bonds, or derivatives.[61]

However, all these categories are not mutually exclusive since a token can be designed to jointly perform all the related functions and include more various rights with different tax consequences.[62]

One more key distinction focuses on the interchangeable nature of the represented assets: in this regard, one can distinguish the so-called "fungible tokens", which are purely equal

56. R. Koulu, *Blockchains and online dispute resolution: smart contracts as an alternative to enforcement*, 13 SCRIPTed 1, p. 40 (2016).
57. Zibin et al., *supra* n. 53.
58. Although non-fungible tokens are often used in blockchain applications, the term has recently been used predominantly for tokens to represent digital ownership of a digital piece of art, a snapshot of a famous sports moment, in-game attributes or, for example, the right to exclusive products
59. L. Oliveira, L. Zavolokina, I. Ingrid & G. Schwabe, *To Token or not to Token: Tools for Understanding Blockchain Tokens*, in International Conference of Information Systems San Francisco, United States, 12-16 Dec. 2018, available at https://www.zora.uzh.ch/id/eprint/157908/ (accessed 30 May 2022).
60. S. Nakamoto, *Bitcoin: A peer-to-peer electronic cash system* (2009), available at https://bitcoin.org/bitcoin.pdf (accessed 30 May 2022).
61. M. Di Angelo & G. Salzer, *Tokens, types, and standards: identification and utilization in Ethereum*, in 2020 IEEE International Conference on Decentralized Applications and Infrastructures, pp. 1-10 (2020), available at https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9126009 (accessed 30 May 2022).
62. E.g. fan tokens of football clubs. For a comprehensive token classification, *see* C. Lo Yuen & F. Medda, *Assets on the blockchain: An empirical study of Tokenomics*, 53 Information Economics and Policy, p. 4 (2020), available at https://www.sciencedirect.com/science/article/pii/S0167624520301256 (accessed 30 May 2022). For the tax qualification of tokens *see* e.g. V. Ooi, *A Framework for Understanding the Taxation of Digital Token*, 50 Australian Tax Review 4, pp. 260-269 (2021).

and interchangeable one with the other, on the one hand, and NFTs, which possess distinct characteristics that ensure their uniqueness, on the other hand.[63]

The potentially unique economics of each token are not based on legal rights, but on their promises and functions, often referred to as "tokenomics" or "token economy".[64] In this sense, tokens can be seen as privately issued currencies used to exchange value within an ecosystem even beyond the mere currency applications. Tokens can be created by any entity; the token issuer defines the governing rules and properties, including the token features, the monetary policy, and the user's incentive system. This way, the tokenization process determines the creation of a self-governed economic system whose rules are programmed by the token issuer.[65]

As tokens are exchanged on a blockchain network, the use of computational logic and algorithms makes it possible to solve the double-spending problem, thus allowing a free and borderless flow of digitized value.[66] Tokens are usually governed by a smart contract on blockchain used to accelerate the exchange of value. When the terms set in the smart contract are fulfilled, the software code is executed automatically through the transfer of tokens mutually accepted by the parties as part of the exchange.[67]

For the purposes of this research, it is also important to make a distinction between tokenization and notarization and to highlight some of the key differences.[68] When speaking about notarization blockchains, typically this refers to blockchains that merely enable the timestamping of documents or a list of entries/transactions.[69] With notarization blockchains, it is generally not possible to transfer something of value but rather notarize (in this example) certain transactions. Conversely, with tokenization blockchains, something of value is being transferred via the blockchain.[70] Tokenization of assets also implies that with the transfer of a token, the exact transfer of that token can be traced throughout its life

63. Id. For an overview on blockchain tokens, *see also* P. Evans, L. Aré, P. Forth, N. Harlé & M. Portincaso, A Strategic *Perspective on Blockchain and Digital Tokens* (Boston Consulting Group 2016), available at https://www.bcg.com/en-gb/publications/2016/blockchain-thinking-outside-the-blocks (accessed 30 May 2022); K. Clarke-Potter, *What Is A Blockchain 'Token'? Is it Just Cryptocurrency?* (Blockhead Technologies 2020), available at https://blockheadtechnologies.com/what-is-a-blockchain-token-is-it-just-cryptocurrency/ (accessed 30 May 2022); S. McKeon, *What is a blockchain token?* (NewsHour Productions 2018), available at https://www.pbs.org/newshour/science/what-is-a-blockchain-token (accessed 30 May 2022).
64. Lo Yuen & Medda, *supra* n. 62, at p. 4.
65. Id.
66. P. Freni, E. Ferro & R. Moncada, *Tokenization and Blockchain Tokens Classification: a morphological framework*, in *2020 IEEE Symposium on Computers and Communications*, pp. 1-6 (IEEE 2020).
67. R. O'Shields, *Smart contract: Legal Agreements for the Blockchain*, 21 North Carolina Banking Institute Journal, p. 177 et seq. (2017).
68. The authors actually believe there is a third term relevant in this context and this is attestation. Generally speaking, attestation may come into play in a situation where a third party may need to attest that certain information is correct and/or complete. This is also where the potential use lies of the verifiable credentials of the World Wide Web Consortium (W3C), an open standard for digital credentials that is referred to in the context of blockchain platforms. For more information, *see* https://www.w3.org/TR/vc-data-model/ (accessed 30 May 2022). At this stage, the topic will not be addressed any further.
69. For example, take all the car sales from an automotive company in the month of January of a certain year and notarize these transactions on the blockchain. These transactions would then be hashed on the blockchain so that one may at a later stage refer back to this list of entries as the sales transaction list for this company for said month. So, it is essentially nothing more than a time-stamped list of entries.
70. For example, if a specific car is being tokenized, one may create a token for the legal ownership of the car, but if desired also for economic ownership. The same may be done for the engine (engine token), other specific parts, or the car insurance.

cycle, including its transaction history. Potentially this may lead to end-to-end visibility of where a specific item of value resides or who owns it.

2.4.3. Oracles

Smart contracts often require the availability of relevant information from the outside world to execute and meet the conditions of the coded agreement. In this regard, the so-called "oracles" assume a fundamental role in the blockchain ecosystem by enabling smart contracts to interact with external sources.[71] Oracles, in fact, play the role of agents who find information in the real world, for example by checking data from reliable websites; they usually operate as online services (e.g. providing currency exchange rates) or event triggers reacting to external events (e.g. a government entity initiating an audit). Accordingly, oracles bring external information into the blockchain and serve as a bridge between the blockchain network and the real world.[72] Furthermore, the role of oracles is not only to simply query the information from the outside world, but also to verify the authenticity and validity of that data.[73] Therefore, oracles have a fundamental relevance within the blockchain ecosystem because in their absence smart contracts would have very limited use as they would only have access to data from within their networks.

Blockchain oracles can be categorized according to their sources in software oracles and hardware oracles. Software oracles, also known as "deterministic oracles", interact with online sources of information and transmit it to the blockchain. This information usually comes from online databases, servers, or websites, and it generally includes exchange rates, digital asset prices, real-time flight information, or any other information. An example in the world of taxation is a tax engine that determines an applicable tax rate on a certain transaction (e.g. value added tax (VAT)/goods and services tax (GST) or sales tax). Hardware oracles are designed to get information from the physical world by translating real-world events into digital values that can be understood by smart contracts. Such information is usually relayed from electronic sensors, QR scanners, or other information-reading devices.[74]

One more distinction can be made with reference to the direction of the transmitted information. In this sense, the so-called "inbound oracles" transmit information from external sources to smart contracts; an example is an oracle transmitting information on the temperature measured by a sensor. Differently, the so-called "outbound oracles" send informa-

71. H. Al-Breiki, M.H.U. Rehman, K. Salah & D. Svetinovic, *Trustworthy blockchain oracles: review, comparison, and open research challenges* (IEEE 2020), available at https://ieeexplore.ieee.org/document/9086815 (accessed 30 May 2022). For an overview of blockchain oracles, *see also* V. Mou, *Blockchain Oracles Explained* (Binance Academy 2020), available at https://academy.binance.com/en/articles/blockchain-oracles-explained (accessed 30 May 2022); P. Collins, *What Is a Blockchain Oracle?* (Better Programming 2020), available at https://betterprogramming.pub/what-is-a-blockchain-oracle-f5ccab8dbd72 (accessed 30 May 2022); S. Voshmgir, *Blockchain Oracles*, (BlockchainHub 2020), available at https://blockchainhub.net/blockchain-oracles/ (accessed 30 May 2022); R. van Mölken, *Blockchain Across Oracle: Understand Details Implications Blockchain for Oracle Developers Customers* (Packt Publishing 2018).
72. A. Beniiche, *A study of blockchain oracles* (2020), available at http://arxiv.org/abs/2004.07140 (accessed 30 May 2022).
73. K. Mammadzada, M. Iqbal, F. Milani, L. García-Bañuelos & R. Matulevičius, *Blockchain oracles: A framework for blockchain-based applications*, in *International Conference on Business Process Management*, p. 21 (Springer 2020), available at https://link.springer.com/chapter/10.1007/978-3-030-58779-6_2 (accessed 30 May 2022).
74. An example of hardware oracles is a sensor that checks if a truck transporting goods has arrived at a loading port. *See* Beniiche, *supra* n. 72.

tion from smart contracts to the external world. An example of an outbound oracle is the case where information is transmitted from the smart contract to the real world to activate a mechanism that unlocks a smart lock as soon as funds are deposited to the recipient's address.[75]

2.4.4. AI and data analytics

Blockchain also requires the use of appropriate analysis tools and functionalities to read, analyse and process all of the information stored in the ledger in a timely and efficient manner. In this sense, the combined use of AI and data analytics can make the difference as they both contribute to improving the way through which blockchain data is processed.

AI is usually defined as "the application of advanced analysis and logic techniques, including machine learning, to interpret events, support and automate decisions".[76] According to experts, AI must be focused on the joint use of five abilities: discover, predict, justify, act and learn;[77] the objective here is to capture the knowledge of experts in the form of rules (expert systems) or reproduce how the brain adopts intelligent decisions (neural networks).[78] In this regard, advanced analytical techniques, such as "deep learning", allow to obtain extreme values (outliers) and create alerts concerning prices, values, ratios, or other risk indicators.

Data analytics involves the examination of data or content using sophisticated techniques that are generally beyond AI to discover a greater amount of profound knowledge, make forecasts, or generate recommendations. In more detail, data analytics uses inductive statistics and concepts of non-linear systems to identify rules (e.g. regression, non-linear relationships and causal effects) starting from large datasets with a low density of information to reveal relationships and dependency or to promote forecasts of results and trends.[79]

Based on AI and data analytics, it becomes possible to read, analyse and process data from the blockchain through the use of new algorithms to learn about undeclared data from the economic reality. This way, also smart contracts can benefit from the previous analysis and selection of the required information from the supply chain or other data sources with a sensible improvement of the efficiency in the automatic execution of the software code.[80]

75. Id.
76. "Artificial Intelligence (AI)", Gartner IT Glossary (2022), available at www.gartner.com/it-glossary/artificial-intelligence/ (accessed 30 May 2022). For an introduction to artificial intelligence, *see* N.J. Nilsson, *Principles of artificial intelligence* (Morgan Kaufmann 2014); M.R. Genesereth & N. J. Nilsson, *Logical foundations of artificial intelligence* (Morgan Kaufmann 2012).
77. G. Singh, *Five components that artificial intelligence must have to succeed* (Bloomberg Finance L.P. 2017), available at https://www.bloomberg.com/professional/blog/five-components-artificial-intelligence-must-succeed/ (accessed 30 May 2022).
78. Inter-American Center of Tax Administrations – CIAT, *ICT as a Strategic Tool to Leapfrog the Efficiency of Tax Administrations* (CIAT 2020).
79. *See* P. Mehta, J. Mathews, S. Kumar, K. Suryamukhi, C.S. Babu, S.V. Kasi Visweswara Rao, V. Shivapujimath & D. Bisht, *Big Data Analytics for Tax Administration*, in *Electronic Government and the Information Systems Perspective*, 11709 Lecture Notes in Computer Science (A. Kő, E. Francesconi, G. Anderst-Kotsis, A. Tjoa & I. Khalil I. eds., Springer 2019), available at https://doi.org/10.1007/978-3-030-27523-5_4 (accessed 30 May 2022); A. Benjamin, A. Niblett & A. Yoon, *Data analytics and tax law* (2019), available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3406784 (accessed 30 May 2022).
80. In this regard, various questions may arise when using AI and data analysis as part of a blockchain-based tax system, for example with respect to the availability and access of the underlying data to the participants on the blockchain as well as with respect to privacy regulations like the European General Data Privacy Regulation (GDPR).

3. The Combination of Blockchain Technology and Tax

Now that some of the basic elements of the technology have been addressed in the previous section, the opportunity of blockchain technology for tax will be explored. More fundamentally, this section will address the main research question formulated in the introduction of when to use blockchain for tax.

In the authors' view, there are two possible perspectives to develop such a question: (i) the "conceptual theoretical perspective", based on the systematic literature review and the consequent identification of the typical issues that need to be addressed when thinking about a blockchain-based tax system; (ii) the "empirical practical perspective", i.e. in which scenarios, in practice, blockchain technology is already seen to be applied to tax use cases as well as what lessons may be taken from those use cases.

This section will focus only on the conceptual theoretical perspective, while the empirical use of blockchain technology will be addressed separately in section 4.

3.1. Systematic literature review

The review of the existing literature on blockchain and tax offers an interesting overview of the related opportunities and challenges. In this sense, the scholars' work sets a conceptual bridge between the blockchain-distinguishing properties, such as immutability, transparency and real-time information, on the one hand, and the fundamental issues that characterize the current tax administration landscape, on the other. Based on these premises, the objective of this section is to scrutinize the ideas of scholars from the functional point of view. For this scope, the present review is organized under two main research streams focusing on the opportunities and challenges of blockchain technology for tax, respectively.

3.1.1. Opportunities of blockchain for tax

Several studies dealing with blockchain in the tax domain aim to address the potential applications of the new technology in the tax administration landscape.

The first example is the use of blockchain technology to overcome the current manual system and automate tax calculations and payments.[81] Some scholars see the blockchain potential for the creation of a system of transactional taxation with tax collection carried out automatically at the time of the taxable transaction;[82] they argue that taxes can be calculated in an automatic transactional manner; consequently, as tax calculation and payment occur in real time, it is possible to automate a fairly complicated and bureaucratic process.[83]

81. L. Dourado, P. Silva, C. Peres & D. Díaz, *Challenges and Opportunities for a Fiscal Blockchain*, 87 American Academic Scientific Research Journal for Engineering, Technology, and Sciences 1, pp. 117-137 (2022).
82. O.I. Lyutova & I.D. Fialkovskaya, *Blockchain technology in tax law theory and tax administration*, 25 RUDN Journal of Law 3, pp. 693-710 (2021).
83. K. Yent, *Applying Blockchain Technology to Cross-Border Tax Reporting*, University College London Centre for Blockchain Technologies, Discussion Papers 4 (2020), available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3910741 (accessed 30 May 2022); R. Müller, *Proposal for an Automated Real-Time VAT Collection Mechanism in B2C E-Commerce Using Blockchain Technology*, 31 Intl. VAT Monitor 3 (2020), Journal Articles & Opinion Pieces IBFD (accessed 30 May 2022).

Within this area, academics present the new technology as an opportunity for tax administrations to improve their performance in terms of revenue collection.[84] In this context, there are also ideas on the use of smart contracts to automate VAT payments; for example, these ideas include the possibility to split the payment of the customer into a part remuneration and a part VAT before it reaches the bank account of the supplier.[85] According to these authors, the introduction of a split payment during the VAT payment process – with the correct VAT amount calculated directly at source – represents a key step to effectively face the issue of VAT fraud in e-commerce;[86] furthermore, the use of blockchain can enable taxpayers to use pre-filled VAT returns, while tax authorities can pay out the VAT reimbursements more rapidly with a consistent improvement of the cash flow for businesses.

Some authors also discuss the opportunity of implementing a blockchain-based VAT in the European Union by formulating a series of recommendations regarding how the European Union can introduce the blockchain technology within its VAT system.[87] The leading idea is that blockchain has the potential to change the VAT landscape, considering the various legislative and implementation aspects that may be affected by this technology.[88] In this sense, there are scholars who explore the potential of DLT and blockchain to simplify VAT administration.[89] Withholding tax is also an interesting area for several scholars;[90] in particular, according to some studies, blockchain, smart contracts and tokens may resolve the

84. C. Cipollini, *Blockchain and smart contracts: a look at the future of transfer pricing control*, 49 Intertax 4, pp. 313-330 (2021); C. Cipollini, *Transfer pricing in Italy and Singapore: What Regulatory Framework for a Blockchain Scenario?*, 28 Intl. Transfer Pricing J. 1 (2021), Journal Articles & Opinion Pieces IBFD (accessed 26 July 2022); R. Müller, *The Blockchain Technology in Transfer Pricing - Artificial Intelligence and Further Synergies*, 27 Intl. Transfer Pricing J. 5, pp. 362-367 (2020), Journal Articles & Opinion Pieces IBFD (accessed 26 July 2022); L. Fjord Kjærsgaard, *Blockchain technology and the allocation of taxing rights to payments related to initial coin offerings*, 48 Intertax 10, pp. 879-903 (2020); M.M.W.D. Merkx, *VAT and blockchain: challenges and opportunities ahead*, 28 EC Tax Rev. 2, pp. 83-89 (2019); S.K. Bilaney, *From Value Chain to Blockchain - Transfer Pricing 2.0*, 25 Intl. Transfer Pricing J. 4 (2018), Journal Articles & Opinion Pieces IBFD (accessed 26 July 2022); T. van der Bosch, D. Diederichsen & C. Demetrius, *Blockchain in Global Finance and Tax*, 20 Fin. & Cap. Mkts 1 (2018), Journal Articles & Opinion Pieces IBFD (accessed 30 May 2022); for VAT blockchain applications in Asian tax administrations, *see also* R. Müller, *Blockchain Applications in Asian Tax Administrations*, 26 Asia-Pac. Tax Bull. 2 (2020), Journal Articles & Opinion Pieces IBFD (accessed 30 May 2022).
85. Merkx, *supra*, n. 84; *see also* B. Vandresse, V. Cilli, C. Walsh, T. Vanhee, S. Venables, S. Blackie, J. Heyvaert, M. Baddeley, J. van der Paal, A. Nurk, & J. Consiglio, *Analysis of the Split Payment Mechanism as an Alternative VAT Collection method. Final Report* (European Commission, Directorate-General for Taxation and Customs Union 2018), available at https://op.europa.eu/en/publication-detail/-/publication/b87224ad-fcce-11e7-b8f5-01aa75ed71a1/language-en (accessed 30 May 2022).
86. Merkx, *supra* n. 84. For invoice reporting to face the VAT fraud issue, *see also* S. Jafari, *Combining Modern Technology and Real-Time Invoice Reporting to Combat VAT Fraud: No Revolution, but a Technological Evolution*, 31 Intl. VAT Monitor 3 (2020), Journal Articles & Opinion Pieces IBFD (accessed 30 May 2022). For the VAT fraud detection potential, *see also* A. Bal, *Taxation, Virtual Currency and Blockchain*, Series on International Taxation 68, para. 2.03.F (Wolters Kluwer International 2019).
87. R. Müller, *Building a blockchain for the EU VAT*, 100 Tax Notes Intl. 8, pp. 1043-1050 (2020); Merkx, *supra* n. 84; R.T. Ainsworth & A.B. Shact, *Blockchain technology might solve VAT fraud*, 83 Tax Notes Intl. 13, pp. 1165-1174 (2016); R.T. Ainsworth & M. Alwohaibi, *The first real-time blockchain VAT: GCC solves MTIC fraud*, 86 Tax Notes Intl. 8, pp. 695-719 (2017).
88. A.M. Bal, *Between hype and disillusionment: will a VAT blockchain ever be possible in the EU?*, 97 Tax Notes Intl. 8, pp. 893-902 (2020).
89. D.A. Wijaya, J.K. Liu, D.A. Suwarsono & P. Zhang, *A new blockchain-based value-added tax system*, in *Provable Security, 11th International Conference, ProvSec 2017 Xi'an, China, 23-25 Oct 2017 Proceedings*, pp. 471-486 (T. Okamoto, Y. Yu, M.H. Au, & Y. Li eds., Springer 2017).
90. Bal, *supra* n. 86, at para. 2.03.D (Wolters Kluwer International 2019).

issues that financial intermediaries face when making treaty claims for withholding tax purposes.[91]

Some literature also underlines the possibility to exploit the blockchain potential to automate the auditing process. The objective here is to redesign the auditing process based on a real-time and integrated perspective.[92] According to some authors, blockchain can increase the monitoring capability of the tax authority.[93] In other words, blockchain enables the tax authority to have more control over the taxation mechanism and therefore minimize fraud risks. This is particularly relevant in the area of transfer pricing (TP), where, according to scholars, blockchain can be used to identify profits from a transaction database and determine how these profits are distributed among the various components of the business.[94] In these cases, smart contracts can assist, confirm, or implement the negotiation or execution of an agreement. The result is a more efficient way to assess and settle tax liabilities.[95] Some studies also discuss the potential use of blockchain technology for payroll tax compliance.[96]

There is also literature focusing on the possible use of blockchain to ensure tax information transparency. According to these studies, blockchain technology enables tax authorities to potentially carry out transactions openly and transparently;[97] in particular, blockchain makes it possible to increase transparency for dividend flows in order to overcome the current double-spending problem in the public taxation sector.[98]

Then, some studies deal with the objective to ensure data integrity through the use of blockchain technology. In particular, as far as the VAT area is concerned, scholars suggest the creation of a "single source of truth for invoices" by introducing a blockchain-based invoice reporting system.[99] This is consistent with the idea of building trust based on the blockchain capability to create unalterable records of transactions. These authors underline the possibility of absolute data integrity with minimal transaction costs in real time for tax professionals and tax administrators.[100] Through blockchain, they see a way to increase the trust of tax authorities and other administrations and enable them to verify the profit of global businesses in different jurisdictions based on reliable data.[101]

91. P. Radcliffe & C. Yung, *Can Distributable Ledger Technology Be Part of the Future Withholding Tax Solution?*, 61 Eur. Taxn. 11 (2021), Journal Articles & Opinion Pieces IBFD (accessed 26 July 2022).
92. Dourado et al., *supra* n. 81.
93. Wijaya et al., *supra* n. 89.
94. D.I. Ryakhovsky, T. Ukhina, I.A. Duborkina, N.N. Kozhukhova, V.V. Goncharov & A.N. Zharov, *Applications of Blockchain in Taxation: New Administrative Opportunities*, 18 Webology (2021), available at https://www.webology.org/data-cms/articles/20211101122930pmWEB18139.pdf (accessed 30 May 2022).
95. Cipollini, *supra* n. 84; *see also* Bal, *supra* n. 86, at para. 2.03.E, where the author argues that "blockchain could be used to support the global efforts to identify value-generating activities and impose taxes accordingly".
96. R.T. Ainsworth & V. Viitasaari, *Payroll tax compliance and blockchain*, 85 Tax Notes Intl. 11, pp. 1007-1024 (2017).
97. J. Stanley-Smith, *Blockchain and tax: What businesses need to know*, International Tax Review (2016), available at https://www.internationaltaxreview.com/article/b1f7ngmvqcf1jc/blockchain-and-tax-what-businesses-need-to-know (accessed 30 May 2022).
98. H. Hyvärinen, M. Risius & G. Friis, *A blockchain-based approach towards overcoming financial fraud in public sector services*, 59 Business & Information Systems Engineering 6, pp. 441-456 (2017).
99. B. Kuijper, T. Cameron & Z. Szatmari, *Technology-Enabled Tax Compliance*, 74 Bull. Intl. Taxn. 10, sec. 2.1.1., p. 584 (2020), Journal Articles & Opinion Pieces IBFD (accessed 26 July 2022)
100. Id., at sec. 3.2.2., p. 594.
101. D. Yayman, *Blockchain in Taxation*, 21 Journal of Accounting & Finance 4, p. 153 (2021).

There are also papers addressing research towards the potential of blockchain to ensure data reconciliation and resolve information asymmetry among different tax authorities or different entities of a multinational group.[102] As long as transactions are confirmed and reconciled in real time, blockchain finally enables efficiency improvement of the tax administration process by offering more equitable conditions for all the stakeholders.[103]

One more line of research focuses on tax data sharing on a real-time basis. In this respect, the authors discuss the potential of blockchain technology to facilitate the sharing of immutable and reliable tax data among the nodes of the network.[104] This includes, for instance, the consideration of the options available for the establishment of an international authority in charge of the administration of the blockchain network where data is transmitted.[105]

Furthermore, there is a large group of studies approaching the idea to use blockchain technology to minimize tax reporting and simplify tax obligations for taxpayers.[106] The authors of these studies propose to achieve this objective by including tax authorities into the smart contract mechanism used in relation to taxable transactions. Some of them suggest the elimination of tax returns due to the creation of a decentralized information database able to track the taxable transactions in real time and ensure the automatic execution of tax obligations.[107] Based on these views, taxpayers do not have to report their tax information separately to different tax authorities at the national and/or subnational level because blockchain can eliminate the need for redundant data entry.[108]

Finally, some studies analyse certain specific effects of blockchain implementation in the tax domain; the focus is on the possibility to use blockchain in order to reduce costs for businesses.[109] Other studies extend the research scope to the possibility of using blockchain and smart contracts in more specific applications, including the enforcement of court decisions[110] and the structuring of tax data.[111]

3.1.2. Challenges of blockchain for tax

Several scholars also approach the challenges deriving from blockchain application. These critical voices, although mainly raised in the area of accounting, are particularly helpful for the purposes of the present literature review.

The first challenge approached in these studies is related to the issue of confidentiality. According to some authors, as the use of a public blockchain makes transactions publicly available, a confidentiality issue arises for companies due to the potential risks of disclosing

102. Y.R.C. Kim, *Blockchain Initiatives for Tax Administration* (2021), available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3798136 (accessed 30 May 2022).
103. Id. *See also* Bal, *supra* n. 86, at para. 2.03.A.
104. Id. *See also* Dourado et al., *supra* n. 81; Bal. *supra* n. 86, at para. 2.03.C.
105. C. Cipollini, *Blockchain and transfer pricing: opportunities and challenges in the International Tax Framework*, Rivista di Diritto Tributario Internazionale (International Tax Law Review) 3, pp. 359-383 (2019).
106. Lyutova & Fialkovskaya, *supra* n. 82.
107. Yent, *supra* n. 83.
108. Kim, *supra* n. 102.
109. Kuijper, Cameron & Szatmari, *supra* n. 99, at p. 594.
110. P. Ricci & V. Mammanco, *Blockchain Technology To Support Italian Tax Process*, 2 European Journal of Engineering Science and Technology 3, pp. 1-10 (2019).
111. Ryakhovsky et al., *supra* n. 94.

information;[112] because of trust issues among nodes, the concept of accounting based on blockchain might be infeasible.[113] Nevertheless, recent papers explore possible solutions to tackle this problem; one idea involves the use of a private blockchain instead of a public blockchain with one central organization controlling the nodes that have the right to read and/or write new information in the blockchain.[114] However, since private blockchains are only partially decentralized networks, this solution would weaken the fundamental characteristics of blockchain technology, especially immutability.[115] Other ideas involve the replacement of transactions data stored in the blockchain with hashes to preserve transaction verification without revealing private data[116] or, alternatively, the use of encryption schemes whereby one party can prove the truth of specific information without disclosing any additional information (e.g. ZKP).[117]

The second challenge is the environmental issue due to the fact that blockchain is computationally intensive. This raises questions on environmental sustainability and scalability considering that blockchain algorithms require a lot of energy.[118] In this sense, as more energy is required to validate transactions, the speed of the network may become one more practical concern.[119]

The third challenge is related to the security of the blockchain. According to some authors, there could be potential risks for the blockchain system to be susceptible to tampering (which includes the breakdown of the consensus mechanism), making information on the blockchain unreliable. Although changes to existing data may be impossible, tampering could take the form of routing payments to an unauthorized recipient.[120]

The fourth challenge is that of multiple blockchain databases or interoperability. If the members of a supply chain adopt different types of blockchain networks, this would force

112. C.W. Cai, *Triple-entry accounting with blockchain: How far have we come?* 61 Accounting & Finance, pp. 71-93 (2021).
113. J. Coyne & P. McMickle, *Can blockchains serve an accounting purpose?*, 14 Journal of Emerging Technologies in Accounting 2, pp. 101-111 (2017).
114. T. Yu, Z. Lin & Q. Tang, *Blockchain: the introduction and its application in financial accounting*, 29 Journal of Corporate Accounting & Finance 4, p. 45 (2018).
115. Id.
116. E. Bonsón & M. Bednárová, *Blockchain and its implications for accounting and auditing*, 27 Meditari Accountancy Research 5, p. 735 (2019); N. Andersen, *Blockchain technology: a Game-Changer in accounting?* (Deloitte 2016), available at: https://www2.deloitte.com/content/dam/Deloitte/de/Documents/Innovation/Blockchain_A%20game-changer%20in%20accounting.pdf (accessed 30 May 2022).
117. N. Narula, W. Vasquez & M. Virza, *zkLedger: Privacy-Preserving Auditing for Distributed Ledgers*, in *Proceedings of the 15th USENIX Symposium on Networked Systems Design and Implementation* (NSDI 2018) available at https://www.usenix.org/system/files/conference/nsdi18/nsdi18-narula.pdf (accessed 30 May 2022).
118. T. Garanina, M. Ranta & J. Dumay, *Blockchain in accounting research: current trends and emerging topics*, Accounting, Auditing & Accountability Journal (2021), available at https://www.emerald.com/insight/0951-3574.htm (accessed 30 May 2022); *see also* A.M. Bal, *Blockchain, Initial Coin Offerings and Other Developments in the Virtual Currency Market*, 20 Fin. & Cap. Mkts 2 (2018), Journal Articles & Opinion Pieces IBFD (accessed 30 May 2022).
119. J. Kokina, R. Mancha & D. Pachamanova, *Blockchain: emergent industry adoption and implications for accounting*, 14 Journal of Emerging Technologies in Accounting 2, pp. 91-100 (2017). In the view of the authors of the present article, this is mainly an issue in connection with blockchains that are based on proof-of-work consensus mechanisms.
120. S. Sinha, *Blockchain - Opportunities and challenges for accounting professionals*, 31 Journal of Corporate Accounting & Finance 2, p. 66 (2020).

each member company to have multiple duplicate blockchain databases.[121] To solve this issue, authors suggest adopting a uniform blockchain standard to which developers and operators in general should adhere to support compatibility and interoperability.[122]

The fifth challenge is the reliability of financial reports. In this regard, the mere fact that a certain transaction is stored on the blockchain does not necessarily assure the reliability of the company's financial reports.[123] This is because the advantages of blockchain end where the new technology collides with the non-digital world.[124] For example, one company might turn to constructing transactions to get the desired accounting numbers. Because of these risks, authors underline the need for auditors engaged in the analysis of the reasonability and authenticity of the business of the audited entity.[125]

Besides these main challenges, some scholars occasionally point out the following further issues relating to the mainstream adoption of blockchain-based innovations in the tax domain: (i) slow transaction processing, (ii) legal uncertainty surrounding the virtual currency market and (iii) technical complexity.[126]

3.1.3. Synthesis of the results

The systematic literature review reveals several potential implementations of blockchain technology in the tax domain. As seen, there is a focus on the possibility to automate the tax auditing and collection process (including the enforcement of court decisions), as well as minimizing and simplifying tax reporting and tax obligations in general. Furthermore, the use of blockchain is strictly related to the objective of ensuring the security and integrity of tax data; in this regard, according to scholars, blockchain technology enables the possibility of data structuring and reconciliation to resolve information asymmetry. Other goals are to improve transparency and to share tax information on real-time basis.

At the same time, blockchain application in the tax domain involves several challenges; as seen, confidentiality, environmental sustainability, security, interoperability and reliability of financial reports are the main issues approached by the literature in the field. Nevertheless, only a few scholars synthetize the above results to directly address, at least partially, the fundamental research question on which this article is based (i.e. when to use blockchain for tax).

For instance, Bal (2019) goes in this direction when she argues that "before embarking on blockchain projects, one should consider what added value a blockchain solution will provide and whether there are any alternative solutions (for example, a traditional database) that could achieve the same outcome in a more efficient way".[127] She then explains in which

121. Bonsón & Bednárová, *supra* n. 116, at p. 735; J.G. Coyne & P.L. McMickle, *Can blockchains serve an accounting purpose?*, 14 Journal of Emerging Technologies in Accounting 2, pp. 101-111 (2017).
122. Bonsón & Bednárová, *supra* n. 116, at p. 735.
123. M. Liu, K. Wu & J.J. Xu, *How will blockchain technology impact auditing and accounting: Permissionless versus permissioned blockchain*, 13 Current Issues in auditing 2, pp. A19-A29 (2019); *see also* E. Mik & N. Noked, *Blockchain and Tax Administration: A Critical Assessment*, 50 Australian Tax Review, pp. 180-192 (2021), available at https://ssrn.com/abstract=4077489 (accessed 30 May 2022).
124. Sinha, *supra* n. 120.
125. T. Yu, Z. Lin & Q. Tang, *Blockchain: the introduction and its application in financial accounting*, 29 Journal of Corporate Accounting & Finance 4, pp. 37-47 (2018).
126. *See* Bal, *supra* n. 118.
127. Bal, *supra* n. 86, at para. 2.04.

circumstances a blockchain-based solution may be beneficial by making a list of the most important questions that one should ask while considering the use of blockchain technology (i.e. do you need to store state? are there multiple writers? can you find a trusted third party? are all writers known? are all writers trusted?).[128] In this respect, she concludes that there are serious limitations to the widespread adoption of the blockchain technology in the tax sector; in particular, the use of traditional databases would be preferable "where a trusted entity to manage the information can be found and where warranting confidentiality is an important issue".[129] Consequently, blockchain would have a strong use case where "disintermediation and transparency are more important than performance and confidentiality".[130] These conclusions are based on a negative view of the author about the potential of private blockchain solutions due to a supposed lack of transparency, disintermediation and immutability typical of public blockchains.[131]

Furthermore, Dourado et al. (2022) summarize key information about blockchain application in the tax domain; in particular, they explicitly define five categories where blockchain could be used for tax purposes, including tax collection management, fraud prevention, tax data sharing, tax auditing and tax compliance.[132] The resulting taxonomy has relevance for the scope of the present research, especially to identify the areas where potential new use cases can be developed in the tax sector.

One more relevant contribution is from Yayman (2021), who investigates the use of blockchain technology from a functional perspective. The author argues that "although blockchain is not a remedy for the tax system, it can be applied in many areas to reduce administrative burden, collect taxes at a lower cost and help narrow the tax deficit".[133]

Based on the efforts of these scholars, it may be concluded that the question of when to use blockchain for tax has not yet been answered in a satisfactory manner. Despite the attempts of the aforementioned scholars to address the functional perspective, the authors of the present article do not see a comprehensive and systematic approach to this fundamental issue.

Therefore, starting from the lessons learnt from the existing literature, it is now necessary to move forward with a more granular analysis of when blockchain can be a good solution for tax.

3.2. Preconditions for blockchain implementation

The conceptual analysis of the aforementioned research streams demonstrates the possibility to make one more step forward in an attempt to define a list of factual preconditions where the application of blockchain technology can generally provide benefits for tax. Accordingly, the following preconditions have been identified:

128. Id. For these questions, *see also* K. Wüst & A. Gervais, *Do You Need a Blockchain?*, in 2018 Crypto Valley Conference on Blockchain Technology (CVCBT), pp. 45-54 (2018), available at https://ieeexplore.ieee.org/abstract/document/8525392?casa_token=EruTNathGc0AAAAA:DOj4TgcSngggOJ3aDLF7M1yIy7XBzsRxM9xzBLMoFXOxRrHhmyY774jD4ICDdDU4ZcWscB671Jw (accessed 30 May 2022).
129. Bal, *supra* n. 86, at para. 2.05.
130. Id.
131. Id.
132. Dourado, et al., *supra* n. 81.
133. Yayman, *supra* n. 101, at p. 153.

(1) data that has to be stored centrally is only available on a fragmented basis (disparate data);
(2) there are multiple parties in a complex ecosystem;
(3) there are multiple versions of the "truth" (e.g. paper, PDF documents, fax, email);
(4) there is a lack of trust between parties transacting with each other;
(5) there is a lack of security in transacting with each other; and
(6) there are multiple processes carried out on a manual basis.

This means that the use of blockchain technology may be considered if one or more of these preconditions are fulfilled within the underlying use case.[134] Nonetheless, the use of blockchain technology does not necessarily always have to be the most appropriate fit to tackle a specific problem.[135] In some cases, other technologies or approaches may facilitate solving the same problem in a more efficient or effective way. Furthermore, the above analysis shows that the implementation of blockchain technology always involves relevant challenges since several critical points need to be addressed.[136]

Starting from these premises, as far as the tax domain is concerned, this comes down to the issue of how to approach a particular tax problem.[137] In this regard, there are still a considerable number of tax processes that are performed on a manual basis or paper driven. Manual and paper-driven processes are typically prone to errors or fraud. The main point is if and to what extent the use of technology may facilitate a more robust process.

On the one hand, this goes back to the issue of whether the underlying tax code can be converted into tax law (so-called "computational tax law") and whether legislators should bear in mind the codability of tax law when drafting new legislation. That is a very interesting, albeit separate, research topic.

On the other hand, one more crucial point is whether the problem at hand is a single point-to-point issue (like the filing of a personal or corporate income tax return) or rather an ecosystem issue. As indicated previously by Post,[138] this latter point may require a fundamental rethinking in terms of how tax problems are being tackled. This in particular seems to be relevant in a situation where transacting between parties leads to tax obligations.[139] For example, one can consider the sale of a good which may lead to a VAT filing obligation for the seller. If something goes wrong, one may review the filing done by the seller, which is merely a small piece of an entire value chain. Alternatively, one may also try to take the entire supply chain into account to address the potential tax issues for the ecosystem as a whole. This also implies that the private parties in this ecosystem need to work with the public stakeholders (e.g. tax administrations) to jointly tackle the tax issues at hand. For this, an unprecedented paradigm shift is required.

134. Post, *supra* n. 1.
135. The typical "blockchain hammer" looking for a nail.
136. *See* sec. 3.1.2. In this sense, *see also* Mik & Noked, *supra* n. 123, at p. 184, where the authors suggest that "when considering ways to improve existing systems, we should compare all possible technological solutions (including blockchains) and choose the optimal technology for the specific use".
137. *See* Post, *supra* n. 1.
138. Id.
139. In this context, with tax obligations one may also think of customs obligations.

Based on these considerations, it is evident that the aforementioned preconditions under which blockchain can potentially provide benefits require a more granular analysis when it comes to defining when blockchain is really needed for tax.

For this purpose, first, the main research question will be elaborated on by formulating a series of sub-questions, each one resulting from the consideration of the aforementioned preconditions (hereinafter Q1-Q6).[140] The objective is to explore whether and how these preconditions may interplay with the tax domain and consequently identify those situations where blockchain technology is the proper solution for tax.

Afterwards, the various perspectives will also be addressed when it comes to developing a blockchain-based tax system, including the tax administration's perspective, the taxpayer's perspective and the ecosystem perspective.

3.2.1. Is the data that has to be stored centrally only available on a fragmented basis (disparate data)? (Q1)

Very often, tax processes are seen where the relevant data is only available on a fragmented basis and several parties each own a particular piece of information. This may occur in the situation where suppliers can only look down or up in their respective supply chain to their direct suppliers and customers. But also other examples in the area of withholding taxes or TP come to mind.

In these scenarios, all parties would benefit from a blockchain-based infrastructure where all the relevant data is equally available in the entire ecosystem, but ideally simultaneously without sharing more information than required (in particular, as it may pertain to commercially sensitive information).

In this set-up it should be noted that a shift to the blockchain may enable the transfer of something of value (e.g. a finite resource) between the parties of the same network. In the world of taxation or customs, such a possibility may open room for more efficiency in the tax assessment and collection processes. For instance, tax or customs filings may be considered something of value as would dividend entitlements or VAT/GST or customs consequences connected to a specific good or service (e.g. origin verification for purposes of applying free trade agreements). Consequently, as long as this data is stored on the distributed ledger of a blockchain network, all parties would benefit from more consistent and reliable evidence of their tax rights and obligations with better results in terms of tax efficiency and legal certainty.

3.2.2. Are there multiple parties in a (complex) ecosystem? (Q2)

The application of blockchain technology requires "ecosystem-thinking". By that, the authors mean that the technology aims to solve an ecosystem problem rather than an individual taxpayer's or tax administration's issue. In fact, looking at how increasingly complex

140. The situations outlined here can be converted into research sub-questions to further develop the main research question of when blockchain is really needed for tax. Hence the reference to Q1, Q2, etc. It should be noted that others use other albeit somewhat similar questions to assess whether you need a blockchain. *See*, e.g., D.L. Shrier, *Basic Blockchain*, p. 49 (Robinson 2020), where the screening characteristics are: (i) automation, (ii) repeatable processes, (iii) multiple stakeholders, (iv) reconciliation, (v) value transfer and (vi) immutability.

the global economy has become, for example as a result of globalization, the pandemic, digitalization, geopolitical developments and trade wars, it must undoubtedly be acknowledged that in a lot of situations there is no binary “yes” or “no” answer to a specific problem.[141]

Multiple parties in an ecosystem are dependent on each other in various ways. For example, if a first-tier supplier has issues around demonstrating where a good originates from, this impacts subsequent parties in the supply chain and this may ultimately impact a consumer’s choice to potentially buy a particular good or service. Also, the aforementioned global developments are typically not siloed but rather integrated into an entire business process.

With regard to the world of taxation, it is key to differentiate between situations where, for example, a taxpayer is dealing directly with the tax authorities (e.g. when filing an income tax return electronically) or when a taxpayer is part of a larger group of parties transacting with each other (e.g. in a supply chain where VAT/GST is due on the transfer of goods). In the first situation, there is typically no direct need to consider blockchain technology to help enhance the income tax compliance process, whereas in the latter situation blockchain may very well facilitate a more robust and transparent tax process that is less prone to fraud or errors.

This also implies that from a behavioural economics perspective, parties in that ecosystem jointly benefit from collaborating in that same ecosystem. And, as may be appreciated, multiple shades of gray may be identified in between these two examples, depending on the specific tax system at hand.[142]

3.2.3. Are there multiple versions of the “truth”? (Q3)

It should not be a surprise that the tax process often contains multiple versions of the truth. This can have several reasons, but mostly it has to do with either (i) multiple “hand-over points” which lead to a potential lack in the quality of data, or (ii) the multiple formats of the same information that are being used.

Also, although tax administrations are also focusing on digitalization and the future of tax administration,[143] in many instances certain tax processes are still paper-based processes that are subject to errors and prone to fraud. The “technology maturity” also differs from a taxpayer’s perspective as taxpayers may be using email, PDF documents, paper, or fax simultaneously.

Evidently, the use of multiple versions of the truth does not lead to trust in the data. In this respect, blockchain technology can have a profound impact on the way data is stored, enabling parties to access the same version of the truth on the distributed ledger.

141. One may also refer to this as a VUCA world. VUCA stands for volatility, uncertainty, complexity and ambiguity and is a term that is often used to describe the challenging contexts many parties are encountering in an era of transformational change and disruption.
142. It is interesting to note that the sub-question here formulated (i.e. are there multiple parties in a complex ecosystem?) already found consideration in the previous literature engaged in determining whether blockchain is the right technology to use (*see*, for instance Bal, *supra* n. 86, at para. 2.04, where the author expressly mentions the question “are there multiple writers?”).
143. *See*, for example, OECD, *Digital Transformation Maturity Model*, OECD Maturity Model Series, Forum on Tax Administration (OECD 2021), available at www.oecd.org/tax/forum-on-tax-administration/publications-and-products/digital-transformation-maturity-model.htm (accessed 30 May 2022).

3.2.4. Is there is a lack of trust between parties? (Q4)

One of the key benefits of blockchain technology is that it solves the lack of trust that parties may have in each other.

Counterparty risk may be eliminated or reduced by the terms and conditions embedded in a smart contract. For example, from a trade finance perspective, a smart contract may release the funds to the seller only when the buyers confirm that the respective goods have been released, effectively reducing counterparty risk. Although one may argue that practically speaking it may not be necessary to have blockchain technology to facilitate that, the immutability of the transaction as well as the terms and conditions embedded in the smart contract facilitate that two parties can still rely on the information that is exchanged via the blockchain under the predetermined conditions.

Despite the rise of various cooperative compliance programs across the globe, in which mutual trust between taxpayers and tax administrations is one of the key elements, it is not uncommon that there can be a lack of trust between taxpayers and the tax administration. But there may also be a clear lack of trust or unwillingness to collaborate between taxpayers that are part of the same supply chain or ecosystem, for example for commercial reasons or in the case of dissenting motives (willingly or unwillingly).

In this context, blockchain technology will facilitate the trust between these parties due to the embedded systemic transfer and sharing of data as described in section 2.

3.2.5. Is there a lack of security in transacting with each other? (Q5)

The potential lack of security in transacting with each other is closely connected to some of the aforementioned preconditions.

Blockchain technology facilitates the secure transfer of information between parties.[144] Additional applications such as ZKP technology (essentially privacy-preserving technology) may also allow for the transfer of commercially sensitive and/or private data. Considering that all participants on the blockchain generally have access to the same information and keep the same system of records, it generally works more securely than a traditional and centralized database (e.g. from a tax administration).

In addition, blockchain transactions are in principle immutable, which should also provide for more security in the sense that the transactional data cannot be tampered with.

3.2.6. Are there multiple processes carried out on a manual basis? (Q6)

Most tax functions still require large numbers of employees with multiple processes carried out on a manual basis. The process for calculating taxes is still very process oriented and carried out on a manual basis involving risks of inefficiency and errors. Tax departments spend a lot of time doing manually oriented tasks to support the tax compliance process. For example, they may manually issue VAT invoices, engage in fulfilling repeated requests for information and data from within their own organizations' business lines, and/or make

144. Although the blockchain itself can typically be considered secure, this does not imply that wallet holders that are transacting on blockchains are not subject to cyber-attacks and potential hacks.

adjustments or reconciliations between their financial statements, their tax returns, and the filing systems of the tax authorities of the countries in which they operate.

A blockchain-based system for recording taxes and automating payments may help to automate existing manual processes, thus saving costs and time for all the parties involved. This way, the tax filing process may be expedited, and quality and consistency can be enhanced by reducing the likelihood of manual errors. In particular, smart contract protocols running on the blockchain could enable to convert agreements into a self-executing code, obviating manual execution.

3.3. Different perspectives of participating in a blockchain-based tax system

3.3.1. Key premises

For the purposes of this research, it is also important to address the various perspectives when it comes to participating in a blockchain-based tax system. Public stakeholders may have different and potentially conflicting incentives compared to those of the private stakeholders and jointly they may also share the ecosystem benefits.

These various perspectives are key to understanding when parties may wish to consider developing a blockchain-based tax system.

On the one hand, the adherence to a (new) tax system, in general, is crucial for adoption by taxpayers. Various elements may come into play here, such as the user-friendliness of the system, preservation of taxpayer's rights, digital inclusiveness of all parties that need to ultimately use the system, and belief in the system itself. Mandatory enforcement of a blockchain-based tax system (albeit possible) may not always be the preferred route and may be detrimental to the adoption of that system.

On the other hand, if taxpayers themselves decide to develop a blockchain-based platform without the possibility for tax administrations to participate, this may create tension between a trustworthy system aiming to facilitate transparency for all parties in the ecosystem and tax administrations not having access to this more efficient and effective system. Although tax administrations may have the possibility to enforce data visibility, it is clear that this may create tension and dissenting views in terms of the contemplated aim of such a platform.

Taxpayers and tax administrations, therefore, need to strike a balance between their benefits and needs versus those of the opposite party. By acknowledging that the interests of the ecosystem may be greater than the individual needs of the participants, an incentive to collaborate may emerge. It is therefore imperative that the potential ecosystem benefits are properly identified.

In this respect, a comparison may be made with cooperative compliance programs. Some countries have implemented cooperative compliance programs where participation from taxpayers is voluntary. However, participation does lead to certain rights and obligations as well as benefits and potential disadvantages for both taxpayers and the tax administration. In such a system, both parties will balance all these underlying rights and obligations, benefits and disadvantages to determine whether it is preferable to participate. Something similar may also occur in the situation of a blockchain-based tax system. All relevant parties, therefore, need to strike a balance between all aspects involved.

Below, the authors will further outline the potential tax administration's perspective of participating in a blockchain-based tax system as well as the taxpayer's perspective. Lastly, the ecosystem perspective will be briefly highlighted.

3.3.2. The tax administration's perspective

It seems evident that tax administrations across the globe would benefit from more robust tax systems based on blockchain technology. Some of the imminent benefits of a blockchain-based tax system for tax administrations may include:

- Digitalization in general: it is evident tax administrations need to advance their digitalization strategy to keep up with the large volume of transactions they are dealing with, the increasing complexity of tax law and execution thereof, digitalization trends in general, as well the lack of capacity they are facing to deal with all these developments. The OECD has issued the roadmap on Tax Administration 3.0;[145] however, surprisingly enough the potential of using blockchain technology is not adequately explored in this report.[146]
- Visibility and transparency: tax administrations typically do not have a clear oversight of the entire ecosystem or value chain beyond intercompany transactions and what, for example, may be documented in TP documentation or ends up in a VAT/GST tax return. Blockchain may increase that visibility and transparency.
- Immutability: although the principle of "garbage in, garbage out" also applies with respect to blockchain, the immutable nature of a blockchain provides for tamper-proof data, which ultimately may increase trust in the underlying data.
- Prevention of fraud: many taxes are subject to fraud on a large scale. As a consequence, tax administrations are missing out on tax revenue on a global basis. Striking examples are the amounts involved in VAT fraud in the European Union (estimated at EUR 134 billion in 2019[147]) and the challenges around dividend withholding taxes due (estimated to amount to EUR 8.4 billion in the European Union alone).[148] Within a blockchain-based tax system, the introduction of a split payment during the VAT payment process – with the correct VAT amount calculated directly at source – is an interesting example of how blockchain could prevent fraud. Furthermore, the combined use of inbound hardware oracles (such as electronic sensors, QR scanners, or other information-reading devices) enables the interaction with external sources to verify the authenticity and validity of data from the real world. This way, blockchain can be used

145. OECD, *supra* n. 1. *See also* Post, *supra* n. 1.
146. In the updated report, OECD, *Tax Administration 3.0: Action Plan Update* (OECD 2022), there is only minor reference to blockchain as it pertains to Action 7: Knowledge sharing. The report is available at https://www.oecd.org/tax/forum-on-tax-administration/publications-and-products/tax-administration-3-0-action-plan-update.pdf (accessed 30 May 2022).
147. More information is available at https://ec.europa.eu/taxation_customs/news/vat-gap-eu-countries-lost-eu134-billion-vat-revenues-2019-2021-12-02_en (accessed 30 May 2022).
148. *See* European Commission, *Report from the Commission to the Council and the European Parliament – Accelerating the capital markets union: addressing national barriers to capital flows* (European Commission 2016), available at https://ec.europa.eu/transparency/documents-register/detail?ref=COM(2017)147&lang=en (accessed 30 May 2022); *see also* EY, *What happens when government, industry and investors seek common digital ground?* (EY 2021), available at https://assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/tax/tax-pdfs/ey-withholding-tax-distributed-ledger-report.pdf (accessed 30 May 2022).

to prevent carousel frauds to ensure that the transfer of physical assets is really taking place as reported in the distributed ledger.

– Faster and better tax audits (near real-time taxation): in a situation where tax administrations would for instance participate on the blockchain (e.g. as a node) they could potentially get access to all the underlying transactions in a better, more efficient manner, which would also allow them to perform faster and better audits. This obviously has benefits for both taxpayers and tax administrations (faster certainty and closure of a period, no/less after-the-fact inquiries).

3.3.3. The taxpayer's perspective

For taxpayers there obviously also needs to be an incentive to participate in a blockchain-based tax system (assuming the use of the platform is not legally enforced and mandatory to join).

Clearly, taxpayers would be incentivized to join the new system as long as they can benefit from some of the aforementioned features, such as:

– Near real-time taxation allows for faster insights into the tax position of a company, thus enabling the tax function at companies to act faster and more directly.
– Many tax functions in companies are facing similar issues: data is increasingly available at a transactional level; however, human intervention is required in many instances.
– Considering the gradual shift in tax administrations towards digitalization, companies are required to take better control of the quality of their tax data.
– Given the rapidly changing local laws and compliance obligations in a global economy, taxpayers need to be able to rely on trustworthy technology to help adapt and comply with new measures in a more efficient and effective way. As blockchain solves the issue of data reconciliation, taxpayers can rely on a single source of truth with databases of updated tax rules. In particular, blockchain additional tools, such as software oracles, make it possible for smart contracts to interact in real time with online databases including tax rules for determining the taxable base and the tax rate. This way, a blockchain solution can simplify the issue of tax compliance for taxpayers as long as software oracles play the role of agents who check applicable tax rules from reliable and updated databases.
– Increased transparency in the ecosystem: also, taxpayers currently cannot always oversee or control what is happening in the entire supply chain.
– Manual reconciliations can be eliminated and contracts, audits and reporting can be automated.
– One single, immutable version of the truth can be accessible at the same time to all authorized stakeholders to reduce the potential for fraud (which is not only an issue for tax administrations).
– Data accuracy can be increased, real-time analytics can be enabled, and siloed systems and processes can be integrated into a single environment.

– Less (tax) litigation: if all parties in an ecosystem can have access to the same data and the same version of the truth, this helps to avoid or reduce any potential (tax or legal) conflict over these data and its legal or tax implications.

As highlighted above, in a business environment, blockchain can typically address several of the typical business process symptoms. For example, with blockchain it is no longer necessary to use multiple databases for the same information. Also, less or no reconciliation is required, and manual and paper processes are being reduced to a minimum. In addition, operational and counterparty risks can be eliminated via algorithms built into smart contracts, whereby tax may (at a certain point in the future) be paid directly, at the moment at which the debtor pays to the creditor. So, clearly, connecting the benefits of blockchain technology with some of the typical and recurring elements in a taxing process makes a compelling use case to be explored further.

However, the authors would still like to emphasize that these benefits should be viewed in close conjunction with the sub-questions highlighted in section 3.2. Consequently, although technology may still facilitate improvement of the "point-to-point" relationship between a taxpayer and the tax administration, this does not imply that blockchain technology per se is the best solution in this process. For this, the referred sub-questions still need to be addressed.

3.3.4. The ecosystem perspective

The ecosystem benefits that may be achieved by implementing a blockchain-based tax system should be incremental to the sum of the benefits for the tax administration and the taxpayer.

One may argue there is a behavioural economics or game theory aspect to participating in such an ecosystem, where it is clearly beneficial to the ecosystem as a whole if all participants join, but also if all parties work together to achieve these ecosystem benefits.

As mentioned earlier in this article, these potential mutual benefits may converge in almost a similar way as with a cooperative compliance program. Both taxpayers and tax administrations need to be sufficiently aware and committed to their mutual rights and obligations, where ultimately every party contributes and, more importantly, benefits from collaboration within the ecosystem. As an example, if tax administrations and taxpayers would work together in a blockchain-based VAT system, all of the aforementioned respective benefits may occur, whilst at the same time they may be clear benefits for the society as a whole if tax revenues would increase, which would potentially allow countries to decrease their external borrowing, increase welfare benefits, or provide other forms of fiscal stimulus.

The authors fully appreciate that this is easier said than done. Companies themselves have enough challenges and issues around a particular tax that does not make it imminent per se to work with others (let alone tax administrations) to actually potentially solve or reduce that problem.

The same line of reasoning *mutatis mutandis* applies to tax administrations. Clearly it requires a paradigm shift in thinking from both tax administrations and taxpayers to realize that working together is in their best interest.[149] In the authors' view, this is one of the most complex aspects of bootstrapping a blockchain ecosystem, in particular given the opposite roles that private and public stakeholders ultimately have.

4. Empirical Overview of Existing Blockchain and Tax Initiatives

4.1. The empirical practical perspective

In recent years, some public authorities and private entities across the globe have begun to develop targeted use cases to exploit the concrete possibilities of blockchain technology within the tax field. The declared objective is to improve the efficiency in the tax assessment and collection process, as well as to simplify the reporting obligations and the compliance efforts from taxpayers.

These projects (mostly in a proof-of-concept or pilot phase) have a fundamental relevance for the scope of the present research. Their extensive review offers a unique opportunity to jump into the real world and measure the distance between theory and practice. In particular, the analysis of these projects can help to better address the research sub-questions included in the previous section (Q1-Q6) and consequently identify in practice under which preconditions blockchain technology is the most appropriate fit to tackle a specific problem based on the parameter of tax efficiency.

In this context, the empirical analysis of the existing blockchain and tax efforts becomes a fundamental step as it offers the possibility to focus on observation and experience rather than on theory and pure logic.

On these premises, the present section first aims to analyse the empirical practical perspective based on the current pilot projects in the blockchain and tax domain and verify whether and how these projects address the aforementioned sub-questions. The ultimate objective is to identify under which preconditions blockchain technology concretely provides additional benefits compared to other existing technologies; in other terms, whether or not blockchain technology is really needed with respect to each of the mentioned sub-questions (Q1-Q6).

To ensure a systematic approach, the analysis is organized by considering each pilot project under a specific sub-area within tax law studies; accordingly, the review includes subsections dedicated to the exchange of taxpayers' information, withholding tax, TP, VAT, customs and excise, respectively.[150]

149. As indicated, this goes down the path of behavioural economics and game theory. This article will not address this topic further but it may be further explored in subsequent research.

150. It should be noted that the authors have not been able to verify the current status of all of the projects referred to in this section. So, it may very well be that some of these projects have been either seized or paused or not risen beyond the point described in this section. Furthermore, it should be noted that several of the use cases described in this section have also been published in Appendix 1 of the recent report from the Global Blockchain Business Council on global taxation, which contains a comprehensive overview of blockchain-based tax systems. Consequently, the footnotes of this section include several references to some of the conclusions of that report; *see* Global Blockchain Business Council (GBBC), *Global Standards Mapping Initiative (GSMI) 2.0, standalone report on Global Taxation* (GBBC 2021), available at https://gbbcouncil.org/wp-content/uploads/2021/11/Global-Taxation_GSMI2_Standalone_GBBC_.pdf (accessed 30 May 2022) [hereinafter GBBC report].

4.2. Exchange of taxpayers' information

The first group of pilot projects resulting from the research is focused on the implementation of blockchain technology for the exchange of tax information between governmental bodies. In this regard, some Latin American countries have already explored the DLT possibilities by creating blockchain-based registries to store taxpayers' information.

Argentina recently introduced a tax registry (the so-called "Registro Unico Tributario – Padrén Federal (RUT)")[151] that makes use of blockchain to allow data transfer between national tax authorities through an advanced coding system. In this case, the transfer of data occurs securely as users can access the registry only with a third-level secure code.[152]

In the same way, Brazil implemented a blockchain-based system, called "Blockchain do Cadastro de Pessoas Fisicas" (bCPF), to share data from the registry of individual taxpayers between tax and regulatory institutions of the three levels of government (federal, state and municipal).[153] The registry exploits blockchain technology based on an auditable open-source software running on a network to which only authorized institutions can participate.[154]

In both these cases, the use of blockchain technology is addressed to solve issues related to some of the sub-questions included in section 3. This is clear for Q1 since the Argentinian and Brazilian tax authorities focus on the use of blockchain to face the problem of disparate data. In the same way, the Latin American experience shows how blockchain technology can solve the issues associated with multiple parties in a complex ecosystem (Q2), multiple versions of the "truth" (Q3), and lack of trust between parties (Q4) thanks to the embedded systemic transfer and sharing of data.

151. AR: Administración Federal de Ingresos Públicos, Resolución General 4624/2019 del 4 Nov. 2019 "Registro Unico Tributario – Padrón Federal" [hereinafter RG 4624/2019].
152. AR: Ministerio de Economía Política Tributaria Armonización Tributaria Provincial, Registro Único Tributario – Padrón Federal, available at https://www.argentina.gob.ar/economia/politicatributaria/armonizacion/registrounicotributario (accessed 30 May 2022). Among the main data stored in the registry, national provisions refer to the taxpayer identification code, mailing and electronic addresses, declared activities, tax regimes applied, total gross income, as well as other information on income and municipal tax. *See* art. 3 RG 4624/2019. For more information *see* the GBBC report, *supra* n. 150, at p. 25; ATER – Administradora Tributaria de Entre Ríos, *En noviembre entra en vigencia el Registro Único Tributario – Padrón Federal* (ATER 2019), available at http://ater.gob.ar/ater2/NoticiasV2.asp?ID=302 (accessed 30 May 2022); Secretaría de Comunicación – Gobierno de Entre Ríos, A*TER suma el Registro Único Tributario – Padrón Federal para los contribuyentes del convenio multilateral* (2019), available at https://noticias.entrerios.gov.ar/notas/ater-suma-el-registro-nico-tributario-padrn-federal-para-los-contribuyentes-del-convenio-multilateral.htm (accessed 30 May 2022).
153. Laws of Brazil, *Blockchain Adopted by Brazil's Tax Authority* (Laws of Brazil 2018), https://lawsofbrazil.com/2018/11/29/blockchain-adopted-by-brazils-tax-authority/ (accessed 30 May 2022); *see also* the GBBC report, *supra* n. 150, at p. 25; M.C. Rocha, M. Monteiro & G. Potenza, *Ordinance Determines That The Federal Revenue Service Shall Adopt A Data-Sharing Mechanism Through Permitted Blockchain* (2018), available at https://www.mondaq.com/brazil/fin-tech/758934/ordinance-determines-that-the-federal-revenue-service-shall-adopt-a-data-sharing-mechanism-through-permitted-blockchain (accessed 30 May 2022); T. Miles, *IRS Launches New Blockchain Platform to Share Data from All People and Companies in Brazil* (Bulletin Bits 2021), available at https://bulletinbits.com/irs-launches-new-blockchain-platform-to-share-data-from-all-people-and-companies-in-brazil/ (accessed 30 May 2022); A. Collosa, *Blockchain in Tax Administrations* (CIAT 2021), available at https://ciat.org/blockchain-in-tax-administrations/?lang=en (accessed 30 May 2022).
154. Centro Interamericano de Administraciones Tributarias – CIAT, *Las TIC como Herramienta Estratégica para Potenciar la Eficiencia de las Administraciones Tributarias* (CIAT 2020), available at https://www.ciat.org/las-tic-como-herramienta-estrategica-para-potenciar-la-eficiencia-de-las-administraciones-tributarias/ (accessed 30 May 2022);

Nonetheless, a closer look at the features of these pilot projects shows that the related infrastructure for the exchange of taxpayers' information is nothing more than a distributed ledger for data sharing. Accordingly, these solutions do not seem to fully exploit the potential of blockchain, especially considering the absence of cryptographic hash functions and smart contracts. Consequently, there do not seem to be any concrete benefits for situations where there is a lack of security in the transactions (Q5) or where multiple tax processes are carried out on a manual basis (Q6).

Besides the Latin American experience, the case of Estonia is extremely important to understand the potential of blockchain technology as far as tax information exchange is concerned. This country makes use of a highly sophisticated digital infrastructure running on an open-source platform called X-Road.[155] To ensure secure transfers within X-Road, all incoming data is authenticated and logged, while all outgoing data is digitally signed and encrypted.[156] X-Road connects different information systems and can be scaled up as new e-services and new platforms are realized.[157] This way, X-Road creates a common layer where tax information exchange is possible.[158]

Nevertheless, the X-Road platform cannot guarantee data safety since the information written into the database can be hacked, modified, or deleted. To overcome the data integrity issue, Guardtime – a Switzerland-based company – developed a permissioned Keyless Signature Infrastructure (KSI) blockchain technology that uses a distributed consensus protocol with a limited number of participants. The main feature of the KSI blockchain is a one-way hash function cryptography[159] converting the original data from X-Road into unique hash values and creating a fully verifiable security proof.[160] This means that the user interacts with the KSI blockchain by submitting a hash value of the data to be stored into the KSI infrastructure; afterwards, the system sends back to the user a signature which provides cryptographic proof of the time of signature, the integrity of the signed data, as well as attribution of origin.[161] Each data is marked with "a fingerprint", being a unique and unre-

155. *See* the GBBC report, *supra* n. 150, at p. 22.
156. Lina Network, *How has Estonia applied Blockchain technology to the e-Government system?* (Lina Network 2020), available at https://lina.network/how-has-estonia-applied-blockchain-technology-to-the-e-government-system/ (accessed 30 May 2022).
157. GovChain, *X-Road and KSI Blockchain* (GovChain 2020), available at https://govchain.world/estonia/ (accessed 30 May 2022).
158. N. Heller, *Estonia, the digital republic* (The New Yorker 2017), available at http://governance40.com/wp-content/uploads/2018/12/Estonia-the-Digital-Republic-The-New-Yorker.pdf (accessed 30 May 2022).
159. The hash can be defined as an alphanumeric code produced by an algorithm that takes the name of "hash function". The hash function is able, starting from a document of any size, to produce a fixed and unrepeatable measurement code that will constitute the fingerprint of that document.
160. R. Prinsloo, *Blockchain: Business Models and Applications* (ResearchGate 2021), available at https://www.researchgate.net/profile/Remo-Prinsloo/publication/351306399_Blockchain_Business_Models_and_Applications_Govtech_Digitisation_Enablers_Blockchain_and_the_Estcoin/links/6091164fa6fdccaebd079073/Blockchain-Business-Models-and-Applications-Govtech-Digitisation-Enablers-Blockchain-and-the-Estcoin.pdf (accessed 30 May 2022).
161. Diritto & Diritti, *Il rapporto fra Blockchain e GDPR nelle strategie di e-government: uno studio sulla protezione dei dati*, (Diritto & Diritti 2019), available at https://www.diritto.it/il-rapporto-fra-blockchain-e-gdpr-nelle-strategie-di-e-government-uno-studio-sulla-protezione-dei-dati/ (accessed 30 May 2022). *See also* R.D. Bishop, *Introduction to Guardtime and KSI Blockchain* (Guardtime 2020), available at https://cred-c.org/sites/default/files/slides/PNW-IW17_7.2_Bishop_Panel2_Emerging-Tech_Keyless-Signature.pdf (accessed 30 May 2022).

peatable signature.[162] This way, data never leaves the X-Road platform; only a hash is sent to the KSI blockchain service while the data continues to be stored in the traditional form.[163]

Since all information on X-Road is anchored to its unrepeatable signature entered on the blockchain, a real-time control allows to detect and inhibit any fraudulent attempt to alter or delete the information. The final result is that history stored into X-Road cannot be altered and the authenticity of the electronic data can be mathematically proven. As a consequence, the KSI blockchain can be used to create legal proof of existence for any digital records.

This also makes it possible to address the security issue raised by the literature in the field.[164] In this respect, the use of the hashing function should exclude – or at least minimize – the risk of unauthorized tampering or data alteration.

Furthermore, as only hashes are stored on the distributed ledger, the KSI system grows linearly with time and regardless of the number of transactions. This represents a major shift from the traditional blockchain approach where the network grows linearly based on the number of transactions. Consequently, the KSI blockchain can easily scale and grow to provide immutability for a very large amount of data.[165]

One more important advantage of the Estonian KSI solution seems to be that the number of participants in the network consensus protocol is limited. This way, it is finally possible to achieve consensus synchronously in only one second by using a proof-of-authority (PoA) based on the aggregation of hashes[166] and without the need for PoW.[167] The latter feature represents a major shift for the Estonian KSI solution with reference to the environmental issue raised by scholars;[168] the departure from the PoW consensus mechanism, which is typical of blockchain-based digital currencies such as bitcoin, makes it possible to address one fundamental critical point dealing with environmental sustainability and scalability. In this sense, the implementation of a new consensus protocol based on PoA does not require computationally intensive activities, thus allowing for better results in terms of cost-effectiveness and environment. In this respect, it should also be noted that other alternatives are seen to be emerging, such as so-called "layer 2" solutions. These are essentially scaling solutions built on top of the blockchain that execute smart contracts and transactions whilst maintaining the full security of the blockchain (i.e. layer 1) itself.

However, given the aforementioned features, the Estonian blockchain-based solution is not used to set up a shared registry where taxpayers' data is stored; the blockchain network here becomes a tool exclusively aimed at ensuring the integrity of certain data that

162. T. Lyons, *EU Blockchain Observatory and Forum, Workshop Report. Government Services and Digital Identity*, p. 7 (EU Blockchain and Observatory Forum 2018), available at https://www.eublockchainforum.eu/sites/default/files/reports/workshop_3_report_-_government_services2fdigital_id.pdf (accessed 30 May 2022).
163. P. Martinson, *Estonia – the Digital Republic Secured by Blockchain*, pp. 1-12 (PricewaterhouseCoopers 2019), available at https://www.pwc.com/gx/en/services/legal/tech/assets/estonia-the-digital-republic-secured-by-blockchain.pdf (accessed 30 May 2022).
164. Sinha, *supra* n. 120.
165. Guardtime, *Keyless Signature Infrastructure – Massive-Scale System Integrity* (Guardtime 2015), available at https://m.guardtime.com/files/KSI_data_sheet_201509.pdf (accessed 30 May 2022).
166. For more information, *see also* K. Nicolaou-Manias & Y. Wu, U*sing Distributed Ledger Technologies to Improve and Maximise the Collection of Property Taxes*, 105 Tax Notes Intl. 11, pp. 1283-1299 (2021).
167. Guardtime, *supra* n. 165.
168. Garanina, Ranta & Dumay, *supra* n. 118; Kokina, Mancha & Pachamanova, *supra* n. 119.

is stored on a more traditional platform. Therefore, it can be concluded that the Estonian blockchain-based solution is more specifically intended to facilitate the secure transfer of information between parties (Q5) and, as an indirect consequence, also to address the lack of trust of these parties in transacting with each other (Q4). This distinguishing feature makes a difference for GDPR and privacy rules. In fact, as no taxpayer's data is stored on the distributed ledger, it is possible to remove it at any time in accordance with the right to be forgotten.[169]

Apart from this, it results that the Estonian KSI solution does not address all the other sub-questions included in section 3. In this sense, as only hashes are stored on the distributed ledger, the use of a blockchain network is not intended here to tackle a situation where data is only available on a fragmented basis (Q1), or where there are multiple parties in a complex ecosystem (Q2), multiple versions of the "truth" (Q3), or multiple tax processes carried out on a manual basis (Q6).

4.3. Withholding tax

Withholding tax is a key area for the development of blockchain-based solutions. In this context, EY has recently announced the first results of a blockchain project involving a partnership with a multinational team of financial institutions, tax authorities and academics. The system developed in this project, which is called TaxGrid, aims to address certain inefficiencies and complexities in cross-border withholding tax systems,[170] by building a shared record book of dividend transactions between financial intermediaries and tax agencies.[171] The objective is to allocate investor dividend entitlements and associated withholding tax across multiple tiers of financial intermediaries. Within this system, all participants, including tax authorities, operate as peer nodes on the blockchain network, allowing near real-time transmission of tax data while carefully preserving commercial confidentiality and investor privacy.[172] This way, tax treaty entitlement and income data can be checked and reconciled in near real time between financial intermediaries and tax authorities in an encrypted and secure manner across the network.

In more detail, the TaxGrid project is based on a process called minting, under which the system creates, validates, or stores on the ledger a collection of fungible tokens for each dividend event; each token represents a dividend entitlement for one share of the security. These fungible tokens are then allocated across the network of financial intermediaries through a cascading set of token splits corresponding to the ownership positions in the security for that dividend event. Smart contracts assume a fundamental role in this process; they manage each token split and transfer ensuring that tokens are not subject to "double-spend" and that the total number of tokens is fully accounted for in this cascading process. The cascading sequence of token splits continues until the beneficial owners for withholding tax

169. Diritto & Diritti, *supra* n. 161.
170. EY, *What happens when government, industry and investors seek common digital ground?* (2021), available at https://assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/tax/tax-pdfs/ey-withholding-tax-distributed-ledger-report.pdf (accessed 30 May 2022); *see also* the GBBC report, *supra* n. 150, at p. 29.
171. According to EY, this system can "automate, decentralize and share tax and financial information" in a secure fashion and in near real time to determine the correct withholding treatment on the simulated dividends. *See also* J. Kennedy, *EY tests blockchain for 'near-real-time' cross-border tax compliance* (Silicon Republic 2021), available at https://www.siliconrepublic.com/enterprise/ey-blockchain-taxgrid (accessed 30 May 2022).
172. EY, *supra* n. 170.

purposes have been identified. This step is done by querying the databases of each financial intermediary. As long as a beneficial owner is identified, the fungible tokens representing the entitlement for that beneficial owner are exchanged for a single NFT.[173] Consequently, the fungible tokens are "burned" with no possibility of "double-spend". The NFT is assigned by the financial intermediary that has a direct relationship with that investor and is known only to that financial entity. The NFT provides all the information needed to calculate the withholding tax due without revealing the identity of the investor.[174] Once the cascading process is completed, the remaining fungible tokens are automatically converted into a special type of NFT called "grey token".[175]

TaxGrid also offers additional privacy and encryption through the use of ZKP technology.[176] ZKP makes it possible that a token's private data is replaced with a cryptographic "hash" of that data; this way, the token can be sent anonymously from the sender to the recipient and encrypted proof of this transaction is recorded on the distributed ledger. Under ZKP technology, it is then possible to retain the commercial confidentiality of data on the distributed ledger; in this situation, a third party can rely on the validity of a ZKP transaction, and the correctness of the associated proof can be verified on the distributed ledger.[177] This makes it possible to address the issue of confidentiality raised by the literature in the field.[178] As long as data transactions stored on the ledger are replaced with hashes, the use of ZKP technology makes it possible to preserve transaction verification without revealing private data. At the same time, the security issue is also consistently addressed since blockchain data cannot be easily altered or tampered with.

Based on these technical features, TaxGrid represents a fundamental pilot project for the purposes of withholding tax administration. Once the next stage of commercial production is finalized, it will be possible to demonstrate cross-border investors' entitlement to tax treaty relief based on the data stored on the blockchain, at the same time making sure the correct amount of tax is paid. This way, TaxGrid could provide a reliable and confidential way to share information and documentation on a near real-time basis across a complex network of intermediaries, including fund managers, withholding agents and tax authorities.

Due to the above features, the TaxGrid project seems to address all the sub-questions included in section 3. Under this system, the parties aim to solve the issues related to disparate data (Q1), multiple parties in a complex ecosystem (Q2) and multiple versions of the "truth" (Q3). Furthermore, blockchain is used here to overcome the problem of lack of trust and security (Q4-Q5), as well as to automate multiple tax processes (Q6).

173. Each NFT uses a unique investor identifier, and it has a value equal to the number of fungible tokens that were exchanged.
174. Such information includes the country of residence and the category of the investor to determine any eventual tax treaty eligibility for a reduced withholding tax rate. *See* V. Combs, *EY's new blockchain platform could solve a major tax headache* (Tech Republic 2021), available at https://www.techrepublic.com/article/eys-new-blockchain-platform-could-solve-a-major-tax-headache/ (accessed 30 May 2022).
175. A grey token has a value equal to the number of fungible tokens that were exchanged but does not identify a specific investor.
176. H. Partz, *EY aims to simplify cross-border withholding tax process with blockchain* (Coin Telegraph 2021), available at https://cointelegraph.com/news/ey-aims-to-simplify-cross-border-withholding-tax-process-with-blockchain (accessed 30 May 2022).
177. EY, *supra* n. 170.
178. Cai, *supra* n. 112.

As far as withholding tax is concerned, apart from the TaxGrid project, it is also worth mentioning the project presented by the Netherlands tax administration for payroll tax.[179] Although to the authors' knowledge this project has not risen beyond the proof-of-concept stage, the main scope is to use the data transmitted on the blockchain to calculate and collect payroll tax and then allocate the net payment to the employee. In more detail, the employer and employee sign an agreement based on data and terms. After signature, this agreement is stored on the distributed ledger within a network in which the tax administration also participates as a validating node. At that point, smart contracts execute themselves autonomously without third parties and, consequently, the employer, who usually acts as a government agent by withholding taxes from the payments to the employee's earnings, is removed as an intermediary.[180] Therefore, when the employer makes the gross payment into the system, no more action from him is required; tax data is automatically matched with the payment using smart contract technology to calculate the correct tax and social security due, and only the net payment goes to the employee, while the government automatically collects the tax.[181] This solution provides many benefits as employers have the opportunity to reduce transaction time and save costs.[182]

Also in the context of this project, the automation based on the use of smart contracts offers the opportunity to address all the sub-questions included in section 3. In particular, blockchain is here used to solve the issues related to disparate data (Q1), multiple parties in a complex ecosystem (Q2), multiple versions of the "truth" (Q3), lack of trust between parties (Q4), lack of security in a transaction (Q5) and multiple tax processes carried out on a manual basis (Q6).

Given the pilot projects described above, it is possible to assume that in the withholding tax field the combined use of a distributed ledger, tokens and smart contracts allows the achievement of fundamental results in terms of data safety, automation and efficiency in tax collection.[183]

179. *See* the GBBC report, *supra* n. 150, at p. 23; *see also* Australian Government - Inspector-General of Taxation, *The Future of Tax Profession* (2018), available at https://www.igt.gov.au/investigation-reports/future-of-the-tax-profession/ (accessed 30 May 2022); E. Bassey, *Disruptive Business Models: Challenges and Opportunities for Tax Administration* (IOTA 2018), available at https://www.iota-tax.org/publication/disruptive-business-models-challenges-and-opportunities-tax-administrations (accessed 30 May 2022); J. Li, N. Jin Bao, S. Hu, W. Hu & M. Zerbino, *Digitalization and International Tax Dispute Resolution: A Window of Opportunities for BRITCOM*, 1 Belt and Road Initiative Tax Journal 2, p. 55 (2020), available at http://www.britacom.org/gkzljxz/dzqk/202012/P020201229609118824967.pdf (accessed 30 May 2022).

180. G. Blankestijn, *Blockchain – new roles and ways of interaction*, in *Disruptive Business Models – Challenges and Opportunities for Tax Administrations*, pp. 41-44 (IOTA 2017), available at https://www.iota-tax.org/sites/default/files/publications/public_files/disruptive-business-models.pdf (accessed 30 May 2022).

181. Australian Government - Inspector-General of Taxation, *supra* n. 179, at p. 8.

182. Li et al., *supra* n. 179, at p. 55; Blankestijn, *supra* n. 180. *See also* OECD, *The Sharing and Gig Economy: Effective Taxation of Platform Sellers* (OECD 2019), available at http://www.oecd.org/ctp/the-sharing-and-gig-economy-effective-taxation-of-platform-sellers-574b61f8-en.htm (accessed 30 May 2022).

183. This is also confirmed by the work of some scholars in the field engaged in the development of research ideas for potential solutions in the withholding tax area based on the use of blockchain technology; *see* for instance Hyvärinen, Risius & Friis, *supra* n. 98, where the authors critically assess the potential of blockchain as a solution for managing dividend flows in order to overcome the current problem of refunding illegitimate tax claims in cross-border dividend payment situations in the context of withholding tax. On the topic of payroll tax compliance and blockchain, *see also* Ainsworth & Viitasaari, *supra* n. 96.

4.4. TP

The efficiency and costs of TP control are a major concern on the international tax law agenda. With this in mind, Grant Thornton is developing a blockchain-based platform, which is called "inter.x", whose purpose is to store the details of intra-group transactions in a safe and immutable way to provide visibility and transparency at a group level.[184] This platform makes it possible to register intercompany transactions on the EOSIO blockchain; this way, data can be aggregated across the world in real-time. The result is a permanent and unforgeable audit trail for consistent transaction information.

Inter.x also delivers real-time data-analytics dashboards that monitor intercompany transactions, including TP compliance and treasury management. This allows companies to have more control of their data and make immediate decisions rather than waiting until a monthly or annual accounting cycle.[185] Inter.x is also designed to provide a simple user experience that can red-flag missed opportunities tied to intercompany transactions and identify situations where transactions do not comply with company policies.

These features (if in production) potentially make inter.x a valuable solution to help companies to improve TP compliance. According to Grant Thornton, thanks to inter.x, users no longer need to focus on applying transfer policies and instead can focus on whether those policies make sense.

It can thus be concluded that inter.x addresses several sub-questions included in section 3: first, the associated entities of an multinational (MNE) group can benefit from a situation where all the relevant data is equally available on a real-time basis thus solving the issue of disparate data (Q1); second, blockchain technology overcomes the issue related to the existence of multiple versions of the "truth" (Q3); third, this solution is useful to solve the problem of the lack of trust and security between parties transacting with each other (Q4, Q5).

Nonetheless, the weak point of inter.x is the absence of involvement of tax authorities in the audit process. Tax administrations do not participate in the network as the access to the data stored on the distributed ledger is reserved to the companies of an MNE group. This way, inter.x does not address a situation where there are multiple tax parties in a complex ecosystem (Q2), or multiple tax processes carried out on a manual basis (Q6). Consequently, this remains a solution exclusively focused on internal compliance. In this respect, it may be called into question whether a blockchain solution is the most suitable for that purpose.

4.5. VAT

Several existing projects in the blockchain and tax domain are specifically focused on VAT.

184. Ledger Insights, *Grant Thornton launches blockchain solution for group intercompany transactions, transfer pricing* (Ledger Insights 2020), available at https://www.ledgerinsights.com/grant-thornton-block chain-transfer-pricing-intercompany-transactions/ (accessed 30 May 2022).
185. Grant Thornton, *Grant Thornton moves intercompany transactions to the blockchain* (Grant Thornton 2020), available at https://www.grantthornton.com/library/press-releases/2020/april/GT-moves-intercompany-transactions-blockchain.aspx (accessed 30 May 2022); EOS GO, *Grant Thornton lntercom pany Transactions on EOSIO* (EOS GO 2020), available at https://www.eosgo.io/news/grant-thornton-intercompany-transactions-on-eosio (accessed 30 May 2022).

In 2018, Tencent, which is a Chinese multinational technology company, developed a blockchain-based invoicing platform for transport systems for the city of Shenzhen.[186] The system makes use of a blockchain network to mediate between the invoice recipient, the issuer and tax departments to automate the reimbursement, reporting and circulation process. A similar system has been recently introduced in Beijing.[187] The new platform helps authorities to tackle VAT fraud.[188] In fact, by using blockchain technology, the authenticity and integrity of invoices are guaranteed; this is because blockchain invoices are tamper proof, traceable and credible.[189]

Keeping an eye on Asia, it is worth noting that also Thailand is contributing to a relevant pilot project in the VAT domain. The mobile application called "Thailand VRT" is a fully digital system for VAT refund for tourists by which they can examine the purchase history of goods and services and also VAT refund data in a single click at any time.[190] By using this app, tourists can inspect their VAT refund transactions from their chosen providers via various channels.[191] The blockchain-based service shortens the VAT refund period from about a month to 1-3 days. In this case, blockchain technology also simplifies the document verification process by saving on printing costs and reducing congestion at VAT refund counters.[192] The tourists can choose to get their refunds through credit or at the time of their departure; in the latter case, the customs department will transfer the money back

186. *See* the GBBC report, *supra* n. 150, at p. 22; Ledger Insights, *Tencent enables blockchain invoicing for transport in Shenzhen, China* (Ledger Insights 2019), available at https://www.ledgerinsights.com/tencent-blockchain-invoicing-china/(accessed 30 May 2022); Shenzhen Daily, *City introduces world's 1st international standardization for blockchain e-invoice* (Shenzhen Government Online 2021), available at http://www.sz.gov.cn/en_szgov/news/latest/content/post_8675223.html (accessed 30 May 2022); for the review of this use case, *see also* Yayman, *supra* n. 101, at p. 149; Müller, *supra* n. 83.
187. M. Wight, *China to Use Blockchain-Based System to Tackle Fraudulent Invoices* (Blockchain Land 2020), available at https://theblockchainland.com/2020/03/13/china-blockchain-based-system-fraudulent-invoices/ (accessed 30 May 2022).
188. China is also making some efforts to develop international standards to harmonize the use of blockchain technology for e-invoicing; in this respect, Tencent recently presented its work in cooperation with the China Academy of Information and Communications Technology and Shenzhen's tax bureau to draft an international standard for blockchain invoices.
189. In this regard, Chinese tax authorities recently have encouraged consumers to take the initiative to check the authenticity of the invoices by verifying the invoice information on their official website. In particular, the information recorded in the electronic invoices shall be consistent with the results obtained on that website. Accordingly, consumers have the right to reject electronic invoices with inconsistent results and can consequently inform tax authorities. *See* Authority of Qianhai Shenzen-Hongkong Modern Service Industry Cooperation Zone of Shenzen, *Qianhai to fully promote blockchain invoice* (2019), available at http://www.szqh.com.cn/What_is_News_Promotion_Event/content/post_4430765.html (accessed 5 Aug. 2022); T. Peng, *China Implements Blockchain Invoicing in Beijing for More Transparent Governance* (Coin Telegraph 2020), available at https://cointelegraph.com/news/china-implements-blockchain-invoicing-in-beijing-for-more-transparent-governance (accessed 30 May 2022.
190. *See* the GBBC report, *supra* n. 150, at p. 22; *see also* Thai Revenue Department, *The Revenue Department with cooperation of other alliances has prepared to be the world's first nation to implement Blockchain technology in VAT refund for tourists (VRT) service* (Revenue Department News 2020), available at https://www.rd.go.th/fileadmin/user_upload/news/englishnews10_2563.pdf (accessed 30 May 2022); R. Asquith, *Thailand blockchain VAT refunds* (Avalara 2019), available at https://www.avalara.com/vatlive/en/vat-news/thailand-blockchain-vat-refunds.html (accessed 30 May 2022).
191. Entrepreneurs who are interested in the system can apply by submitting the form requesting approval to issue a VAT refund request via electronic methods. In this case, some requirements are provided for having access to the system; for example, entrepreneurs must be registered with the Thai Revenue Department to sell goods to tourists; they must not have a history of issuing or using unlawful tax invoices and, finally, they must have a real-time electronic connection with the Thai Revenue Department.
192. W. Chantanusornsiri, *Blockchain-led VAT refund app in global debut* (Bangkok Post 2020), available at https://www.bangkokpost.com/business/1838339/blockchain-led-vat-refund-app-in-global-debut (accessed 30 May 2022).

through the channel registered by tourists.[193] Besides VAT refunds for tourists, the Thai Revenue Department is also testing blockchain to track VAT payments and prevent fraud by companies using fake invoices for deductions.[194]

Pilot projects in the VAT area have also been launched in the private sector. In this regard, Microsoft and PwC announced the development of a VAT Fraud Prevention Prototype to enable the implementation of blockchain technology in VAT fraud management.[195] The VAT Fraud Prevention Prototype aims to increase trust, promote transparency, eliminate fraud and reduce reconciliation efforts for society by leveraging the immutable, cryptographically signed and decentralized capabilities of blockchain. This solution focuses on three phases. The first phase is based on information exchange: the objective is to establish the blockchain as a trusted information exchange and logging platform where all transactions are registered and exchanged between different stakeholders. The second phase focuses on how smart contracts can resolve the liquidity problem of the real VAT scenarios; smart contracts are used here to implement automated VAT payments between companies, automatically adjust VAT accounts of companies, automate the VAT returns from the tax administration agencies and minimize the administrative burden of the management of VAT processes for businesses. The third phase moves to the most advanced scenario where business-to-business (B2B) VAT transactions can be done using a cryptocurrency.

The VAT Fraud Prevention Prototype aims to enable a framework where an e-invoice from the sales transaction between supplier and buyer can be used to record transactions on the blockchain with details on the eligible VAT. Based on this approach, all VAT payments are traced in the distributed ledger with details on the VAT balance. The VAT balance is settled automatically at the end of the certain period through smart contracts, and then the amount of VAT due is paid to the tax administration. Banks are members of the network, and all the transactions are implemented through the banking system. Businesses can get immediate returns from the tax administration, gain efficiency in capturing and reporting VAT transactions, and file VAT returns more conveniently saving time and expenses for administrative and accounting services. Tax authorities can have real-time access to VAT transactions, assess VAT compliance, and get reports on VAT collections and pending refunds.

One more use case from the private sector has been developed by a Dutch company named Summitto.[196] This solution involves real-time reporting activities based on blockchain technology to allow tax authorities to perform automated controls on invoices. In this case, a hash function transforms input data (e.g. invoice data) to a fixed-size output (i.e. the hash). The hash function hashes the input data in such a way that the same input data will always

193. TNA, *Thailand to introduce blockchain vat refund for tourists* (Pattaya News 2020), available at https://www.pattayamail.com/thailandnews/thailand-to-introduce-blockchain-vat-refund-for-tourists-284633 (accessed 30 May 2022); *see also* Asia&Pacific, *Thailand to introduce value added tax return via blockchain for tourists* (Asia&Pacific 2020), available at http://www.xinhuanet.com/english/2020-01/15/c_138707326.htm (accessed 30 May 2022).
194. Ledger Insights, *Thai government to use blockchain for VAT refunds, bonds, procurement* (Ledger Insights 2019), available at https://www.ledgerinsights.com/thai-government-blockchain-vat-bonds-procurement/ (accessed 30 May 2022).
195. Microsoft, Pwc & Vertex, *Two practical cases of blockchain for tax compliance* (Microsoft, Pwc & Vertex 2019), available at https://www.pwc.nl/nl/tax/assets/documents/pwc-two-practical-cases-of-blockchain-for-tax-compliance.pdf (accessed 30 May 2022).
196. *See* the GBBC report, *supra* n. 150, at p. 29.

hash to the same random-looking fingerprint. Therefore, in the invoice reporting systems described above, all invoice information is stored in a centralized manner while only hashes are stored on the blockchain network.[197] Based on this mechanism, when a tax authority implements real-time reporting, all companies are required to upload their invoices to the tax authority. This allows the tax authority to "trace" the invoices according to the hashes safely stored on the blockchain and link them to the VAT return. This makes it impossible to report an amount of VAT that does not correspond with the amount of VAT stated on the invoice. Consequently, the VAT solution developed by Summitto helps to combat fraud and improve overall compliance.[198] Furthermore, the extensive use of the hash function is useful to address the issues of confidentiality and data security preserving transaction verification without revealing confidential information.

In this context, it is also worth mentioning the new blockchain-based platform launched by Etisalat, an Abu Dhabi-headquartered telecommunications company.[199] This platform is designed to inspect trade invoices and other trade-related documents to scan for fraudulent and suspicious transactions. Results are posted on a private permissioned blockchain between participant banks, so that a permanent record is created of financed trades, preventing duplication of invoices while also preserving data secrecy.[200]

Given these results, the authors' research confirms that the pilot projects in the VAT area are all at an advanced stage of development. In the case of China and Thailand, the tax authorities are already efficiently exploiting the benefits of blockchain, while in Europe and the United Arab Emirates the private sector is giving a strong push towards a concrete implementation.

However, for the scope of the present research, it should be clear that all the above blockchain-based invoicing systems specifically address all the sub-questions formulated in section 3, facing issues related to data only available on a fragmented basis (Q1), multiple parties in a complex ecosystem (Q2), multiple versions of the truth (Q3), the lack of trust and security in the transactions between parties (Q4, Q5) and the automation of multiple tax processes carried out on a manual basis (Q6).

4.6. Customs

The customs field is characterized by a few projects across the globe involving the use of blockchain technology.

197. Summitto, *Introduction to invoice hashing: securing VAT reporting with cryptography*, Summitto Blog (Summitto 2020), available at https://blog.summitto.com/posts/invoice_fingerprints/ (accessed 30 May 2022).
198. Summitto, *Summitto's real-time reporting pilot is now publicly available!*, Summitto Blog (Summitto 2021), available at https://blog.summitto.com/posts/summittos_real-time_reporting_pilot_is_now_publicly_available/ (accessed 30 May 2022)
199. *See* the GBBC report, *supra* n. 150, at p. 27.
200. ICLG.COM, *UAE welcomes new blockchain platform* (ICLG.COM 2021), available at https://iclg.com/ibr/articles/16377-uae-welcomes-new-blockchain-platform (accessed 30 May 2022); Linklaters, *Linklaters advises Etisalat on new UAE blockchain-based platform to help financial institutions combat fraud and invoice duplication* (Linklaters 2021), available at https://www.linklaters.com/en/about-us/news-and-deals/deals/2021/may/linklaters-advises-etisalat-on-new-uae-blockchain-based-platform (accessed 30 May 2022).

In Latin America, the Mercosur customs authorities are connected by a blockchain network developed by a Brazilian company named Serpro.[201] This system, which is called "bConnect", is used to connect customs in Brazil, Argentina, Paraguay and Uruguay, and it aims to guarantee the authenticity and security of customs data shared between these countries. Data stored in this registry includes information from a network of companies certified by public authorities as authorized economic operators. This system uses a permissioned blockchain developed under an open source platform called "Hyperledger Fabric" so as to limit the nodes having access to the data stored on the ledger and consequently address the issue of blockchain confidentiality as raised by several scholars in the field.[202] Further characteristics involve data protection and consistency, control of members' permissions and access rights, confidential transactions, as well as group transaction visibility control based on cryptographic keys.[203] The latter feature is an example of the efforts made here to address the issue of data security by minimizing the risk of data tampering.

Based on this solution, when a Brazilian company wants to export to a company in Uruguay, the entire customs process is simplified as both companies are registered on bConnect.[204] In this case, all the sub-questions included in section 3. seem to be effectively addressed: data previously stored on a fragmented basis is now safely shared on the distributed ledger on a (near) real-time basis (Q1); the use of blockchain involves multiple parties in a complex ecosystem (Q2) and multiple versions of the "truth" (Q3); there is a focus on the issues related to the lack of trust and security between parties transacting with each other (Q4, Q5) as well as on multiple tax processes previously carried out on a manual basis (Q6).

A similar system has been launched in Georgia to check the authenticity of certificates of origin and the legality of documents submitted for verification.[205] The steps of this blockchain-based process include: (i) issue of a certificate of origin in XML format, (ii) calculation of the corresponding hash; (iii) adding of a signature including the hash to the original XML file; (iv) sending of the hash to Ethereum blockchain; (v) use of smart contracts to receive transaction ID from Ethereum; (vi) check of the transaction validation on the blockchain; (vii) conversion of the transaction ID to QR code; and (viii) adding of the QR code to the certificate of origin in PDF format.[206] Therefore, this system seems to specifically address problems related to the lack of trust between taxpayers and tax authorities (Q4) and the lack of security in transactions (Q5). Apart from this, the use of blockchain technology to share data on a distributed ledger brings some positive benefits also as regards the other questions mentioned in section 3., such as data available only on a fragmented basis (Q1), multiple

201. Portal ERP, *Las aduanas del Mercosur están conectadas por blockchain*, (Noticias ES 2020), available at https://latam.portalerp.com/las-aduanas-del-mercosur-estan-conectadas-por-blockchain (accessed 30 May 2022).
202. Cai, *supra*, n. 112; Coyne & McMickle, *supra* n. 113.
203. R. Mota, *Brazil regulates blockchain in foreign trade systems* (Olhar Digital 2020), available at https://olhardigital.com.br/en/2020/11/30/pro/brasil-regulamenta-blockchain-nos-sistemas-de-comercio-exterior/ (accessed 30 May 2022).
204. M. Lopez, *Brazil wants to build customs connectivity with blockchain* (Contxto 2019), available at https://contxto.com/en/brazil/brazil-build-customs-connectivity-blockchain/ (accessed 30 May 2022).
205. I. Mikhelidze, *Digital Transformation of Georgia Revenue Service*, 1 Belt and Road Initiative Tax Journal 2, p. 23 (2020), available at http://www.britacom.org/gkzljxz/dzqk/202012/P020201229609118824967.pdf (accessed 30 May 2022); MG Law, *Potential of Blockchain Technology in Georgia* (MG Law 2018), available at https://mglaw.ge/2018/10/03/potential-of-blockchain-technology-in-georgia/ (accessed 30 May 2022).
206. Georgian Revenue Service, *New Blockchain Initiative. Issuing Certificate of Origin* (Georgian Revenue Service 2019), available at https://unece.org/fileadmin/DAM/cefact/cf_forums/2019_UK/Conf_SingleWindow/PPT_12_Georgia-Certificate.pdf (accessed 30 May 2022).

parties in a complex ecosystem (Q2), multiple versions of the "truth" (Q3) and multiple tax processes carried out on a manual basis (Q6).

Moving again to East Asia, Singapore Customs have concluded a blockchain trial to prove that trade documents can be issued and verified digitally across two independent systems: the Australian Border Force's Intergovernmental Ledger (ABF's IGL) and Infocomm Media Development Authority's (IMDA) TradeTrust. Under this system, QR codes embedded with unique proofs are inserted into digital certificates of origin enabling immediate verification of authenticity and integrity of various documents,[207] such as the electronic certificate of origin.[208] This system makes transactions "more cost-effective and offers scalability without the need for expensive data exchange infrastructure, lowering barriers to the adoption of paperless cross-border trade".[209] This may (partly) solve the environmental issue considering that no computationally intensive activities are needed under this system. Also, this pilot project is developed within a permissioned blockchain infrastructure under Hyperledger Fabric.[210] It is then possible to conclude that the main focus of this project is to solve the issue of a lack of trust between taxpayers and tax authorities (Q4) and the lack of security in transactions (Q5). On the other hand, there does not seem to be any specific focus on the other sub-questions included in section 3. (Q1, Q2, Q3, and Q6).

Something very similar has also been implemented in South Korea (Korea Rep.). Samsung developed a pilot project related to export clearance in cooperation with several business participants, consisting of exporters, shippers and warehouse operators. During the pilot, the participants shared several types of documents in real time, including the commercial invoice, the packing list, the bill of lading, the booking request or confirmation, and the export declaration.[211] Also, in this case, the project aims to test the feasibility of mutually sharing real-time information between e-commerce, transport companies and the Korea Customs Service. This system makes use of smart contracts to handle transactions under the clearance procedure: required information is collected automatically if the procedure's conditions are satisfied. Therefore, as this technology is implemented at full scale, the process for customs clearance of goods can be simplified through data sharing and the automatic generation of customs declarations.[212] For the scope of this research, it is interesting

207. Australian Border Force (ABF) – Infocomm Media Development Authority of Singapore (IMDA), *Australia and Singapore's blockchain trial shows promising results for reducing transaction costs* (IMDA 2021), available at https://www.imda.gov.sg/news-and-events/Media-Room/Media-Releases/2021/Australia-and-Singapores-blockchain-trial-shows-promising-results-for-reducing-transaction-costs (accessed 30 May 2022).
208. S. Jenkins, *Australia-Singapore trial to simplify cross-border trade a success* (The Mandarin 2021), available at https://www.themandarin.com.au/166372-australia-singapore-trial-to-simplify-cross-border-trade-a-success/ (accessed 30 May 2022); *see also* the GBBC report, *supra* n. 150, at p. 26.
209. Z. Marzouk, *Australia and Singapore complete blockchain trial of cross-border trade* (IT Pro 2021), available at https://www.itpro.co.uk/technology/blockchain/360613/australia-singapore-complete-successful-blockchain-trial (accessed 30 May 2022).
210. FST Media, *Border Force 'pioneers' blockchain goods certification platform with Singapore* (FST Media 2021), available at https://fst.net.au/government-news/border-force-pioneers-blockchain-goods-certification-platform-with-singapore/ (accessed 30 May 2022); *see also* T. Farren, *Australia and Singapore conclude digital verification blockchain pilot* (Coin Telegraph 2021), available at https://cointelegraph.com/news/australia-and-singapore-conclude-digital-verification-blockchain-pilot (accessed 30 May 2022).
211. *See* the GBBC report, *supra* n. 150, at p. 27.
212. T. Kang, *Korea pilots blockchain technology as it prepares for the future* (WCO News 2020), available at https://mag.wcoomd.org/magazine/wco-news-88/korea-pilots-blockchain-technology-as-it-prepares-for-the-future/ (accessed 30 May 2022); Ledger Insights, *Korean Customs Service pilots Blockchain* (Ledger Insights 2018), available at https://www.ledgerinsights.com/korean-customs-service-pilots-blockchain/

to note that in this case, besides the focus on data only available on a fragmented basis (Q1), multiple parties in a complex ecosystem (Q2), multiple versions of the "truth" (Q3) and the lack of trust between these parties (Q4), the project also aims to introduce automation in a situation where multiple tax processes are carried out on a manual basis (Q6). On the other hand, no specific reference is shown to the question about the lack of security in transactions (Q5).

Finally, mention has to be made of the Global Trade Origin blockchain platform (Origin) that is being developed by EY. The aim of this solution – currently still at the proof-of-concept stage – is to increase trust in global trade, allowing importers and suppliers to assert the country of origin of goods on a shared distributed ledger. This way, producers can look upstream to the supply chain to collect reliable information to qualify the traded goods for preferential or non-preferential tax treatment, whilst preserving privacy on commercially sensitive data.[213] It is clear that the Origin platform aims to address all the sub-questions included in section 3. (Q1, Q2, Q3, Q4, Q5 and Q6).

4.7. Excise

Finally, it is necessary to mention one more pilot project in Thailand in the excise field. In this regard, the Thai Excise Department has recently begun to develop a blockchain-based system for assessing the tax returns of oil exports.[214] According to recent reports, this blockchain use case allows collecting excise revenue by helping to identify the price, import duty and tax liability of each imported product.[215] Furthermore, this system helps to determine whether oil is actually exported out of Thailand or if it is circulated for sale domestically.[216] To improve the efficiency and the results in terms of revenue collection, the Excise Department will share a single database to conduct tax audits together with the Revenue Department and the Customs Department. The objective is to concretely face the issue of tax evasion in the excise duty field thanks to the implementation of a synchronized system between different tax authorities in conducting tax audits.[217]

With respect to the sub-questions included in section 3., it is evident that this solution aims to solve the issues related to data only available on a fragmented basis (Q1), multiple parties

(accessed 30 May 2022); S. Das, *Korea Customs Authority to Test Blockchain Clearance System for Imports, Exports* (CCN 2018), available at https://www.ccn.com/korea-customs-authority-to-test-blockchain-clearance-system-for-imports-exports/ (accessed 30 May 2022); M. Huillet, *Korean Customs Service to Develop Full-Scale Blockchain Customs Platform* (Coin Telegraph 2018), available at https://cointelegraph.com/news/korean-customs-service-to-develop-full-scale-blockchain-customs-platform (accessed 30 May 2022);

213. *See* the GBBC report, *supra* n. 150, at p. 29.
214. W. Chantanusornsiri, *Excise opts for blockchain* (Bangkok Post 2020), available at https://www.bangkokpost.com/business/2031099/excise-opts-for-blockchain (accessed 30 May 2022).
215. S. Sinclair, *Thai Excise Department Will Deploy Blockchain Tech to Boost Tax Collection* (Yahoo!finance 2020), available at https://finance.yahoo.com/news/thai-excise-department-deploy-blockchain-101958847.html (accessed 30 May 2022).
216. Coinspeaker, *Thai Excise Department to Integrate Blockchain to Aid in Tax Collection* (Coinspeaker 2020), available at https://www.coinspeaker.com/thai-excise-blockchain-tax-collection/ (accessed 30 May 2022).
217. S. More, T*hai Excise Department is using blockchain to more efficient collect taxes on goods* (The Block 2020), available at https://www.theblockcrypto.com/linked/86892/thai-excise-department-is-using-blockchain-to-more-efficiently-collect-taxes-on-goods (accessed 30 May 2022); Postcrypto.net, *Blockchain as a tax collection solution: Thailand's Ministry of Finance presents new experience* (Postcrypto.net 2021), available at https://postcrypto.net/blockchain-as-a-tax-collection-solution-thailands-ministry-of-finance-presents-new-experience/ (accessed 30 May 2022).

in a complex ecosystem (Q2), the existence of multiple versions of the truth (Q3) and lack of trust between parties transacting with each other (Q4). On the other hand, no specific objective is shown referring to the questions on the lack of security in transactions (Q5) and multiple tax processes carried out on a manual basis (Q6).

4.8. Lessons learnt from the empirical experience

The review of the existing pilot projects confirms that the application of blockchain technology can address the sub-questions formulated in section 3. for the purposes of the conceptual theoretical perspective.

As seen, there are examples where the parties involved can benefit from relevant data equally available on a real-time basis. In all these cases, blockchain is used to overcome a starting situation where data is only available on a fragmented basis (Q1).[218]

There are also several projects whose focus is set on multiple parties operating in a complex ecosystem (Q2).[219]

Furthermore, there are situations where blockchain is used to solve the issues related to multiple versions of the "truth" (Q3),[220] the lack of trust between parties (Q4),[221] or the lack of security (Q5).[222]

Finally, there are also projects that address a situation where multiple tax processes are carried out on a manual basis (Q6) focusing on automation as their main goal.[223] Based on this framework, the last step of the analysis process involves the identification of the preconditions under which blockchain technology can concretely represent a valuable opportunity for tax and provide additional benefits compared to other existing technologies. In other words, based on the parameter of tax efficiency, the main research question, of when to use blockchain for tax, will have to be answered considering the outcomes of this study with reference to each of the formulated sub-questions (Q1-Q6).

218. *See* Argentina and Brazil for exchange of taxpayers' information, TaxGrid for withholding tax, the payroll tax pilot of the Netherlands tax administration, inter.x for transfer pricing, the existing projects on VAT described under sec. 4.5., the solutions developed in Latin America (bConnect), Georgia and Korea (Rep.) for customs duties, EY's Origin platform for customs duties, and the Thai Revenue Department project for excise.
219. *See* the TaxGrid solution for withholding tax, the payroll tax pilot of the Netherlands tax administration, the existing projects on VAT described under sec. 4.5., the bConnect solution for Mercosur, the pilot project of Georgia for customs, the Samsung pilot project developed in Korea (Rep.), EY's Origin platform for customs duties, and the Thai Revenue Department project for excise.
220. *See* Brazil and Argentina for exchange of taxpayers' information, TaxGrid for withholding tax, the Netherlands tax administration project for payroll tax, inter.x for transfer pricing, the existing projects on VAT described under sec. 4.5., the solutions developed in Brazil, Georgia, Korea (Rep.) and by EY's Origin platform for customs duties, and the Thai Revenue Department project for excise.
221. *See* Brazil, Argentina, and Estonia for exchange of taxpayers' information, TaxGrid for withholding tax, the Netherlands tax administration project for payroll tax, inter.x for transfer pricing, as well as all the existing pilots for VAT, customs and excise.
222. *See* the Estonian KSI solution for the exchange of taxpayers' information, the TaxGrid solution for withholding tax, the Netherlands tax administration project for payroll tax, the inter.x solution for transfer pricing, all the existing projects for VAT, the bConnect solution for Mercosur, the solutions developed in Georgia and Singapore for customs, as well as EY's Origin platform for customs duties.
223. *See* the TaxGrid solution for withholding tax, the Netherlands tax administration project for payroll tax, all the existing projects on VAT, the bConnect solution for Mercosur, the pilot project developed in Georgia for customs, the Samsung solution in Korea (Rep.) and EY's Origin platform for customs duties.

For such a purpose, it is necessary to appreciate the projects described above and the sub-questions they address in the light of the blockchain's distinguishing properties outlined in section 2. In other words, it is key to identify the projects where these technical properties are fully exploited to provide additional innovative benefits compared to other existing technologies.

In this regard, there is the possibility to make a clear distinction between projects where only a few blockchain distinguishing properties are exploited and projects where, on the contrary, all such properties are jointly implemented to enable additional and innovative functionalities compared to existing technologies.

For instance, the solutions developed in Argentina and Brazil for the exchange of taxpayers' information do not focus on blockchain properties associated with immutability since they are essentially nothing more than registries of reliable data shared between multiple parties on a (near) real-time basis. In these situations, the use of blockchain mainly aims to enable transparency and availability of real-time information, thus focusing on only two of the three main properties on which this technology is based.

From the technical perspective, one could argue that similar results can also be achieved without the use of blockchain; for example, this could be done by a more simple DLT not involving a cryptographic hash function to link one data block to another. In this respect, when the purpose is the mere sharing of reliable data on a ledger between multiple parties in real time, it is not always easy to justify a choice for blockchain technology.

This leads to the conclusion that a positive answer to Q1, Q2, or Q3 integrates only a basic and starting requirement to consider the use of blockchain technology for tax as an alternative to other existing technologies.

Differently, when the analysis of a tax use case highlights the possibility of a positive answer also for Q4, Q5, Q6 (in addition to one or more of the first three sub-questions Q1, Q2, Q3), it becomes easier to justify a shift to blockchain technology. In these situations, as the technical focus is not only on transparency and availability of real-time information but also on immutability, the use of blockchain makes it possible to overcome any issue related to a lack of trust between parties (Q4). For instance, this is evident for the blockchain-based solutions for VAT where the blockchain immutability solves the problem of the lack of trust between taxpayers and tax authorities. The same considerations can be made for data security (Q5). In this latter case, the use of a cryptographic hash function ensures that data cannot be altered once stored on the blockchain (see for example the case of the Estonian KSI solution where extensive use of the hash function is made). Likewise, as far as the issue of multiple tax processes carried out on a manual basis is concerned (Q6), it is crystal clear that only the specific properties of blockchain technology can enable the automation of the related functions. In this respect, the execution of smart contracts on the blockchain ensures additional functionalities that are not available under all the other existing technologies. An example is the TaxGrid solution developed for withholding tax where the automation of complex tax processes is based on the extensive use of smart contracts running on the blockchain.

Based on these considerations, the main lesson learnt from the analysis of these pilot projects is that the preconditions resulting from a positive answer to Q4, Q5, Q6 provide an additional layer that ensures the full employment of the blockchain's distinguishing properties and, consequently, a solid ground for developing a powerful use case for tax.

Differently, a positive answer to Q1, Q2, Q3 only involves basic preconditions for the use of blockchain for tax; in these latter situations, even though blockchain undoubtedly provides several valued benefits, it should be considered that, depending on the circumstances of the case, other technologies might facilitate solving the same problem in a more efficient or effective way.

Besides, the analysis of the above pilot projects also reveals that the empirical experience is addressing only a few of the critical points raised by the literature about the use of blockchain in the tax domain.

In this sense, while the issues of confidentiality, environmental sustainability and security find adequate consideration in at least some of the above use cases, the authors have not been able to identify examples in practice whose main scope is to face the issues related to the existence of multiple blockchain databases and the reliability of financial reports.

In the first case, the recent implementation of less energy-intensive consensus protocols (e.g. PoA and PoS) provides sufficient evidence of how blockchain technology is currently developing rapidly in a sustainable way in terms of confidentiality, environment preservation and security.

In the second case, it is worth noting that the reviewed pilot projects do not contemplate any strategy to adopt a uniform blockchain standard at the international level and consequently do not tackle the risk of multiple duplicate blockchain databases. Furthermore, these projects do not include any tools (e.g. oracles) to assure the reliability of the company's financial reports and the alignment of blockchain data with the non-digital world. These are all major critical points that still need to be addressed in the practical experience in order to comprehensively explore the blockchain potential in the tax domain.

5. Exploring Scenarios for New Tax Use Cases

5.1. Key premises

As seen in the previous section, the picture of blockchain technology in the tax field includes a certain number of pilot experiments, each one at a different stage of advancement. In this regard, several tax administrations already put in place some interesting use cases to exploit the potential of this technology; besides, also the private sector is directly involved in pilot projects with companies assuming a leading role in the development of blockchain-based protocols for tax purposes.

Nonetheless, it has been made clear that a more detailed analysis of these projects can show where blockchain really makes the difference. In this sense, in approaching the sub-questions included in section 3., the empirical perspective shows additional benefits from the use of blockchain with respect to situations involving lack of trust (Q4) and/or security (Q5), as well as when there is the need to automate multiple tax processes carried out on a manual basis (Q6). In all these cases, the blockchain properties associated with immutability open room for new solutions within the tax domain compared to other existing technologies where data immutability is not ensured in the same way.

Starting from this framework, the authors strongly believe that a powerful blockchain-based use case in the tax domain should show its capability to address all the sub-questions included in section 3. (Q1-Q6) and not only a few of them.

Furthermore, it should be noted that the current scenario of indirect taxation – as shown in the previous section – is already characterized by several use cases in the area of VAT and customs. However, moving to the analysis of direct taxation, there are still completely unexplored areas with the sole exception of withholding taxes where interesting pilots projects have already been put in place.

On these premises, the authors see additional possibilities for future blockchain-based use cases in the following key areas within direct taxation: revenue sourcing rules under the OECD Pillar One proposal and TP control.

5.2. Blockchain for revenue sourcing rules under the OECD Pillar One proposal

The OECD unified approach under Pillar One introduces new profit allocation mechanisms and nexus rules to expand the taxing rights of market jurisdictions. Under this proposal, the quantum of revenue to be reallocated to the market jurisdiction – the so-called "Amount A" – is determined under ad hoc revenue sourcing rules focusing on relevant indicators such as the geolocation[224] or the Internet protocol (IP)[225] of the user device. As a result, revenue sourcing rules require MNEs to have full control of the relevant indicators by first collecting reliable data on the geolocation or the IP address of the user devices.

To comply with these rules, the OECD Report on Pillar One Blueprint[226] provides that MNEs should retain documentation evidencing the existence of a robust internal control framework related to revenue sourcing, as well as the aggregate and periodic information regarding the reliability of MNEs' aggregate data about the location of users at a jurisdictional level.

The outcome of the public consultation on Pillar One held at the end of 2020 points out relevant doubts around the functioning in practice of the new revenue sourcing rules. The main point is that such revenue sourcing rules based on geolocation and IP address of users would require reliable data, substantial automation and technology-intensive supervision; thus, in the absence of the proper technological environment, market jurisdictions would not be able to control the compliance with the revenue sourcing rules.[227]

224. From a technical perspective, geolocation is based on various data points and coordinates including IP address, GPS-derived location data, cell tower IDs to which the user is connected, as well as data associated with Wi-Fi positioning systems. In geolocation, the use of various data points and coordinates to triangulate a user's location results in higher levels of accuracy and is therefore considered the most reliable way to determine a user's location for the purposes of Pillar One sourcing rules.

225. The IP address is based on a Wi-Fi or cellular IP address, depending on how the user is connected to the Internet. It is the number that is assigned to each device connected to a computer network, meaning that every device connected to the Internet has an IP address. Although an IP address does not inherently contain the location of the user, IP address databases are widely used by MNEs to determine the location of the user for business reasons. In such databases, certain ranges of IP addresses are assigned to certain jurisdictions, which allows MNEs to identify the jurisdiction from the IP address.

226. OECD, *Tax Challenges Arising from Digitalisation – Report on Pillar One Blueprint: Inclusive Framework on BEPS, OECD/G20 Base Erosion and Profit Shifting Project* (OECD Publishing 2020), available at, https://www.oecd.org/tax/beps/tax-challenges-arising-from-digitalisation-report-on-pillar-one-blueprint-beba0634-en.htm (accessed 2 Aug. 2022).

227. *See* OECD, *Tax challenges arising from digitalisation: Public comments received on the Pillar One and Pillar Two Blueprints* (OECD 2020), comments from WU Transfer Pricing Center, https://www.oecd.

In particular, as far as geolocation is concerned, commentators argue that, to ensure that revenue sourcing rules work properly, geographic locations claimed by users must be trustworthy.[228] Nevertheless, according to many critics, geolocation services present many points of failure that do not allow tax authorities to rely on them.[229] Then, as for the reliability of IP address location data, virtual private networks (VPNs) and other emerging technology are capable of affecting the accuracy of the resulting information and, consequently, the same implementation of the revenue sourcing rules.[230] Moreover, users can actively contribute to the inconsistency of their location data by masking their IP address or simply having their global positioning system (GPS) off.[231]

The resulting situation clearly involves a lack of trust between parties transacting with each other (Q4). Consequently, the application of blockchain technology should be considered based on the outcomes of the analysis process carried out in the previous sections. In particular, to solve the issue of reliability of geolocation and IP address data for revenue sourcing rules, there is the possibility of a blockchain-based use case focused on a digital certificate, the so-called proof-of-location, that confirms the user presence at a certain geographic location at a certain time.[232]

In fact, according to information technology (IT) experts, blockchain can be used to create a decentralized network where mobile nodes connected to the Internet can exchange information with neighbouring nodes through short-range communication technologies (e.g. wireless or Bluetooth). This way, participating nodes can interact via an algorithm and consequently generate proofs-of-location for a user device following a verification process based on the maximum distance that is reachable with the adopted short-range communication technology.

More in detail, some researchers point out that issuing a proof of location within a blockchain network is possible through the interaction between nodes with different roles (basically a Prover and a Witness) as well as through continuous checks on the signal round trip time to verify if the user device is somewhere around.[233] Under this scheme, a user who needs a location proof (Prover) broadcasts a request to the neighbour devices

org/tax/beps/public-comments-received-on-the-reports-on-pillar-one-and-pillar-two-blueprints.htm (accessed 30 May 2022).

228. M. Amoretti, G. Brambilla, F. Medioli & F. Zanichelli, *Blockchain-based proof of location*, in *International Conference on Software Quality, Reliability and Security Companion (QRS-C)*, pp. 146-153 (IEEE 2018).

229. For instance, geolocation services are not suited for use in dense urban environments and indoors; furthermore, the GPS is unencrypted, and it has no proof-of-origin or authentication features with the consequence that the system remains extremely susceptible to fraud and cyber-attack. For these considerations, *see* D. Rjazanovs & E. Petersons, *Decentralized Byzantine Fault Tolerant Proof of Location*, PoEM Workshops, pp. 1-10 (2020); S. Mattern, *A Map That Tracks Everything* (The Atlantic 2018), available at https://www.theatlantic.com/author/shannon-mattern/ (accessed 30 May 2022); A. Trouw, M. Levin & S. Scheper, *The XY Oracle Network: The Proof-of-Origin Based Cryptographic Location Network* (2018), available at https://static.icoholder.com/files/18940/6f21b0fefff8fa7d327fcbadc6ad5423.pdf (accessed 30 May 2022).

230. *See* OECD, *supra* n. 227, comments from Amazon.com, the International Bar Association, Loyens and Loeff, Uber.

231. Id., comments from Amazon.com.

232. Amoretti, Brambilla, Medioli & Zanichelli, *supra* n. 228.

233. Id.; *see also* A. Hua & S.L. Chang, *Algorithms and architectures for parallel processing* (Springer International Publishing 2020), available at https://link.springer.com/content/pdf/10.1007/978-3-642-03095-6.pdf (30 May 2022); H. Hacid, W. Cellary, H. Wang, H.Y. Paik & R. Zhou, *Web Information Systems Engineering–WISE 2018* (Springer International Publishing 2018), available at https://link.springer.com/content/pdf/10.1007/978-3-030-02925-8.pdf (accessed 30 May 2022).

through a short-range communication interface.[234] The neighbour device that decides to respond (Witness) starts to authenticate the request coming from the Prover. The Witness verifies the validity of the proof-of-location request according to a set of predefined rules. For example, the request should contain an admissible geographic location, i.e. not farther than the adopted maximum distance reachable with the short-range communication technology. Once all checks have been fulfilled, a proof-of-location response is generated by the Witness, wrapping the received request into a new message sent back to the Prover, together with its geographic location. In case the response is correctly verified also by the Prover, the proof-of-location is issued attesting that two peers are geographically close to each other and specifying their geographic locations. Afterwards, the Prover puts the proof-of-location into a new block, together with a reference to the previous valid block known. In addition to this, the new block contains the identifier of the Witness, as well as its signature with the private key. Finally, the newly created block is broadcasted to the participating nodes of the network which decide whether to add the block to the end of the blockchain or not according to a consensus algorithm. If most peers add the block to the blockchain, then consensus is achieved and consequently the proof-of-location is made immutable. Otherwise, the block is discarded and not attached to the blockchain.[235]

Based on these findings from IT researchers, a future use case could involve the use of a blockchain-based proof-of-location to solve the issue of user's location reliability under Pillar One.

In this sense, MNEs falling within the scope of Amount A could be required by law to operate as Provers within a decentralized blockchain network and to broadcast proof-of-location requests to Witnesses for the IP address of a certain user device. Under the proposed scheme, institutional entities under the aegis of the OECD could operate as Witnesses through wireless points of access widespread at the local level. This way, starting from the IP address contained in the proof-of-location request coming from an MNE, a Witness could verify, through its neighbouring wireless points of access, the signal round trip time to confirm if the device is somewhere around. As long as the outcome of this verification process is positive, a digital certification for the proof-of-location will be issued by the Witness guaranteeing location trustworthiness for Amount A and revenue sourcing rules.

With regard to the underlying blockchain infrastructure, the proposed solution could be implemented through a consortium blockchain network with a managing authority (e.g. an OECD body) granting different rights and permissions to the participating nodes. For instance, MNEs, as they are required to join the network as Provers, will have the right to broadcast proof-of-location requests to Witnesses and to verify the corresponding response. Other institutional nodes operating as Witnesses at the local level will have the right to verify the proof-of-location requests from MNEs and to vote for adding new blocks. Finally, local tax administrations will have the right to access MNEs' data stored on the distributed ledger and to carry out real-time audit focused on users' proof-of-locations.

This scheme can fully exploit the potential of blockchain technology addressing all the sub-questions included in section 3. As for Q1, all the nodes of the consortium blockchain network would benefit from a situation where all the relevant data on users' proof-of-loca-

234. Amoretti et al., *supra* n. 228; *see also* M.R. Nosouhi, S. Yu, W. Zhou, M. Grobler & H. Keshtiar, *Blockchain for secure location verification*, Journal of Parallel and Distributed Computing 136, pp. 40-51 (2020).

235. Amoretti et al., *supra* n. 228; *see also* Rjazanovs & Petersons, *supra* n. 229.

tions is equally available on a real-time basis. Then, as far as Q2 is concerned, this solution would be intended to solve the issues related to multiple parties in a complex ecosystem, considering that MNEs, tax administrations and other institutional entities would have access to the same distributed ledger. In the same way, this infrastructure would overcome the problem of multiple versions of the "truth" (Q3) and facilitate the trust between taxpayers and tax authorities based in different jurisdictions due to the embedded systemic transfer and sharing of data (Q4). Finally, blockchain would here be used to solve the problem of lack of security in the transfer of data (Q5), as well as to automate multiple tax processes usually based on several reporting obligations on taxpayers (Q6). In this respect, as long as specific rules for issuing proof-of-locations and validating the corresponding blocks are written in a smart contract protocol, the validation process for proof-of-location can be done automatically in a way that is consistent with the revenue sourcing rules provided under Pillar One.

5.3. Blockchain for TP control

TP is one more key area for future development. In this case, future pilot projects could focus on the establishment of a blockchain network when sufficient comparative reliable data is available for a TP analysis. For this scope, multinationals (MNEs) should digitalize their TP data from the supply chain and store that data in real time on the blockchain.

Besides data from the supply chain, TP analysis could also benefit from facilitating the storage of a large number of other sources of information on the blockchain, including economic or market conditions, the organizational structure of a particular MNE, or the nature of the functions and risks of the enterprises involved in the transactions, as well as tax treaty provisions, relevant national legislation, tariffs, duties, or government regulations. In this respect, the use of less energy-intensive consensus protocols, such as PoA and PoS, could ensure the development of the blockchain network in a sustainable way in terms of confidentiality, environment preservation and security.

This way, tax administrations could implement TP audits on a real-time basis having access to reliable data stored on the blockchain network and thus solving any issue related to disparate data stored on a centralized server (Q1), lack of trust between parties (Q4) and lack of security in transactions (Q5). The result would also involve the use of blockchain technology to address the issues deriving from the existence of a complex ecosystem with multiple parties (Q2) and multiple versions of the truth (Q3).

Furthermore, smart contracts could improve the efficiency of TP control within a software solution running on the blockchain network. In this respect, as highlighted earlier by Cipollini,[236] future use cases could involve the development of a standardized methodology for coding TP policies and advance pricing agreements (APAs) into smart contracts. This should involve the identification of the proper matches between conventional language and computer language according to an analytic review of the basic structure of TP policies or APAs and the association with the corresponding components of a unifying model of smart contracts.

236. C. Cipollini, *Blockchain and smart contracts: a look at the future of transfer pricing control*, 49 Intertax 4, pp. 313-330 (2021).

More advanced use cases could involve the correct transfer price calculation of a controlled transaction. For instance, a use case could explore the possibility of a system where there is a "green light" for validating the transaction any time the transfer price of an intra-group transaction is within the range of prices automatically calculated by a smart contract representing the conversion of the terms of a TP policy or an APA. Therefore, once there is the green light, the MNE will operate as a validating node in the blockchain network, having the right to confirm a transaction at a given price within the range of prices established under the smart contract. At that stage, since the transaction has already been positively verified under the terms of the smart contract, tax administrations will automatically validate that transaction with no exceptions. Consequently, a new block of data – representing that transaction – will be added to the blockchain in an immutable and safe manner.

Based on these possibilities, future use cases in this field can contribute to fully automating the transfer price control process with no more need for multiple tax processes carried out on a manual basis (Q6).

6. Summary of the Results and Initial Conclusions

Before zooming into the relevant aspects of blockchain for a blockchain-based tax system, in section 2. of this article the general characteristics of blockchain technology were elaborated on. Subsequently, in section 3. of this article, based on a systematic literature review, the following sub-questions relevant to assessing whether blockchain technology should potentially be considered for tax were identified:

(1) Is the data that has to be stored centrally only available on a fragmented basis (disparate data)? (Q1)

(2) Are there multiple parties in a (complex) ecosystem? (Q2)

(3) Are there multiple versions of the "truth"? (Q3)

(4) Is there a lack of trust between parties? (Q4)

(5) Is there a lack of security in transacting with each other? (Q5)

(6) Are there multiple processes carried out on a manual basis? (Q6)

Also, several aspects have been addressed of the taxpayer's perspective, of the tax administration's perspective, but more importantly also of the ecosystem perspective as a whole, to participate in blockchain-based tax systems.

In section 4., the aforementioned sub-questions were applied to the several use cases identified in practice. This has resulted in the overview in Table 1 summarizing the positive answers provided for each use case.

Based on these results, it can be observed that, while some use cases address all the above sub-questions, other use cases only focus on some of them.

In this respect, the analysis process showed that when a use case also addresses the issues related to Q4, Q5, Q6, there is an additional layer that ensures the full utilization of the blockchain's distinguishing properties and, consequently, a more solid ground to justify a shift to blockchain technology.

Table 1 – Use cases overview

Use case	Country	Q1	Q2	Q3	Q4	Q5	Q6
Exchange of taxpayer's information							
Registro Unico Tributario – Padrén Federal (RUT)	Argentina	X	X	X	X		
BCPF	Brazil	X	X	X	X		
KSI	Estonia				X	X	
Withholding tax							
TaxGrid		X	X	X	X	X	X
NL tax administration (wage tax)	Netherlands	X	X	X	X	X	X
TP							
Inter.x	N/a	X		X	X	X	
VAT							
Tencent	China	X	X	X	X	X	X
VRT	Thailand	X	X	X	X	X	X
Microsoft/PwC	N/a	X	X	X	X	X	X
Summitto	Netherlands	X	X	X	X	X	X
Etisalat	United Arab Emirates	X	X	X	X	X	X
Customs							
BConnect	Brazil		X	X	X	X	X
Georgia Customs	Georgia	X	X	X	X	X	X
ABF's Intergovernmental Ledger (IGL) and IMDA's TradeTrust	Singapore				X	X	
Samsung	Korea (Rep.)	X	X	X	X		X
Origin (EY)	N/a	X	X	X	X	X	X
Excise							
Thai Excise Department	Thailand	X	X	X	X		

Differently, any time a use case limits its scope to the issues related to Q1, Q2, Q3, there is only a set of basic and starting preconditions to consider the use of blockchain for tax; in this situation, the main point is that, even though blockchain undoubtedly provides several valued benefits, other technologies might facilitate solving the same problem in a more efficient or effective way.

This framework, which is the result of an analysis process carried out from both the theoretical and the empirical perspective, suggests the final answer to the research question of when to use blockchain for tax in the following terms.

To maximize the ratio between benefits and costs compared to other existing technologies, the development of a powerful blockchain-based use case for tax always requires complying with some preconditions. In principle, the use of blockchain technology may be considered if one or more of the above sub-questions (Q1-Q6) can be answered affirmatively in relation to the underlying use case. Nonetheless, the above analysis showed that the use of blockchain technology does not necessarily have to be the most appropriate fit to tackle a specific problem when only a few of the above sub-questions can be concretely addressed. In some cases, especially when only situations under Q1, Q2, Q3, are considered, other technologies or approaches may facilitate solving the same problem in a more efficient or effective way.

Consequently, it results that a powerful use case for tax should ideally ensure a positive answer to all the sub-questions identified in the present study, thus addressing not only the issues related to disparate data (Q1), multiple parties in a complex ecosystem (Q2) and multiple versions of the "truth" (Q3), but also the other issues related to lack of trust (Q4) and security (Q5) between the parties in transacting with each other, as well as multiple processes carried out on a manual basis (Q6).

If these preconditions are jointly fulfilled, the development of a tax use case will allow the concrete use of all the blockchain's distinguishing properties ensuring a positive outcome with respect to the principle of tax efficiency compared to other existing technologies.

Other solutions, where only a few of these sub-questions are considered, could very likely involve the risk of inefficient outcomes as for the ratio between benefits and costs.

In accordance with these results, the possibility was also discussed of more powerful blockchain-based use cases in the tax domain able to fully comply with these preconditions. In this respect, the conceptual features were outlined of two possible future blockchain-based use cases in the area of direct taxation focusing on revenue sourcing rules under the OECD Pillar One proposal and TP control, respectively. Both examples demonstrated the capability of these uses cases to comprehensively address all the sub-questions included in section 3.

The conclusions from this research hopefully allow an extra step forward with respect to the existing literature having now the availability of a clear list of combined factual preconditions to consider blockchain technology a good solution for tax. In this regard, the authors strongly believe that experts in the field and policymakers should always consider the preconditions identified under this study when developing a new blockchain-based use case for tax. This should logically involve a case-by-case analysis aimed at exploring how many factual situations – identified under Q1-Q6 – can properly be addressed within a potential use case.

Besides, the development of a use case within the framework of these preconditions will also require comprehensively addressing the different challenges raised by the tax literature including the issues of confidentiality, environmental sustainability, security, multiple blockchain databases, and the reliability of the company financial reports. Within this scope, it will be necessary to design future use cases based on a set of international standards including less energy-intensive consensus protocols (such as PoA and PoS) and the use of specific tools to align blockchain with the non-digital world (e.g. oracles).

With this article, the authors have contributed to identifying the preconditions that make blockchain technology a good choice for tax. This has been the first step towards the comprehensive definition of the fundamental elements of a blockchain-based tax system.