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Final thesis

Blockchain implementation in taxation

A case study in EU VAT

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Abstract

Blockchain is a promising technology that has known great development within the last years. Although its first application has been cryptocurrency trade, Blockchain's functionality is much wider. Scholar research has shown that blockchain technology could be implemented in taxation in order to achieve several benefits. Given its decentralized character, blockchain would provide the tax system with transparency and enhanced data security. As a result, fraud would be significantly reduced, helping to close the tax gap. Moreover, it would simplify administrative processes, resulting in easier compliance for taxpayers and lower costs for the tax administration.

In this paper, the adoption of a blockchain-based tax system will be explored, detailing its functioning as well as its different use cases. In particular, the possibility of a blockchain-based EU VAT system will be discussed. The European Union has struggled in the past years to reform the Value Added Tax system in such a way that it would end VAT fraud. Regarding this, the introduction of a blockchain-based digital invoice custom exchange (DICE) has been proven to significantly reduce MTIC fraud. Furthermore, the adoption of VATCoin, the first cryptotaxcurrency, as the sole means of VAT payment could end VAT fraud altogether.

Keywords: *blockchain, smart contract, transfer pricing, VAT, VATCoin, MTIC fraud*

Number of words: *13654*

Resumen

Blockchain es una tecnología altamente prometedora que ha sido objeto de un gran desarrollo en los últimos años. A pesar de que su primera y más conocida aplicación sea el trading de criptomonedas, el potencial de blockchain va mucho más allá. La investigación académica del último lustro ha demostrado que la tecnología blockchain podría reportar numerosos beneficios al sistema fiscal. Dado su carácter descentralizado, blockchain podría aumentar la transparencia y la seguridad, ayudando de esta forma a reducir el fraude. Asimismo, blockchain ayudaría a simplificar el sistema, de forma que fuese más fácil para los contribuyentes cumplir con sus obligaciones tributarias y menos costoso para la Administración supervisar que así sea.

En este trabajo se examinarán tanto el funcionamiento como los casos de uso de un de un sistema fiscal basado en blockchain. En particular, se analizará la posibilidad de utilizar la tecnología blockchain en el IVA intracomunitario de la Unión Europea, dado que en los últimos años la UE ha tratado de buscar soluciones al fraude en este impuesto y la adopción de blockchain podría ser la solución a este problema. En este sentido, la implementación de un sistema de facturación digital basado en blockchain lograría reducir de forma significativa el fraude MTIC. Adicionalmente, la adopción de VATCoin, la primera criptomoneda fiscal, como único medio de pago del IVA podría acabar definitivamente con el fraude.

Palabras clave: *blockchain, smart contract, precios de transferencia, IVA, VATCoin, fraude MTIC*

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1. Introduction

Blockchain is an emerging technology that has captured the attention of a wide range of industries and applications. Although it has been primarily used in the context of cryptocurrencies, the potential of blockchain goes beyond this. Since its inception in 2008, blockchain has been considered a revolutionary tool for facilitating trust and transparency in digital transactions.

In the recent years, scholar research has investigated whether blockchain technology would be useful in improving the tax system. During the 2016 World Economic Forum held in Davos, Switzerland, 816 observers and technology specialists were asked when they thought their governments would begin to use blockchain for tax collection. 73% of respondents said 2025, with the average answer being 2023 (Deloitte, 2017b). Although their prevision might have been too optimistic, it is undeniable that blockchain-based taxation will become a reality in the medium term.

In this paper, the implementation of a blockchain-based tax system would be discussed. Firstly, a conceptual framework will be introduced in order to briefly explain some of the key concepts needed to understand this thesis. Secondly, it will be examined how exactly a blockchain-based tax system would work, detailing both the benefits and challenges that this may pose. Thirdly, the main use cases of blockchain-based taxation will be analyzed. Lastly, a special emphasis will be made on a blockchain-based VAT system and how it could be implemented throughout the European Union in order to reduce fraud. To sum up, the main conclusions obtained will be presented.

2. Conceptual framework

Taking into consideration both the complexity and the novelty of the topic, some concepts will be introduced in this first epigraph to facilitate the comprehension of the whole dissertation. Terms such as blockchain technology and smart contracts will be discussed in order to provide a clear definition that can be understood without previous knowledge on the subject.

2.1. Blockchain

The blockchain technology was first introduced by Satoshi Nakamoto in 2008 with the release of his paper *Bitcoin: A Peer-to-Peer Electronic Cash System*. Although its origins and its current reputation are strongly related to cryptocurrency, the potential of this innovative technology goes further than that, as it will be explained thoroughly in this paper.

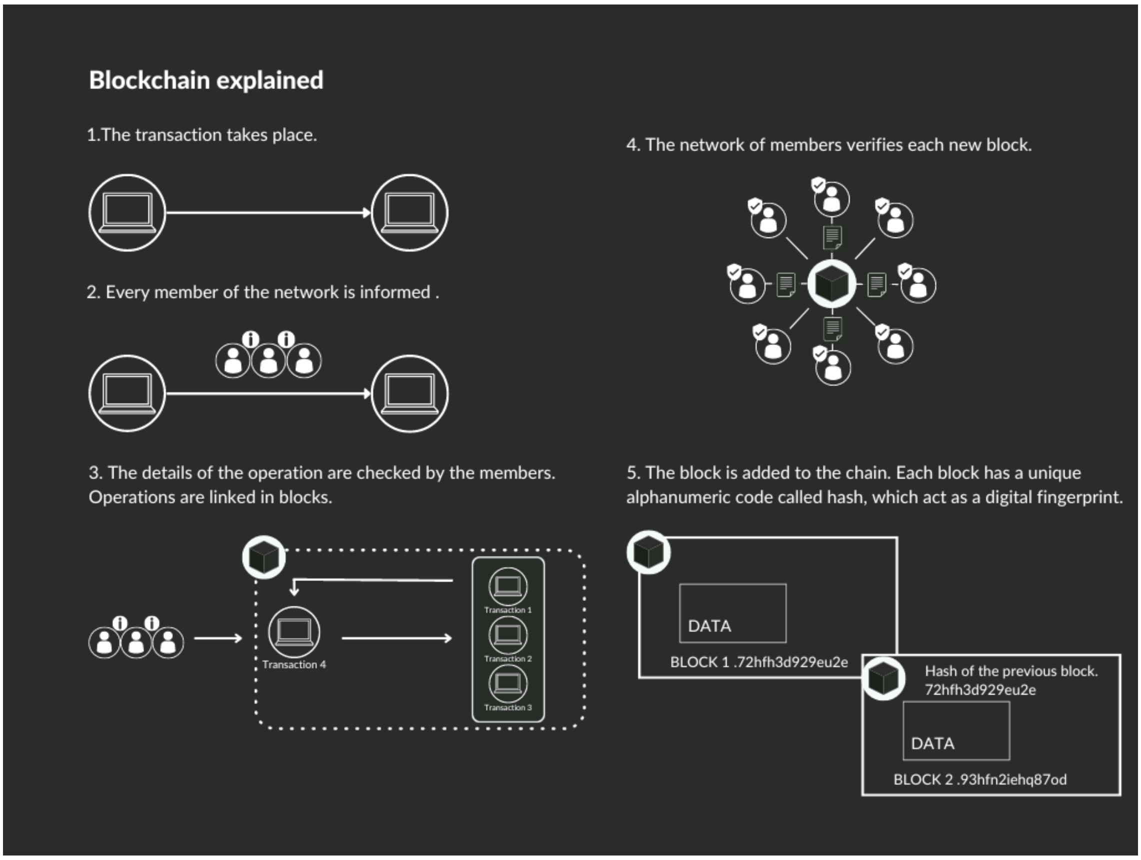
Nakamoto's main intention was to create a system that could replace the need of a third trusted party with cryptographic proof, enabling individuals to make transactions directly with each other (Nakamoto, 2008). Blockchain can be described as *"a ledger of information that is replicated across computers that are joined in a Peer-to-Peer network (P2P)"* (Deloitte, 2017a).

P2P is used to designate computer networks in which no central administrator is needed. The network is based on dispersed and distributed architecture, which results in each device or peer having a part in it. Peer-to-peer networks enable collaborative work, making it possible to share every resource available within the network without the supervision of a central party.

Blockchain is a type of distributed ledger technology (DLT), which can be defined as a protocol that allows a decentralized database to run safely. It enables the information to be recorded secure and accurately using cryptography, making sure it cannot be tampered with once it is stored. This information can consist of currency, as in the case of Bitcoin, but that is not the sole category of data that this technology can manage.

In order to add a piece of information to the ledger, a peer's transaction must be confirmed by the rest. Once it has been verified, it will be added to a block. Blocks link together creating a chain, each one containing its own unique hash as well of the hash of the previous one. The information contained in each block cannot be altered without altering its hash, which makes it simple to detect any fraud attempt.

Figure 1. Blockchain step by stepp



Source: own work based on Deloitte (2017b).

It must be pointed out that not every blockchain is made equal. The most important classification regarding this aspect divides blockchains into two main types: permissionless and permissioned, depending on which parties are able to access the network.

Permissionless blockchains, also referred as public blockchains, are the most well-known category, as they are the ones used by Bitcoin. As their name suggests, they are open to any potential user, meaning there are no restrictions to access them. Everyone can act as a node in the chain through their computer processor, thus being able to verify transactions within the blockchain. In order to do that, the sole step to follow is to download the software and the required ledger.

This type of blockchain presents several problems that would difficult its use for taxation. For instance, transaction speed may slow down as more users join the network, as the initial settings would be set up using the best available technology at the time. Due to the rapid evolution of technology, the blockchain may quickly become out of date (Deloitte, 2017b).

Moreover, transaction history would be stored in the database and be available to every user of the network. Even though identification of any participant requires certain information, once someone is identified all their transactions can be made entirely public. This would pose serious privacy issues.

Also known as private blockchains, permissioned blockchains solve some of the limitations inherent to public blockchains. In the case of this type of networks, access is restricted to users who have obtained the authorization of an administrator.

More precisely, this type of DLT could be defined as *"replicated, shared ledgers which can be administrated by one or more organizations in order to guarantee adequate levels of network coordination, reliability, and security through human intervention, when necessary"* (Atzori, 2015). As they are particularly useful to enterprises and consortiums, adoption rate by these parties has grown considerably within the last years (Deloitte, 2017a).

Restricted or private blockchains present some advantages over unrestricted or public ones. In the first place, they are separated from the highly speculative cryptocurrency markets, hence being suitable for use cases of general interest. Moreover, access is only granted to a few trusted nodes which can be identified. As a result, the validation process requires less computational power, thus being able to be performed much faster (Buterin, 2015).

However, permissioned blockchains also lack some of the potential benefits that public blockchains offer, as the need for an administrator makes the truly decentralized environment not available anymore. In spite of this fact, they largely outperform centralized databases as far as efficiency, data security, data integrity, availability, reduction of errors and infrastructural costs are concerned (Atzori, 2015). This is mainly due to the centralized structure inherent to centralized databases, which only allows the master database to perform writing operations. Contrary to that, every node in the blockchain can upload transactions once they are verified by the rest of the nodes.

It is yet to de discovered whether public blockchains will evolve in a manner that their limitations will disappear or, on the other hand, private blockchains will become the default setting. As far as the present time is concerned, permissioned blockchains have been preferred by authors in their proposals to implement blockchain in taxation (Ainsworth & Alwohaibi, 2017).

Even though blockchain technology has reaped great success in the recent years, there are still several misconceptions about it. The most important one might be the belief that blockchain implies the use of cryptocurrencies. As Bitcoin was blockchain's first use case, the general public tends to associate the technology (bockchain) with its application (cryptocurrencies). However, blockchain can be used for several use cases without implementing cryptocurrencies, as it will be discussed in this paper.

Another usual misconception regarding blockchain is that it lacks security and privacy. However, it is false that once any piece of data has been uploaded to the blockchain it is available to the public. On the contrary, the combination of integrated digital signatures and unalterable audit logs helps to ensure data security and privacy within permissioned blockchains (PWC & Microsoft, 2019).

2.2. Consensus mechanisms

A consensus mechanism could be defined as the protocol used to ensure that the added blocks do not contain fraudulent information (Deloitte, 2017b). This task would be performed by a third trusted party in centralized networks. As it has already been stated, one of the main benefits of blockchain is the lack of need for such central party, which means another way of verifying transactions is needed.

Permissionless blockchains are unable to validate transactions using a "one-head one-vote" system. This is due to the possibility of Sybil attacks, which consist of the creation of multiple network addresses by one user. In this way, a large number of votes could be emitted in order to unilaterally validate a transaction or licit transactions could be denied due to an artificial flood of the network with an unmanageable cypher of requests (Pinna & Ruttenberg, 2016).

Consequently, more sophisticated protocols have been developed. The most popular consensus mechanisms are proof of work (PoW) and proof of stake (PoS), although it is expected that new ones will be developed as the adoption rate of blockchain technology rises.

In PoW, which is currently used by Bitcoin, the participants of the network, called miners, compete to add the next block in exchange for a reward. In the case of Bitcoin, that reward consists of coins. To be successful, a miner must be the first to solve an increasingly difficult cryptographic puzzle (Nair & Dorai, 2021). In order to do that, high computational power is needed. This means that the more computer processors a miner has, the higher his chance of coming up first with the solution is. As a result, PoW is extremely electricity demanding, which poses serious environmental and cost issues (Saleh, 2021).

Moreover, reaching consensus within this method can take up to an hour for the recommended 6-block transaction confirmation, reaching a maximum speed of seven transactions per second with small transactions between 200 and 250 bytes. For comparison, credit-card payment companies process an average on 2000 transactions per second, being able to sustain up to 10000 at their peak capacity (Vukolić, 2016).

For these reasons, the need for other methods has grown within the last years, resulting in the development of PoS. Proof of Stake, contrary to proof of work, requires that validators, called miners in PoW, are also stakeholders (Saleh, 2021). In PoS, validators place a bet on their block, being awarded if it turns out to be correct and punished if not, getting the amount of their bet reduced from their balance (Deloitte, 2017a). The users with the highest stakes are more likely to be selected, as they are interested in maintaining the credibility of the ledger, ensuring the avoidance of fraud attempts. However, this consensus mechanism has been proven as not scalable, which reduces its suitability to private blockchains (Nair & Dorai, 2021).

2.3. Smart contracts

The term *smart contract* was first introduced in 1994 by Nick Szabo, who defined them as *"a computerized protocol that executes the terms of a contract"* whose main goals are *"to satisfy common contractual conditions (such as payment terms, liens, confidentiality, and even enforcement), minimize exceptions both malicious and accidental, and minimize the need for trusted intermediaries"*.

In his paper *The idea of Smart Contracts,* released in 1997, Szabo compared smart contracts with vending machines, which could automatically execute a contract (providing the customer certain product) once a condition was met (the client had introduced the right amount of money). Smart contracts can be seen as the evolution of this simple mechanism, using programming tools to ensure contract enforcement (Szabo, 1997).

Cipollini (2022) addresses that most scholar definitions of smart contracts contain *"the basic assumption that smart contracts are conventional clauses written in a computer language that automatically execute contractual terms when certain conditions are met"*, also highlighting the fact that they *"run on the distributed ledger of* *a blockchain network where data is replicated throughout all of the validating nodes in a peer-to-peer (P2P) manner without the use of a centralized server"*.

As the use of smart contracts increases, legal definitions have also arisen. Within the European Union, both Malta and Italy have introduced such definitions in their legislations. In the case of the Republic of Malta, the concept of smart contract can be found in the article 2, chapter 591 of the Malta Digital Innovation Act, where it is presented as:

"a form of innovative technology arrangement consisting of (a) a computer protocol; and, or (b) an agreement concluded wholly or partly in an electronic form which is automatable and enforceable by execution of computer code, although some parts may require human input and control, and which may also be enforceable by ordinary legal methods or by a mixture of both"

Their neighbor country, Italy, defines smart contracts in the article 8 *ter* (2) of their Decree Law no. 135 of 14 Dec. 2018 as *"software based on distributed ledger technologies which, once the relevant ledger entry has been validated, automatically gives effect to the relevant terms agreed between two or more parties".*

Their main features are immutability, decentralization, and transparency. Immutability results from the fact that smart contracts cannot be altered once they are stored and deployed on the blockchain. Decentralization is directly inherited from the blockchain, hence not being able to suffer from a single point of failure. Moreover, self-execution avoids the need for supervision of a third trusted party (di Angelo et al., 2020). As for transparency, it must be stated that this characteristic depends on whether the smart contract runs on a public or private blockchain. As a result, smart contracts can also be divided into permissionless and permissioned, depending on which parties can deploy them into the network (Hu et al., 2019).

When considered from a dynamic point of view, it can be observed that smart contracts experience four life-cycle stages: coding, deployment, execution, and completion (Cipollini, 2021).

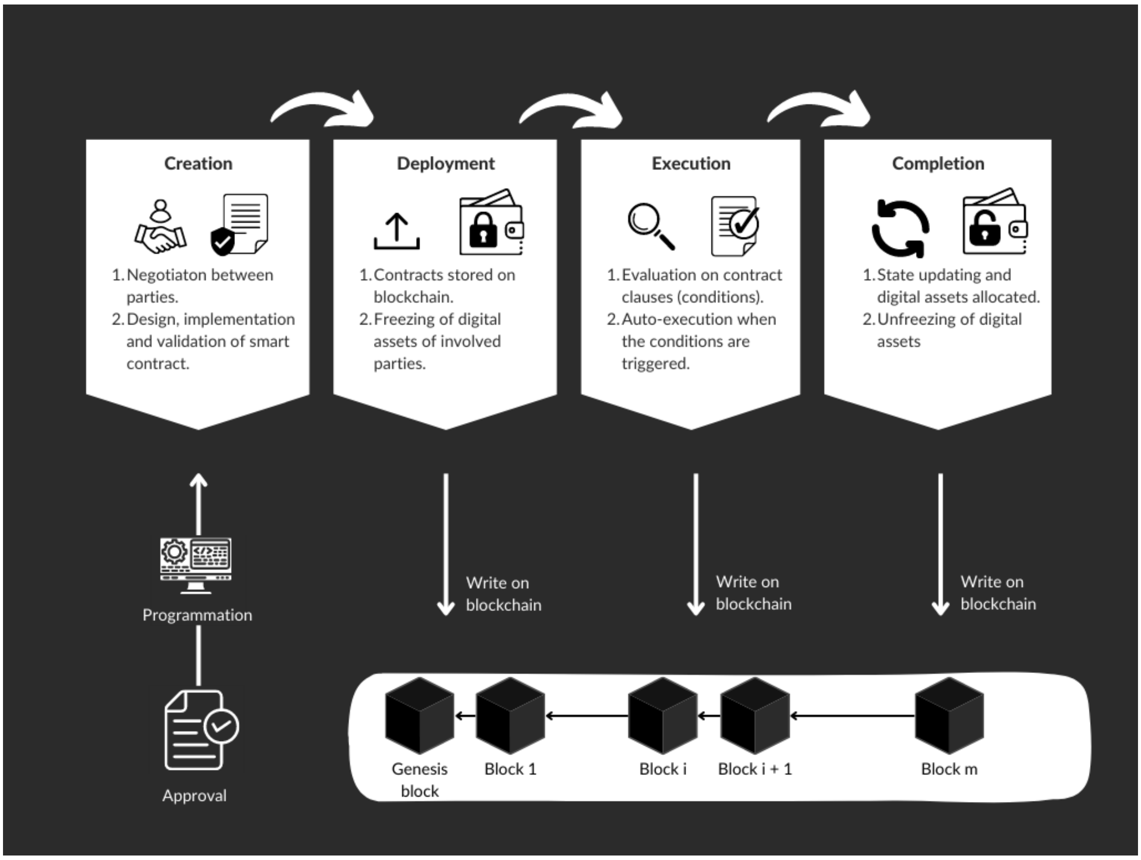
The first stage implies converting a conventional contract into a smart one. This requires a collaborative work between lawyers and programmers, as the resulting code should reflect the same terms and conditions and have the same legal implications than the original contract.

In the second stage, the smart contract is uploaded to the blockchain. Therefore, the data it contains is replicated and verified by every node of the network. Once the deployment has been completed successfully, every peer will have access to the smart contract and the digital assets of every party involved will be locked through the freezing of their digital wallets (Zheng et al., 2020).

The third phase will take place automatically when the conditions written on the contract take place. As it has been previously stated, smart contracts are self-executory. They are composed of declarative statements with logical connections. When a condition is triggered, the corresponding statement is automatically executed (Zheng et al., 2020). This means that when a condition written on its code is met, its consequence will take place without need for human interaction.

Finally, the completion of the smart contract takes places. As a result, all the transactions resulting from it will be stored on the blockchain and the digital assets of every involved party will be transferred, therefore unlocking their digital wallets.

Figure 2. Lifecycle of a smart contract



Source: own work based on (Zheng et al., 2020)

3. Towards a blockchain based tax system

Blockchain technology and smart contracts have several applications. In the recent years, some authors (Ainsworth & Shact (2016a) Ainsworth & Alwohaibi (2017), Zinca & Negrean, (2018), Nemade et al. (2019), Alkhodre et al. (2019), among others) have proposed their use in taxation, arguing that this would led to an easier-to-understand and harder-to-avoid tax system. Both calculation and payment would benefit from the implementation of this technology, which would also imply a significant cut in costs.

3.1. How would it work?

Implementation on blockchain technology in taxation is yet a promising idea to be tested. Although several models have been proposed by scholars, the heterogeneity they present makes difficult the task of explaining how this technology would run in real life. Nevertheless, this epigraph will try to find the common features those models present in order to make visible how blockchain would function once it has been implemented.

The first step would be to decide what type of blockchain should be constructed. Most authors agree on the unsuitability of a public blockchain for this purpose, as some privacy and control are needed. Thus, private blockchains would be the preferred choice (Atzori, 2015). As not every user should be granted access to all data, it would be necessary to design a system that would organize the information into several categories and grant access to it to the right users, hence protecting the leakage of confidential data.

One of the first questions that arise at this point is who would be in charge of building and administrating the network, as well as who would manage the different permissions a private blockchain requires. As the answer is yet to come, we can only explore the alternatives that have been proposed.

Ainsworth & Viitasaari (2017) deemed likely that the private sector would play an important role in the development of tax blockchains. In this sense, they predicted that some countries would use permissioned blockchains entirely developed by private enterprises, in which government agencies would act as regulators. For instance, United States is most likely to follow this path. On the other hand, government-built blockchains would also be a possibility, which is expected to flourish in countries such as Finland and Estonia. Government administration is also expected in Saudi Arabia regarding the development of blockchain-based VAT collection (Alkhodre et al., 2019).

However, some of the use cases require the participation of several jurisdictions, demanding the establishment of an international consortium blockchain. Therefore, collaboration between states to administrate the blockchain would be needed. This can pose several issues, as each jurisdiction often insists in keeping its own centralized database, as in the case of EU regarding VAT (Ainsworth & Shact, 2016b).

Cipollini (2021) addressed the political difficulties this would pose, proposing as an alternative *"the identification of an international authority in charge of the administration of the network"*. This authority would be in charge of overseeing which parties qualify for becoming permitted users, deciding which data would be accessible to whom and grating the required rights and permissions to each user. For this matter, the Italian author considered that an OECD coordinating body would be the best option. Nevertheless, it should be considered that his proposal concerned transfer pricing and that other use cases may require different solutions.

Another relevant question that must be answered is what is needed to design an effective blockchain, specially in the case of an international one. According to Ainsworth & Shact (2016b), there are three key elements every distributive ledger should have: a network of computers, a network protocol and a consensus mechanism.

Firstly, a computer network provides stability and security to the blockchain. Each device constitutes a node. The higher the nodes a network has, the more secure it is. In international blockchains, each country should contribute with a different number of computers based on their GDP, as states with higher GDPs are more likely to perform a larger number of transactions (Ainsworth & Shact, 2016b).

A network protocol can be defined as the way devices communicate among themselves. As this topic concerns informatics more than economics, it will not be largely discussed. To sum it up, different methods can be used to exchange information between nodes, each one requiring different data models and language of transactions. For instance, the network protocol "Sawtooth Lake", developed by Intel in 2016, would be suitable for this purpose.

Finally, a distinctive consensus mechanism should be applied. Most authors agree on the fact that PoW is not electable as an option, although the particular protocol that should be used remains as a question to be solved (Alkhodre et al., 2019). Nevertheless, it should be taken into consideration that different blockchains may require different consensus mechanisms, as the later ones can be adapted to the particular use case that the DLT deals with (Peters & Panayi, 2016).

For instance, Ainsworth & Shact (2016a), regarding VAT, have proposed the use of Artificial Intelligence (AI) to assess transactions in an auditor-manner to detect their likelihood to be fraudulent, verifying only the ones that are not deemed suspicious. This will be further discussed in later epigraphs.

Once the blockchain has been successfully built and every participant has been granted its correspondent permissions, it should be clarified how it would run on a daily basis. Regarding this aspect, although models differ greatly, the academic discussion could be reduced to two groups. Whereas some authors only consider uploading relevant tax information to the blockchain -for example, mapping invoice information in the case of VAT-, others have designed their models in such a way that taxes would be directly paid through it. Furthermore, the most ambitious ones have proposed the adoption of tax coins, a form of state cryptocurrency that would be used to pay taxes (Müller, 2020).

In the first case, blockchain would only be used to store information in a safer and more accessible manner, allowing authorities to share data in a more manageable way and making fraud attempts easier to spot due to the immutability of the ledger. Consequently, digital invoices, APAs or payroll information could be easily accessible to all the concerned parties. In this case, blockchain would serve as a mere improved version of a centralized database.

On top of that, smart contracts could be deployed on the network to automatize tax calculations. For instance, they could compute how much an intra-group transaction should be worth according to the arm’s length principle or what percentage of their salary an employee must pay each month to the tax administration taking into consideration their personal circumstances.

The second step presents larger complexity, as it would aim for the integration of blockchain based payments. As a result, banks would also be implied in the network. The payment of taxes though the blockchain would determine that, each time a transaction happens, a smart contract would automatically calculate the tax amount due and transfer it directly to the correspondent authority, storing the rest in the recipient's bank account.

As blockchain technology was designed for the purpose of eradicating friction from monetary flows, it is easy to imagine this possibility. Moreover, consortium blockchains are already used in interbank transfer, in which the value of the currencies is linked to an existing physical currency. The same technology could be used to perform real-time tax payments through the blockchain (PWC & Microsoft, 2019).

Ultimately, some authors have proposed the use of virtual coins in this process, which may have some advantages depending on the use case and the model developed. Richard Ainsworth has been a pioneer as far as this topic is concerned, coining the term VATcoin in his paper *"VATCoin: The GCC's Cryptotaxcurrency"* (Ainsworth et al., 2016) and further developing the concept in *"A VATCoin Solution to MTIC Fraud: Past Efforts, Present Technology, and the EU's 2017 Proposal"* (Ainsworth et al., 2018).

3.2. Benefits

In this epigraph, some of the most important benefits of blockchain implementation in taxation will be discussed. However, the advantages of each use case will be detailed further in their correspondent epigraph.

Transparency is one of the main features that characterizes blockchain. As every transaction is recorded on the ledger, this technology offers provenance and traceability (PWC, 2016). As a result, no transaction can be excluded or omitted, as DLT is one of the most reliable means when it comes to record economic transactions, transfer ownership and reconciliate accounts receivable and payable (Vishnevsky & Chekina, 2018).

The second relevant feature would be *real-timeness*. Our current tax system could be defined as retrospective, as tax charging and mobilization are performed once the reporting period is due. As blockchain allows information to be updated at real-time to every node of the network (PWC, 2016), a tax system based on this technology would be able to perform tax calculations and payments in step with the execution of economic transactions, as they happen (Vishnevsky & Chekina, 2018).

Furthermore, the possibility of confirming transactions in real-time would increase the speed at which processes that involve shares or property assets happen (Grundel et al., 2021).

Security also stands as an important trait. As it has already been stated, once a transaction is stored on the blockchain it cannot be altered or tampered with, which makes fraud attempts both less likely and easier to spot (PWC, 2016). Both the storage of transactions in distributed ledgers and the capacity every node has to secure immutable transaction trails precludes transaction manipulation and engagement in detrimental rent-seeking (Cho et al., 2021).

Moreover, as a result of real-time mode, it is not possible to duplicate records (Grundel et al., 2021). Decentralization also plays an important role in securing the network, as the lack of a central server significantly reduces the likeliness of a hacker attack (Merkx, 2019). Security would also increase with the use of digital signatures, which would be required in every transaction (Grundel et al., 2021).

As a result of the previous features, tax fraud would decrease, reducing the tax gap and increasing the available resources of the tax administration, hence increasing its efficiency. This could be reinforced by the possibility to impose a ban on the user account on the blockchain when a citizen has been non-compliant, hence saving the government significant amounts in tax recovery operations and related costs (Phadke et al., 2021).

The need for tax inspectors would be lower and, as the blockchain would automatically execute a wide range of processes, the expenses on administration and personnel would also be reduced. Moreover, the cost of compiling tax record would decrease significantly. (Vishnevsky & Chekina, 2018).

Processes would take less time, proof of payment would be guaranteed and a large amount of paper documentation and postal mail would be saved (Phadke et al., 2021).

Lastly, the possibility of self-checking would be another distinctive advantage. Individuals would largely benefit from blockchain implementation. Not only the tax system would be much easier to understand, but every citizen would be granted the possibility to check the amount of tax they owe for a specific period whenever they want. Citizens could have user accounts that showed in a simple way how much they owe and when it is due. Moreover, this apps could also offer the possibility to enter into payment plans with the tax bureau (Phadke et al., 2021).

3.3. Challenges

Although the implementation of blockchain technology in taxation is a promising idea, there are still some issues that would need to be solved before its adoption. Regulatory and technical risks may appear if not enough attention is paid.

As every new technology, blockchain lacks sufficient legal regulation, which may pose several problems. Moreover, its implementation in the tax public system would require ruling additional laws and directives, which can pose problems due to the lack of experience regulators have within this topic. As a consequence, legislation gaps are likely to arise. In conclusion, a detailed labor is required in order to accomplish an accurate regulation.

Technical problems can also be a significant risk. Zheng et al (2020) have made exhaustive research along this topic. However, given the scope of this paper, only a brief explanation of the most relevant ones will be discussed. More complex issues related with computer science will be omitted.

The first technical issue refers to the lack of a universal programming language that can ensure the compatibility of multiple chains (Vishnevsky & Chekina, 2018). For instance, smart contracts are often coded using Solidity, Go, Kotlin or Java, although many more languages are available (Zheng et al., 2020). General consensus would be needed in order to implement a unified model, especially in the use cases that concern several jurisdictions, such as transfer pricing or VAT. Moreover, some process modeling languages, such as BPMN, lack DLT-specific concepts, which make them unsuitable for this purpose unless they face updating (Fatz et al., 2020).

In addition, the readability of those languages often requires specific computer science knowledge, which is not currently possessed by most tax public employees. Regarding this, Frantz & Nowostawski (2016) have proposed a semi-automated translation system that can convert human-readable contract representations into computational programs. The implementation of this technology would help to solve this problem. In addition, it is expected that, as programming becomes more and more essential, computer languages will become more comprehensible for people without background knowledge.

The second technical issues concern scalability. As it has already been stated, consensus mechanisms that suit best private blockchains have been proven to be not scalable (Nair & Dorai, 2021). It is yet to be known whether the capacity of this mechanisms will be able to sustain a network that includes all the taxpayers of a certain jurisdiction. However, as new consensus mechanisms are developed, it is expected that this problem will be solved.

Nevertheless, the main challenge regarding the adoption of blockchain may be the balance between transparency and privacy. As it has already been stated, public blockchains are not suitable for tax purposes, as they would not be able to prevent the disclosure of sensitive information. On the other hand, the design of private DLTs *"is always a trade-off between the two opposing goals of transparency and confidentiality"* (Fatz et al., 2020). This means that a balance between both assets should be reached, which may be difficult to accomplish. However, as technology develops, a sufficient amount of both privacy and transparency can be achieved simultaneously. For instance, zero-knowledge proof allows parties to show properties of confidential data to another party without actually showing such confidential data (Narula et al., 2018).

Lastly, some social aversion to change is expected, as blockchain is an extremely disruptive technology and society is always reluctant to significant change (Vishnevsky & Chekina, 2018). Moreover, blockchain is highly associated with Bitcoin and cryptocurrency, which are perceived as unstable, volatile, and sometimes fraudulent. It is imperative that the population correctly understands blockchain in order to adopt it, which may require both time and effort for the public authorities.

4. Use cases

As it has already been stated, blockchain models largely vary depending on the particular use case they are designed to serve. In this epigraph, the most relevant tax use cases of this technology would be analyzed.

4.1. Transfer pricing

Transfer pricing remains a major issue within taxation. Although most jurisdictions use the arm's length principle (ALP) as a guide to value transactions among related parties, translating such a general principle into tangible numbers still requires large amounts of effort. This is reinforced due to regulatory differences among countries and the general lack of trust between parties. As blockchain technology can be deemed as trustless, it could significantly simplify the proceedings that concern transfer pricing (Nemade et al., 2019).

In a report made by PWC (2016), experts agreed on the fact that blockchain technology would be suitable for verifying transfer pricing. As far as they were concerned, codifying the judgements made when deciding how profits should be split within the different parts of an enterprise is already a possibility from a technological standpoint. A more recent expert survey concluded that 75% of experts think blockchain technology could be successfully applied in transfer pricing, in particular, they found that it could help *to "capture profits from a transaction database to determine how the profits are distributed among the various components of the business"* (Grundel et al., 2021).

According to Deloitte (2017b), blockchain based transfer pricing would offer major advantages. DLT would make it easier to track transactions made and identify all the parties involved. Moreover, it would eradicate the possibility to tamper with the data once it has been uploaded to the ledger. Agreements could be coded into smart contracts, hence making payments automatic once the given conditions have been met.

This would prevent firms from drowning into a nightmare of documents and data stored on multiple databases that do not communicate with each other efficiently. Furthermore, it would build trust between governments and corporations, eliminating the need for costly audits and inspections.

The applications of blockchain in transfer pricing are diverse, including documentation, comparable data, functional analysis, and smart APA coding. As far as the present time is concerned, smart contracts have not been yet applied for this purpose. The idea of coding transfer pricing agreements into computer language has not been tested and remains as a theoretical possibility that could be taken into practice soon.

Transfer pricing documentation

Information asymmetry is the main concern within transfer pricing issues, as multinational enterprises (MNE) often possess more information than tax authorities. Furthermore, asymmetries can also be found among different entities of the same MNE, as well as between different tax administrations from different countries. This may result in a lack of understanding of the supply chain, poor documentation for billing and a lack of fulfillment of regulatory and compliance requirements.

The adoption of blockchain regarding this field would imply the register on a distributive ledger of intra-group transactions and any other relevant information for this purpose. As a result, financial reports of multinational entities would be auditable on a real-time basis (Cipollini, 2021).

The recording of intra-group transactions on the blockchain would make them transparent and traceable, significantly facilitating the fulfilling of transfer pricing documentation. The supply chain would be presented in a clear and comprehensible way, hence resulting in an enhanced capability of a MNE to document the functions, assets and risks located throughout it. In such a way, compliance and audit defense burden would be reduced (Sim et al., 2017).

It is important to assess how this solution would interact with the BEPS project, especially regarding action 13. This action aims to provide standardized transfer pricing documentation in order to ensure transparency regarding MNE's allocation of income and taxes paid in the jurisdictions they are present in.

For this purpose, a three-tiered approach has been developed. The first tier comprises a master file that includes information related to global business operations and transfer pricing documentation. The second tier consists of a local file for each country that contains more detailed transactional transfer pricing documentation. The third tier includes a country-by-country report (Cbc), in which information about each tax jurisdiction is compiled, including profit before income, tax, the income tax paid, and other indicators of economic activity (OECD, 2015b).

However, the adoption of such measures does not guarantee an enhanced level of trust between tax authorities and enterprises, nor does it end with the information asymmetries mentioned above. Blockchain technology could help to provide a contemporaneous and immutable record of transactions (Sim et al., 2017).

Regarding this, information concerning the master file, the local file and the CbC should be recorded on the blockchain. As a result, this information, which would be updated and verified in real time, would be available immediately for tax audits. As all the participants in the network would share the same version of the DLT, asymmetries of information would disappear (Cipollini, 2021).

Given that all the relevant data would be available in real time on the blockchain, reporting and monitoring activities could be carried out through an automated two-step process that comprises transfer pricing calculation and transaction verification. As a result, a significant amount of time, costs and efforts would be saved (Bilaney, 2018).

Comparable data

The arm's length principle requires the analysis of comparable transactions. However, finding this data is often a burdensome task for tax authorities. Although in some cases such information is simply non-existent, in many others it is just not available to the public. The implementation of blockchain would result in more retrievable ledgers of transactional information. Furthermore, as the use of smart contracts would contribute to the standardization of terms and conditions, comparability would be enhanced (Sim et al., 2017).

As a result, some TP methods, such as the Comparable Uncontrolled Price (CUP), will be easier to adopt. According to PWC (2018), CUP can be deemed as *"the most direct and reliable way to apply the principles of free competition".* However, its implementation has been significantly reduced due to the lack of comparable data, a problem that blockchain could help to solve.

Functional analysis

Compensation in transactions between independent parties often takes into consideration the functions each party carries out. Consequently, transfer pricing requires performing a proper functional analysis in order to delineate intra-group transactions and compare them with uncontrolled ones. In this sense, the OECD (2015a) has underlined the importance of *"identifying the functions performed, the assets used and the risks assumed by the parties to that controlled transaction"* regarding Actions 8-10 of the BEPS plan.

Several methods can be used to deliver a functional analysis. However, whichever one the company may choose, they all require high level of accuracy and coordination managing substantial amounts of information. Given this fact, the use of blockchain could significantly reduce the complexity of these processes (PWC, 2018).

As it has already been stated, recording intra-group transactions on blockchain would provide MNEs with enhanced transparency and traceability. Consequently, the creation of value in a transaction could be smoothly understood. Proof of where a transaction was originated, as well as when and under which terms it took place would be easy to obtain (PWC, 2018). In addition, the availability of such reliable data would result in a decline in the number of disputes, as well as in the amount of time it would take to settle them (Sim et al., 2017).

Transactions regarding intangible assets would especially benefit from this, as blockchain could be used to support DEMPE (development, enhancement, maintenance, protection, and exploitation of intangibles) analysis. Furthermore, it could be automatically performed by a smart contract. This method was developed to ensure that the revenues of an asset would effectively be distributed according to the contribution each member of the group made to its development and exploitation, thus avoiding profit allocation in low tax jurisdictions-located entities that were transferred the legal ownership. Recording intangible assets-related transactions on blockchain would *"enable more accurate allocation of intangible-related returns to key people functions"* (Sim et al., 2017).

Smart APAs

Cipollini (2021) has largely contributed to the topic exploring the development of blockchain-based APAs. APAs are domestic law instruments enforceable between a taxpayer and the tax authority of the correspondent jurisdiction. Additionally, they can also concern the related associated entities of the taxpayer and tax authorities of the jurisdiction of such entities (Lang et al., 2018). The main goal of such an agreement is to settle the particular methodology that will be used to calculate transfer pricing within a certain period of time, hence preventing litigation, ensuring tax compliance, and giving certainty to all the parties involved. Although some APAs settle a final ALP price, most of them merely agree on less specific terms.

APAs could be coded into smart contracts, automatizing transfer price calculation and verification. Using the terms and conditions agreed within the APA, the smart APA would be able to determine the correct transfer price or possible range of prices for a certain intra-group transaction. As this process would take place automatically, both multinational enterprises (MNEs) and tax authorities would significantly reduce their workload.

Moreover, the results offered by smart APAs could be used for transfer pricing documentation and CbC reporting. The data automatically calculated by the smart contract could provide useful real time information regarding *“MNE’s intangibles, MNE’s intercompany transactions, tax positions, intercompany agreements concluded by the local entity, global allocation of the multinational group income and taxes paid, allocation of risks, and criteria for the selection and application of the most appropriate TP method”* (Cipollini, 2021).

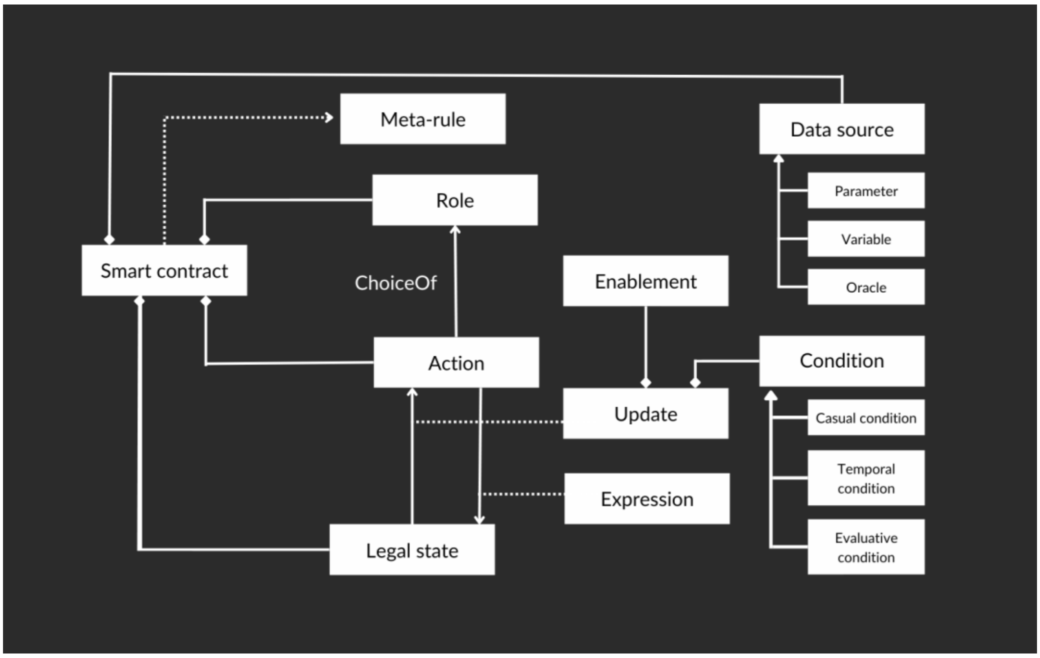
Once the calculation is made, the MNE, which would operate as a node in the ledger, would be able to confirm the transaction if its value matches the range of prices previously determined. Consequently, it would be the tax authorities’ turn to validate the operation. This verification would occur automatically if, as in the previous case, the transaction price is in line with the one calculated by the smart APA. Once verification by all parties is achieved, the transaction would be added to the blockchain as a new block (Cipollini, 2021).

For this purpose, conventional clauses written on conventional APAs should be translated into computer code. This task would require the combine efforts of lawyers, tax experts and data scientists. It should be considered that legal prose should be avoided as much as possible, giving certainty to undetermined terms. If that is not the case, they will not be able to be translated into code. For instance, the term *within a reasonable amount of time*, should be substituted for a determined range of time that is considered reasonable for the specific situation. Moreover, a unified model of smart APA should be enforced.

Regarding this aspect, Ladleif & Weske (2019) have developed a model of legal smart contract that would be suitable for APAs. The main benefit of their model is that it is simple enough to comprehend, but complex enough to accurately capture the structure of a conventional APA.

The model is composed of five main elements: roles, data sources, actions, conditions, and metarules. The relationship among them is showed in the following graphic.

Figure 3. Diagram of a Smart APA



Source: own work based on Ladleif & Weske (2019).

The first component, *roles*, is introduced to set the number of parties involved, as well as the different categories they fall in and their correspondent rights and permissions.

Data sources, which are the second component, can be subdivided into three smaller categories: parameters, variables, and oracles. The first ones come in the form of quantitative values that can range from simple numbers to complex functions and should be determined for each contract, such as the price or the quantity. Variables are custom run-time values that, contrary to parameters, are not subjected to negotiation before the agreement and usually change over time. Lastly, oracles act as information seekers, checking data from reliable web pages, for example, looking for the current price of a certain stock.

The third component has been named *actions* and it can be defined as any relevant event that may take place while the contract is enforceable. They are either carried out by the involved parties (for example, certain parties delivering goods) or happen autonomously (for instance, the price of a certain stock reaching certain price). The execution of an action results in the updating of the legal state of the parties, which can be defined as *“a snapshot of the legal relations between the roles that enable a set of actions at a specific point in time”* (Ladleif & Weske, 2019).

The fourth component is referred to as *conditions* and they play a mediating role in the relationship between actions and legal states. Conditions can be categorized into three types: temporal conditions, evaluative conditions, and causal conditions. The first ones indicate a certain timer, whether it is absolute or relative. For example, an action that occurs automatically may be triggered by a temporal condition (e.g., stock options expiring on a certain date or within a determinate amount of time since the agreement is signed). The second ones assess the values of different data sources, usually through a formal expression (for instance, an action may take place when a variable is between a determined set of values). Causal conditions rely on the history of the smart contract itself, requiring no interpretation to trigger a certain action.

Finally, the fifth component consists of *metarules,* which aim to introduce in the model any relevant legislation that may have an influence on the contract, for instance, due to the need for interpretation.

As a result of applying this model to a conventional APA, the resulting smart APA will be standardized, hence being more suitable for its purpose. The different parties involved, that is, the taxpayer and its foreign-related entities and the correspondent tax authorities, will be assigned different roles.

The transaction that aims to be covered by the APA will be set a causal condition, whereas the TP methodology chosen for its valuation will be shaped by parameters. Other central assumptions such as the MNE's strategy or structure, as well as the factual circumstances and economic conditions that surrounds them, can be configured as evaluative conditions. These conditions will sometimes need the intervention of an oracle in order to be triggered.

In some cases, critical assumptions may be coded as *metarules* when they concern domestic tax law or treaty provisions. In addition, others may be set as variables if they are expected to change over time, such as duties, tariffs, or sales volume. The determination of their current value will be performed by an oracle.

Furthermore, a temporary condition regarding the duration of the APA should be configured and the enabled actions will be defined taking into consideration the interaction between roles and legal states once some pre-defined conditions are given.

Lastly, it should be stated that, in order to function properly, the model needs to have access to all the relevant data that may be required in any step of the process. For this purpose, this data should be stored on the blockchain, whether is it intra-group

TP data from the supply chain, transactions made by the MNE coded into smart contracts or other reliable sources of information that concern critical economic, legal, or political conditions.

4.2. Payroll

Although payroll processes are mostly digitalized in every developed country, payroll calculation remains an exceedingly complex procedure. This is due to the implication of several government institutions, each of which duplicates data, holds it centrally, and performs overlapping compliance audits. As a result, payroll appears to be an environment that would highly benefit from blockchain implementation (Ainsworth & Viitasaari, 2017).

Employers would largely benefit from this, as the calculations they must do every month in order to transfer the correct amounts of tax and social security to the relevant institutions could be done automatically by smart contracts (Deloitte, 2017).

This would be especially useful in the case of cross-border employees, as the observation of more complex regulations is required. International payments often require time to be processed and are subjected to different bank commissions. Moreover, they have been traditionally deemed as hard to trace. The use of blockchain would solve all these issues.

The basic functioning of a blockchain-based payroll system would be really simple. Firstly, information about employees would be updated into the network. This data would concern their contracts and any personal information required to apply for tax benefits. Secondly, a smart contract should be deployed into the DLT. Such contract would be able to correctly calculate the amount of taxes due from each salary using the relevant information stored in the network. If this is done correctly, the employer would only have to insert the gross amount of salary of each worker in the system and, automatically, taxes would be calculated and deposited in the correspondent authority's bank account, transferring the rest into the employee's bank account.

Other models have proposed and inverted functioning, in which tokens are issued to the taxpayer's account according to the amount of tax due and the contributor must reduce its balance to zero paying their correspondent taxes (Phadke et al., 2021). However, this structure is harder to understand and has not yet proved additional benefits.

Given how simple it appears to be, one could wonder why blockchain-based payroll is not yet a reality. According to Ainsworth & Viitasaari (2017), this is mainly due to two reasons: entry-barriers in the payroll business and the lack of a fiat cryptocurrency. Start-ups are often reluctant to enter the payroll field, as it is dominated by a small number of large corporations with which competition is nearly impossible.

Moreover, those attracted by the business may consider waiting until the creation of a fiat cryptocurrency, which would make the development of such system simpler and more convenient.

As far as the present time in concerned, only a few projects have been launched. Futurice's Spice Program is an example of this. Futurice is a Finnish enterprise that provides a wide range of digital services. Their Spice Program is an initiative that aims to remunerate every open-source activity that their employees choose to contribute to in their free time. To calculate their payrolls, the Ethereum blockchain is used. It must be noticed that this program does not automate payment, only payroll calculations.

In order to do that, employees must access and internal web UI to report their contributions. They must provide relevant information about it, such as where it can be found, a brief description and the amount of time dedicated. This information, except for the description, is stored in the Ethereum blockchain along with an encrypted user identifier, which aims to protect the employee's privacy. At the end of each month, the blockchain uses that data to calculate the corresponding payroll to each worker and the result of those calculations is automatically sent to Human Recourses.

4.3. VAT

Value Added Tax (VAT) has become a major contributor to public budgets within the last decades. As a result, its correct functioning is a priority to every government. For this reason, tax authorities are highly concerned about making the system more effective, thus contributing to reduce the tax gap.

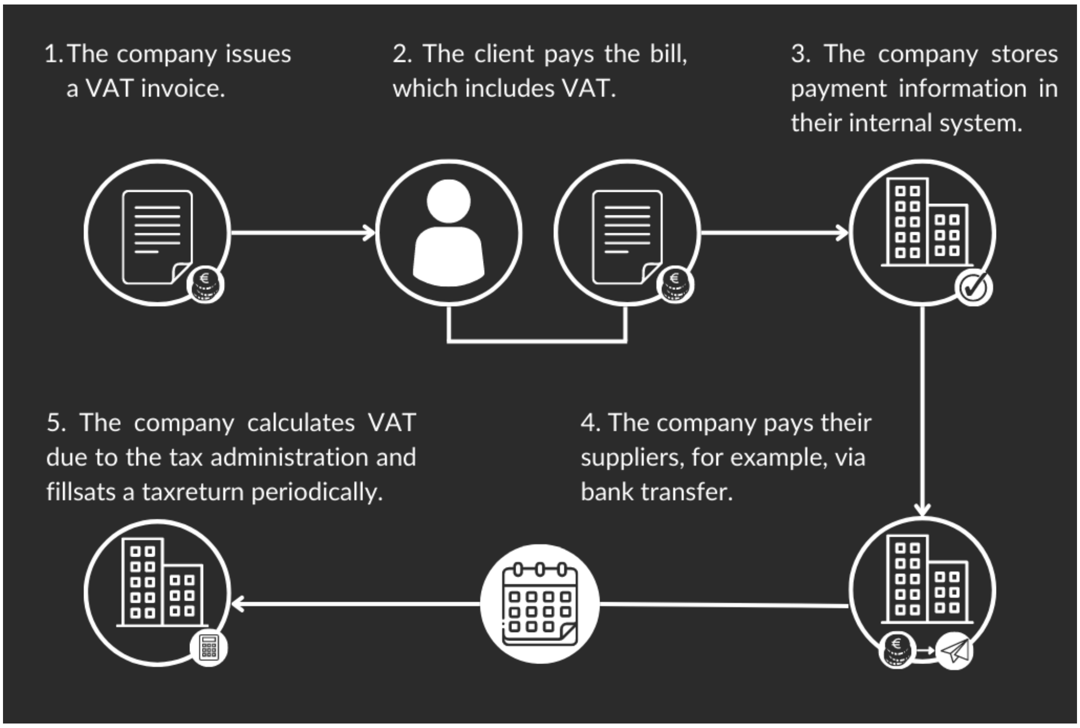
Up to the present time, VAT systems present several problems both on the national and the international level. The most significant one derives from its reliance in corporations to calculate themselves the amount of tax due.

In the current VAT system, each company keeps their own register of their paid and collected VAT, filling periodic returns claiming or paying the amount of VAT due. In a blockchain-based VAT system, every stakeholder of the supply chain would become a participant of the blockchain network, which would be introduced by the government. Smart contracts will keep track of valid transactions and automatically execute payments in real time, as transactions happen (Alkhodre et al., 2019).

Comparing these two processes, we can infer several advantages from the second model. Firstly, companies would face lower administrative burdens, as VAT calculation would be mostly carried out automatically. Furthermore, as smart contracts are tamper proof and transparent, the risk of both fraud and mistakes would lower significantly. This would also be achieved thanks to the fact that the same system that would process VAT transactions would be able to perform multi-dimension checks and transaction verifications. Transactions would be recorded in real-time, providing an immediate insight into a corporation's finances. In addition, money transfers between enterprises and governments would speed up (Deloitte, 2017).

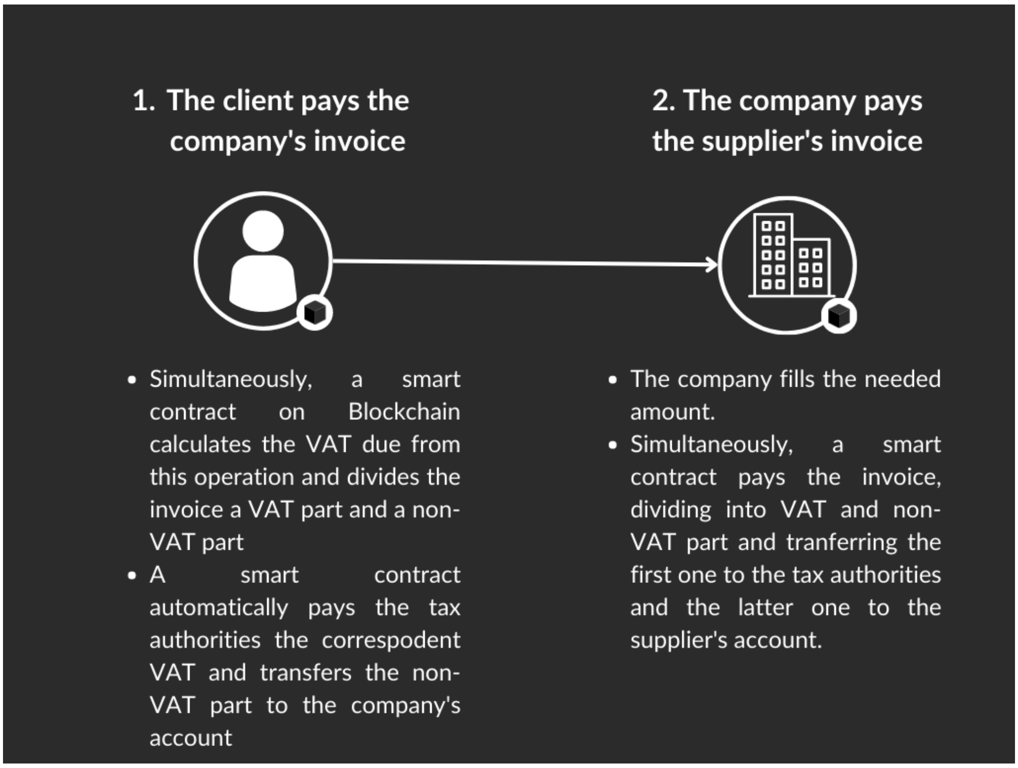
To better understand this, a brief explanation of the functioning of VAT with and without Blockchain will be showed.

Figure 4. How a VAT transaction is processed without Blockchain



Source: own work based on Deloitte (2017b)

Figure 5. How a VAT transaction would be processed with Blockchain



Source: own work based on Deloitte (2017b)

The current system makes it is extremely difficult for tax authorities to trace VAT payment. This results in high rates of fraud, with MTIC, MTEC and carousel being the most common types (Deloitte, 2017b). In their most recent VAT gap report, the European Commission cyphered the 2020 VAT loss in 93 billion euros (European Commission, 2022).

The reason behind the complexity of tracking VAT data concerning international transactions resides on the lack of a central database, as every country keeps their separate ledger. VAT transactions that concerned several jurisdictions are firstly recorded in only one of them, meaning that the other ones must contact the first one to obtain the required data. As this process is time consuming, fraudsters find an opportunity to quickly disappear before they are caught by authorities (Ainsworth & Shact, 2016a).

Some authors have proposed the use of electronic invoices as a solution for this problem. This has already been implemented in Brazil under the name of Sistema Publico de Escrituraçao Digital or Public System for Digital Accounting (SPED). Through a centralized database, SPED coordinates cross-border transactions of the state-level consumption tax between the 26 different sub-national states, each of which applies a different tax rate (Ainsworth & Shact, 2016b).

However, the existence of a unique central database in the case of international economic unions has been problematic, as each country insists on keeping its own. Blockchain implementation could solve this problem, as it would allow each tax jurisdiction to maintain its own decentralized database at the same time that it would ensure synchronization between them.

The most promising scholar research regarding this topic has been centered on international VAT transactions, as the implementation of blockchain could significantly lower fraud in this field (Ainsworth & Alwohaibi, 2017). Investigations have been mostly carried out around two economic communities: the European Union and the Gulf Cooperation Council. This paper would mainly discuss the possibility of blockchain adoption within the EU.

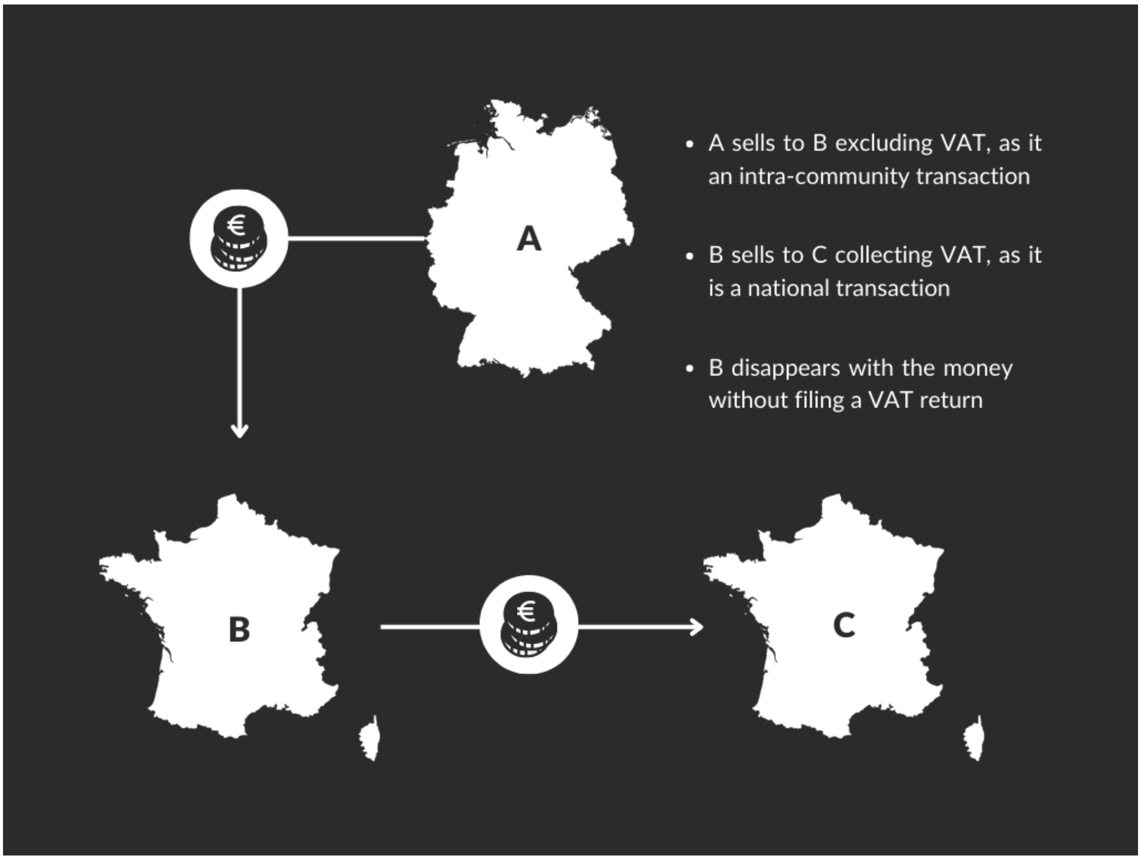
5. A blockchain-based EU VAT

In order to comprehend how a blockchain-based VAT would help to reduce fraud within the EU it is necessary to briefly introduce which are the most common types of VAT fraud and how do they function.

Missing Trader Intra-Community fraud (MTIC) is the most frequent category. Its operational scheme benefits from differences of VAT treatment among EU Member States. In order to do that, a structure of connected enterprises residing in different European countries is used.

MTIC profits from zero-rated cross-borders transactions. This mechanism allows companies to not pay VAT right away in operations between traders of different EU Member States. The VAT corresponding to that transaction should be declared and paid to the importer’s jurisdiction by the importer himself. When this type of fraud takes places, the trader sells the goods, collects VAT in its Member State, and then disappears without declaring nor paying VAT due from the cross-border transaction (Europol, 2022).

Figure 6. Basic MTIC fraud scheme

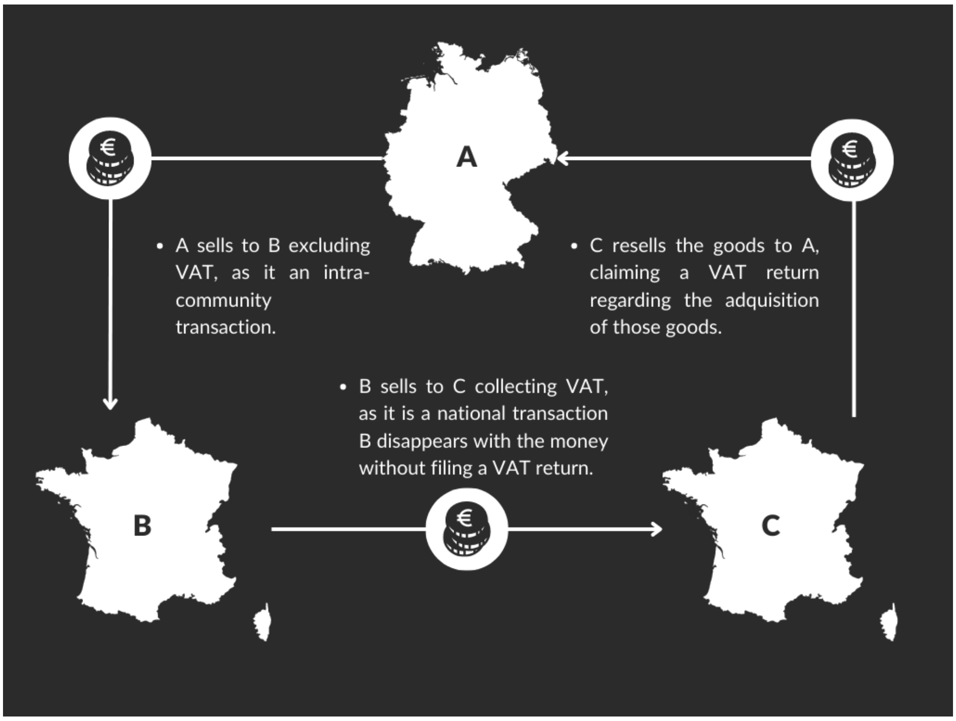


Source: own work based on Pouwells (2021)

Other common types of fraud include carousel fraud, which requires a more complex structure in order to be executed. In this case, several linked companies sell goods in a circular path, in a such a way that they return to the country where the fraud first originated. This is the main difference between carousel and MTIC fraud. In most cases, the circle is consisting of several enterprises and includes buffer companies, which are located behind the missing traders. As a result, investigations are severely obstructed (Pouwells, 2021).

As in the previous case, the first trader in each domestic chain sells on with VAT without submitting the due amounts to the authorities. On the other side, exporters obtain a full reimbursement of VAT payments that never took place (Europol, 2022).

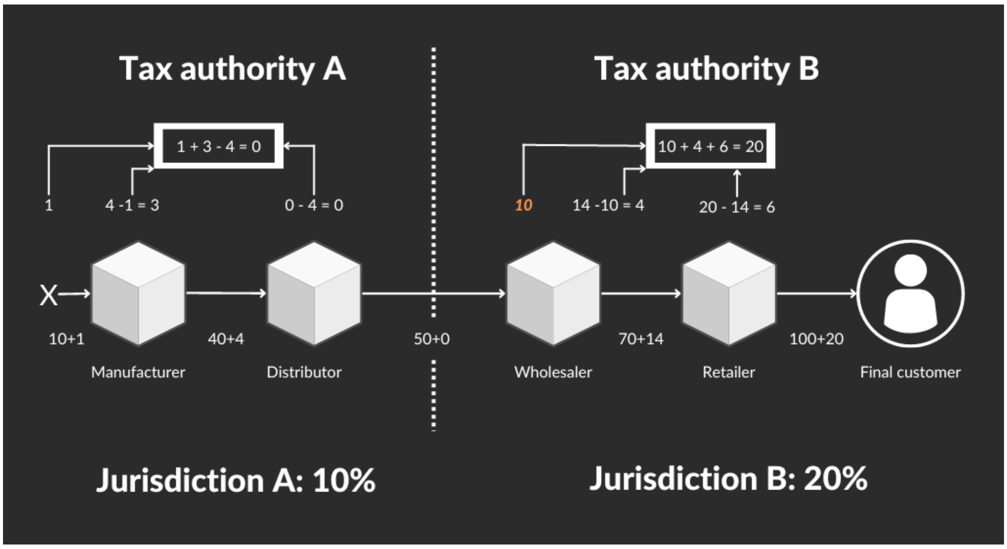
Figure 7. Basic carousel fraud scheme



Source: own work based on (Pouwells, 2021)

In the figure shown underneath we can see how an intra-community sale of goods developed after customs were removed within the European Union. Within this scheme, MTIC takes place when the Wholesaler sells on with VAT to the Retailer, but does not file a return on VAT, rapidly disappearing with the amount of tax collected to a foreign offshore banking institution.

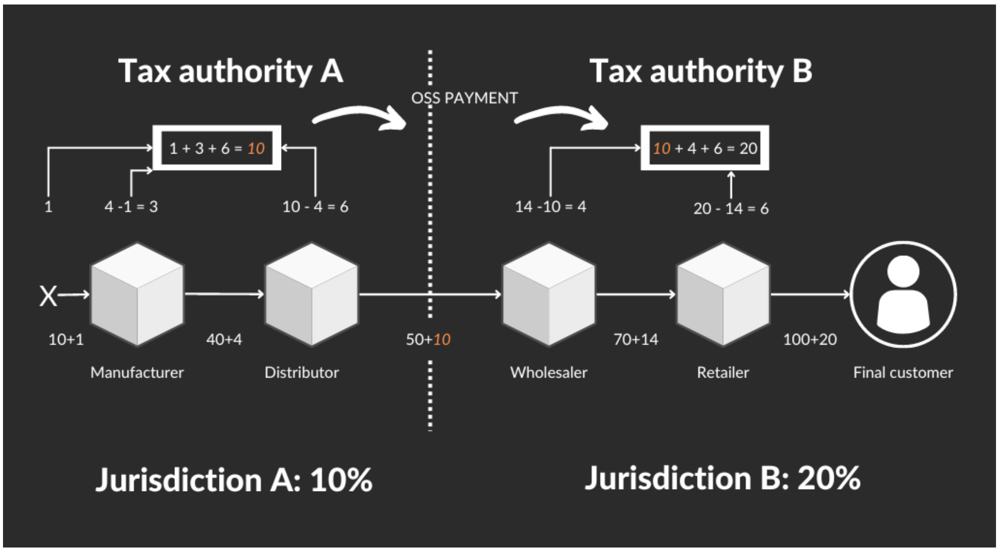
Figure 8. Intra-Community sale of Goods post January 1, 1993



Source: own work based on Ainsworth et al. (2018)

In an effort to solve fraud, or at least minimize it, the European Commission proposed the One-Stop-Shop (OSS) model in 2017, which has been finally implemented in July 2021. Using this mechanism, the cross-border seller (distributor seen in the above diagram) would collect VAT at the buyer's (wholesaler in the above diagram) jurisdiction rate. The distributor would file a one-stop-shop return and tax authorities from both jurisdictions would be noticed that VAT was paid by the wholesaler, collected by the distributor, and listed in Jurisdiction A to be sent to Jurisdiction B.

Figure 9. Intra-Community sale of Goods with One-Stop-Shop system



Source: own work based on Ainsworth et al. (2018)

Even though this system poses some advantages over the past one, it does not end MTIC fraud. Most likely, MTIC pattern will morph so the distributor, instead of the wholesaler, becomes the missing trader. Therefore, OSS has still room for fraud, even though its amount would be lower. For instance, in the example of the diagram, the wholesaler would be able to steal 14 money units with the former model, whereas the distributor could only steal 10 with OSS.

Furthermore, this solution also presents some complexity regarding its enforcement. In the example presented above, Jurisdiction B will have allowed a deduction of 30 money units to the Wholesaler. However, as the Distributor has disappeared with that money, it is unlikely that Jurisdiction A will transfer that sum to Jurisdiction B. In such a case, Jurisdiction B will have several trouble trying to find de the fraudster, as most of the relevant data and the audit obligation resides in

Jurisdiction A, which will likely have little interest in solving the case, as their taxes have already been paid.

Scholar research has pointed out that the implementation of blockchain technology would help to end VAT fraud. This idea was initially proposed by Ainsworth and Shact in their paper “Blockchain technology might solve VAT fraud”, published in 2016. By the end of the same year, both authors published “Blockchain (Distributed Ledger Technology) solves VAT fraud”, as their research had already proved their hypothesis. Their findings were shared among the scholar community [Alkhodre et al., (2019), Nguyen et al. (2019), Müller (2020)…], whereas both Deloitte and PWC included them in their report “Blockchain technology and its potential in taxes”, and “Two practical cases of blockchain for tax compliance” published in 2017 and 2019. At the same time, Ainsworth maintained a close collaboration with Alwohaibi, resulting in several papers that explained how to apply blockchain to GCC VAT.

As far as the present time is concerned, there are two main directions to end VAT fraud using blockchain: digitalizing VAT-relevant information and implementing a cryptographic tax currency (Müller, 2020).

DICE on blockchain

Digital Invoice Customs Exchange (DICE) was originally designed for the European Union in order to update the VAT information Exchange System (VIES). The main goal of DICE was to make data exchange more automated and immediate. This system in based on the digital signature of invoices, the upload of encrypted invoice data to databases and the performance of risk assessments regarding that data, allowing tax authorities to invalidate fraudulent transactions immediately.

DICE system consists of eight steps, which can be explained as it follows (Ainsworth & Alwohaibi, 2017):

1. The seller creates a digital invoice including all relevant transaction information and then adds their digital signature, which constitutes a pro-forma digital invoice. The seller then signs the invoice digitally in order to ensure both authorship and data integrity. The file is sent electronically to the Origin Tax Administration, acting as a request for authorization of use.

2. The tax administration receives the file in XLM format and acts on it. As this process is fully automated, it is available on a 24/7 basis. It only implies a brief

verification for accuracy and completeness of the file, taking no more than a few seconds in the process.

3. If the data provided in the invoice is accurate and complete, the Origin tax administration will sign it electronically and transmit the invoice back to the seller. The signature will act as an access key to information about the invoice and the document will become part of a ledger shared by the seller, the buyer, and the tax administration in order to verify the file. The access key will be available in the form an alpha-numeric bit string that will present the form of a bar or QR code when reproduced on paper. The scan of this code will provide information about the whole supply chain.

   Simultaneously, the Origin tax administration will notify the Destination tax administration of the actions taken, remitting a copy of the full documentation and access keys.

4. The seller will compose a proposed invoice that will include all the relevant data of the file as well as the access key and they will send it to the buyer.

5. The buyer will receive the file, having the possibility to check its validity using the access key. The buyer will then sign electronically the file and send it to the Destination tax administration.

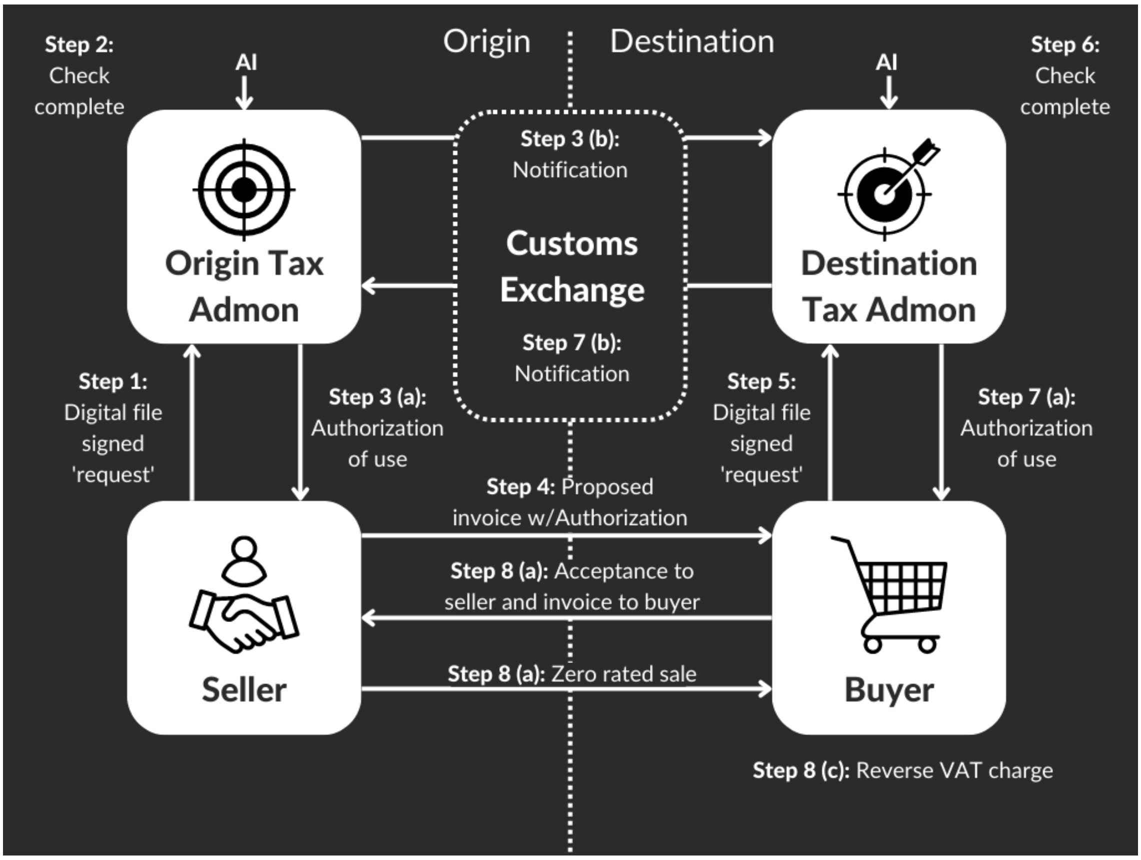
6. The Destination tax administration will receive the file sent by the buyer and verify its data. If everything is correct, it will be digitally signed and saved, and a second access key will be generated. The files from seller and buyer should match.

7. The Destination tax administration will issue an authorization of use and remit it to the buyer. At the same time, they will notify the Origin tax administration and send them a copy of the file as well as the second access key.

8. Finally, the buyer saves a copy of the file and sends it to the seller along with both access keys. A VAT invoice containing all the relevant data, as well as

both keys, is generated. The seller will then zero-rate the transaction and the buyer will perform a reverse charge.

Figure 10. Functioning of DICE



Source: own work based on Deloitte (2017b)

Under this regime, both Origin and Destination tax authorities will have access to complete digital files not only of transactions that occurs in their jurisdiction, but also of intra and extra community transactions that involve their taxpayers. Artificial Intelligence (AI) programs will be used in order to assess the risks every transaction may pose as it happens. When a suspicious transaction is detected, the tax administration will be able to deny digital invoice certification, hence invalidating and stopping the transaction.

The adoption of a blockchain-based DICE would require three main elements: a network of computers, a network protocol, and a consensus mechanism. As it has already been stated, the network of computers should be composed of as much nodes as possible to ensure security. In the case of the EU, each country should contribute with a number of nodes proportional to their GDP (Ainsworth & Shact, 2016b). The choice of an appropriate network protocol, as it has already been discussed, is out of the scope of this paper, as it mainly concerns informatics. Lastly, the consensus mechanism used should be based on objective criteria, in such a way that it allows AI to detect fraudulent transactions so they can disapprove their verification.

Blockchain-based DICE would imply that every transaction regarding the supply chain would be recorded on a block, which would be linked to the following ones. When a cross-border transaction is negotiated, both the buyer and the seller should transmit a pro forma invoice containing their tentative agreement to their respective tax administrations. Such file would be sent to the cloud and then assigned to the nodes of each jurisdiction, who will act as verifiers.

Ainsworth and Alwohaibi (2017) suggest that the analysis should be guided by an analytical approach that matches the preferences of each node manager. As an example, they have proposed the following non-exhaustive list of criteria:

"• Are the prices charged below market?

• Is the buyer or seller a newly registered taxpayer with insufficient capital to engage in transactions like those proposed?

• Has either tax authority specifically notified one party that previous deals involving the supplier had been traced to a VAT loss and/or had involved carousel movements of goods?

• Has either tax authority specifically notified one of the parties to the current transaction that other MTIC VAT fraud characteristics (such as third parties' payments) have occurred in other transaction chains by this taxpayer?

• Are the buyer and seller current on other tax obligations (income tax, property taxes, payroll taxes)

• Based on available payroll records do the buyer and seller appear to have a sufficient number of employees to justify the transaction volumes on the proposed invoices?

• What is the buyer's/supplier's history in the trade?

• Does the deal carry no commercial risk – e.g., no requirement to pay for goods until payment received from customer?

• Does the deal involve consistent or pre-determined profit margins, irrespective of the date, quantities or specifications of the specified goods traded?

• Does the supplier (or another business in the transaction chain) require 3rd party payments or payments to an offshore bank account?

• Are the goods adequately insured?

• Are goods of high value offered with no formal contractual arrangements?

• Are high value deals offered by a newly established supplier with minimal trading history, low credit rating etc?

• Can a brand-new business obtain specified goods cheaper than a long established one?

• Does the volume purchased (or sold) fit within normal trading patterns for these companies?"

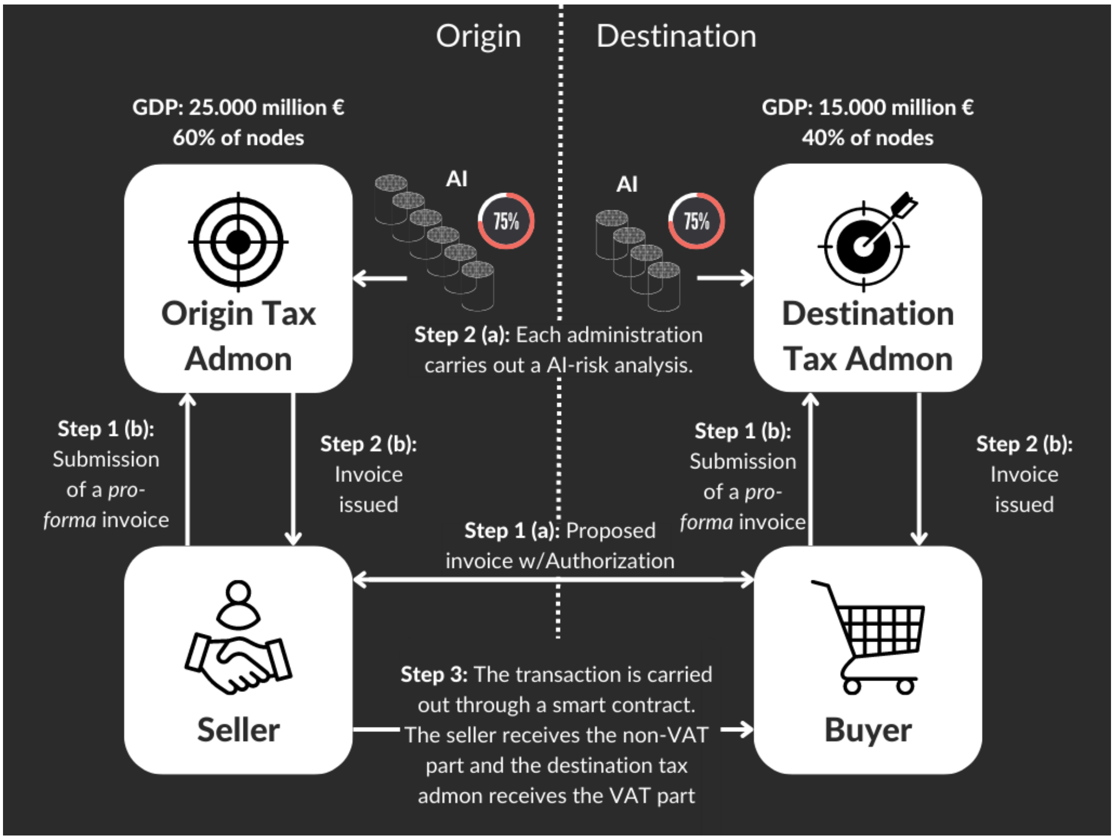
Each node will carry a risk analysis according to the selected criteria, resulting in the approval or disapproval of the transaction. A consensus threshold should be established, for instance, a transaction may be considered valid when it has been approved by at least 75% of the nodes of each jurisdiction.

In order to perform such analysis, each node should have access to all the standard invoice-level data concerning both parties, such as their names, addresses, VAT IDs, price per item, volume… Furthermore, nodes should also have access to a large number of public and private databases that will help them find statistic anomalies in real time. AI operators should be trained auditors with vast knowledge in the field.

If the transaction is approved, the invoice will be issued. Every invoice must display a digital fingerprint resulting from the blockchain consensus process. As a result, this fingerprint will identify each of the blocks of the supply chain as permanently linked with each other. Consequently, the entire historical commercial chain of an item can be easily followed with the help of a scanner connected to a tax-auditing program.

The implementation of blockchain throughout this process would significantly speed the process, as the eight-steps of traditional DICE would be reduced to 3. Firstly, the buyer and seller would agree on the terms of their intra-community transaction, creating a pro forma invoice and submitting it to their respective tax authorities. Secondly, each tax administration would perform the analysis described above. If the transaction was approved, an invoice would be issued. Lastly, the transaction would be executed through a smart contract, which would calculate the non-VAT and VAT part and transfer those amounts to the seller and the buyer's jurisdiction, respectively.

Figure 11. Functioning of blockchain-based DICE



Source: own work based on Ainsworth & Shact, (2016b)

Although this solution creates an efficient and secure train of commercial activity, there are still some centralized aspects in it. It remains unclear whether governments would willingly share their databases with other jurisdictions. It is likely that, in the event of a cross-border transaction, one of the countries uses confidential data that is not available for the other to perform their risk analysis. As a result, the consensus reached by each country may predominantly favor their own taxpayers (Ainsworth & Alwohaibi, 2017). The following blockchain-based solution proposed would fix this problem.

VATCoin: the first cryptotaxcurrency

VATCoin was first proposed by Richard Ainsworth, Musaad Alwohaibi and Mike Cheetham in their 2016 paper "VATCoin: The GCC's Cryptotaxcurrency", which revolved around the implementation of a blockchain-based VAT in the GCC. These authors have worked together in further developing this idea in the last years, analyzing its suitability for the European Union. If adopted, VATCoin would be the world's first *cryptotaxcurrency* ever used.

VATCoin has been modelled after Bitcoin, but it presents significant differences over it. Firstly, VATCoin should operate on a private blockchain, whereas Bitcoin's ledger is public. Secondly, speculation would be avoided in the case of VATCoin by fixing its value to the local currency.

VATCoin is a digital currency with no physical form available. The idea is to convert VATCoin in the sole means of acceptable payment for VAT. As a result, no tax would be paid nor held in real currency. Only the government would be able to convert VATCoins to real currency. Every transaction that implied VATCoins would be recorded on the blockchain, so every coin would be traceable. This would lead to several significant benefits (Ainsworth & Alwohaibi, 2017):

- VAT would no longer be held by traders. As every VATCoin would be stored in the cloud, no company would hold it, hence eliminating the possibility of disappearing with it.
- Real-timeness. Smart contracts would balance taxpayer's accounts on a daily basis, performing payments or refunds depending on whether the balance is positive or negative.
- Enhanced cybersecurity. As VATCoins would have no material representation, a black market would not be possible. As this cryptotaxcurrency can only be converted to real currency by the government, any stolen VATCoin would immediately become worthless.

As VAT would have to be paid in cryptotaxcurrency, companies would need to fill a request to obtain VATCoins from their government in order to pay their invoices. VATCoins would be denominated in local currency, meaning that there would exist euro-based VATCoins as well as other types, such as Polish zloty-based VATCoins or Swedish krona-based VATCoins.

Once a jurisdiction (e.g., Jurisdiction A) has received a request, their Treasury would proceed to mint the requested amount of cryptocurrency. This amount would be transferred to its tax authorities, who would remit it to the taxpayer that had originally requested it. Once the transfer had been made, a smart contract would automatically send to the tax authorities of Jurisdiction A the equivalent in real currency. All of these transactions would be recorded on the blockchain. As some time is expected to pass between them, it can be assumed that each of them would conform a different block, all of which would be linked in the same ledger.

Once the trader has the sufficient amount of VATCoins to carry out the cross-border transaction, these will be transmitted to the seller as a form of VAT payment. This transaction, which would also be recorded on the DLT, would conform a fourth block in the chain. The seller, resident in Jurisdiction B, would then apply for the refund of input VAT and fill an OSS return. As a result, Jurisdiction B would collect the VATCoins implied in the transaction and remit them to Jurisdiction A. Lastly, Jurisdiction A would proceed to burn them (Ainsworth et al., 2018).

Regarding this scheme, two considerations shall be made. Firstly, it must be said that every VATCoin would be perfectly identified in the commercial chain, which would be entirely recorded on the blockchain. As it has already been stated, stealing VATCoins would not provide the thief with real currency, only with a means of payment for VAT amounts due. However, the latest option would not be a possibility neither, as every coin in traceable.

Secondly, each country would mint their own type of VATCoins, even if they are denominated in the same real currency. Spain would mint Spanish euro-based VATCoins, whereas Germany would mint German euro-based VATCoins. Although their value may be the same, this allows for further traceability.

6. Conclusions

Blockchain technology was first introduced in 2008, a few months before the launch of the Bitcoin network. Since then, the technology has evolved significantly and has been applied to a wide range of industries beyond just cryptocurrency. The variety of areas in which decentralized ledger technology has been applied includes chain management, digital identity, and voting systems.

In recent years, there has been a growing interest in the use of blockchain for enterprise and government applications. This has led to the development of more advanced blockchain platforms, which provide additional functionality and scalability. As a result, PoW has been slowly replaced with other consensus mechanisms, such as PoS, which enhance not only scalability but also sustainability. However, the search for the ultimate consensus mechanism is still ongoing.

Additionally, there has been an increase in the use of decentralized finance (DeFi) applications on blockchain, which allow for the creation of decentralized financial instruments and services. Overall, the evolution of blockchain technology has led to new and exciting possibilities for various industries and has the potential to revolutionize the way we conduct transactions and transfer value.

Consequently, it was a matter of time that experts became aware of its suitability to improve the tax system. The inherent features of this technology would lead to enhanced transparency, data security, a significant increase in the fraud detection rates and an overall reduction of time and efforts both for taxpayers and tax authorities.

As one of the main characteristics of blockchain, transparency would largely contribute to the improvement of the tax system. DLT ensures no transaction can be omitted nor modified or tampered with once it has been included in the network. Furthermore, provenance and traceability would be enhanced. As a result of decentralization, single point failure would be avoided. Moreover, hacker attacks would be less likely to occur, hence improving the security of the tax system.

In addition, the tax system would shift from a retrospective to a real-time approach. As data would be updated in real-time to every node of the network, it would be possible to calculate and pay taxes as transactions happen. Consequently, tax audits would stop being performed retrospectively, which would make fraud easier to spot.

The combination of these features would lower burdensome tasks for both taxpayers and tax authorities. The tax system would become more accessible to every citizen and considerable amounts of time and money would be saved by the administration, as the need for personnel would be substantially reduced. Furthermore, as tax fraud would be harder to perform and easier to detect, the tax gap would drop significantly. As a result of the previous features, the tax administration would increase its available resources, hence increasing its efficiency.

Moreover, the implementation of smart contracts within the blockchain network offers a range of additional benefits. Smart contracts are computer programs that are designed to automatically execute the terms of a contract when certain conditions are met. They are used to facilitate, verify, and enforce the negotiation or performance of a contract. The introduction of smart contracts could automatize several tasks for both taxpayers and tax administrations. As a result, compliance would be simpler and clearer for ordinary people, who often fail to comprehend our current tax system. Tax inspections would also be less time and effort-consuming, as most data could be directly analyzed automatically.

The implementation of blockchain in taxation would require the development of a decentralized network managed by the authorities. However, the development of such network could be provided by the private system, as some sectors are already experienced in the field. Despite of the loss of some decentralized properties, the use of a private blockchain would be the most suitable option, as privacy is required in order to process confidential data. Within this network, a permission system would be developed, ensuring every member has access exclusively to the data required to perform its duties.

Regarding this, there are three proposed levels of blockchain implementation. The first one implies recording tax-relevant information on the network in order to facilitate compliance and fraud detection. Recording transactions on blockchain would enhance their traceability, hence facilitating disputes between taxpayer and tax authorities. Furthermore, smart contracts could be used to calculate the amount of tax due in real time.

The second proposal goes a step forward and suggests the use of smart contracts to integrate payments in the network. In such a way, every transaction recorded would be automatically divided into its non-tax and tax part, transferring the first one to the recipient 's bank account and submitting the latter one to the tax administration.

The most advanced level of blockchain adoption within the tax system would imply the implementation of *cryptotaxcurrencies*. This form of currency would be entirely digital. To avoid fluctuation in its value, its price would be directly linked to the State's official currency. This measure aims to avoid the use of these assets for speculative purposes, thus establishing a clear distinction between them and other forms of cryptocurrencies. Converting cryptotaxcurrency in the sole possible tax payment method would lead to a significant drop of fraud, as tax-money would be taken out of the trader's hands.

The implementation of blockchain in the tax system could include several use cases. Payroll, transfer pricing and VAT are the most relevant ones. Regarding the first one, taxes related to salaries, mainly income tax, could be calculated and paid automatically via smart contracts. As a result, payroll processes would become more efficient and less time demanding. However, the payroll industry has several entry barriers that difficult innovation in the field. This factor could explain the lack of initiatives within the sector.

Regarding transfer pricing, recording intra-group transactions on the blockchain would facilitate compliance with TP documentation. As operations would become entirely transparent and traceable, information asymmetries would be reduced. Moreover, DLT would provide a more comprehensible way to see value creation across de supply chain and perform functional analysis. MNEs would utterly improve their capability to document the functions, assets and risks located throughout the supply chain. Intangible assets would largely benefit from this, as DEMPE analysis requires high traceability.

In addition, the availability of comparable information would profoundly broaden, facilitating the use of certain TP methodologies, such as comparable uncontrolled price, which has often been deemed as the purest way to calculate transfer pricing. Consequently, the number of disputes between taxpayer and tax authorities would be significantly lower. Furthermore, the ones who may occasionally appear would take less time to settle.

APA's may even be coded as smart contracts, resulting in an automatic calculation of a range of possible transfer prices. As a result, both MNEs and tax authorities would save great amounts of time of money. This use case would require the development of legal smart contracts, for which several models have been already proposed.

In order to record the transaction on blockchain, the smart APA would first determine the range of possible transfer prices. Immediately after, the MNE would be able to confirm the operation if it matched the calculated range. After this, tax authorities would have to verify the transaction, which would happen automatically if the price fell in the bracket given by the Smart APA. Once it had been validated by every node, the transaction would be included on the blockchain, conforming a new block.

However, the use case in which blockchain offers the most promising prospects is VAT, as the reduction of the tax fraud would be significant in this field. As far as the present time is concerned, high rates of fraud can be found in intra-community transactions. Despite the European Commission's efforts in stopping MTIC, it still largely contributes to the 93 billion euros of VAT lost in 2020 along the UE due to fraud.

MTIC exploits differences across Member States' VAT legislation. The missing trader first acquires goods from another Member State, which are zero-rated, as it is an intra-community transaction. After this, the goods are sold with VAT to a national customer. The missing trader does not report a VAT return and disappears with the tax money collected.

In order to stop this fraud scheme, OSS has been implemented. With this system, VAT is applied to intra-community transactions at the destination's jurisdiction rate. Such VAT is collected by the origin jurisdiction and transmitted to the correspondent authority. Nevertheless, this mechanism still has room for fraud, as the missing trader would simply have to change roles and become the exporter instead of the importer.

Regarding this, the implementation of a blockchain-based DICE would help to detect in real time suspicious transactions, immediately blocking them so they cannot take place. Each international transaction would be recorded on the blockchain. In order to be processed, it would need verification from each of the jurisdictions implied. With the use of AI, Member States could easily perform quick risk analysis using objective criteria, leading to the validation or rejection of each transaction.

Furthermore, the use of VATCoin as the sole means of payment for VAT would take VAT money out of the trader's hands. As a result, even in the case they would be able to disappear, they would be left with worthless numbers in a computer. Taxpayers would need to fill in a request for VATCoins before carrying out a certain intra-community transaction. The correspondent Member State would proceed to mint them and exchange them for their face value. Only the government would be able to convert VATCoins into real currency. Smart contracts would balance taxpayer's accounts on a daily basis, performing payments or refunds depending on whether the balance is positive or negative.

As far as the present time is concerned, the effective fight against intra-community fraud has been a matter of cooperation and trust among Member States. The use of blockchain, which is often denominated *the trust machine,* would solve this problem altogether, as the governments would only have to trust technology. This would even make possible international cooperation between countries with conflictive diplomatic relationships.

Even though blockchain offers highly promising possibilities, there are still challenges to be addressed. DLT is a still-evolving technology that has not reached its potential yet. Further development in consensus mechanisms is needed, as the already available ones are not sustainable nor scalable. Other technical issues, such as standardization of programming languages, should also be noticed.

Moreover, both corporations and tax administrations would need to face major changes, which would take significant time to implement. At the present time, not enough people possess the required knowledge to develop, maintain or operate through a blockchain. In addition, new regulation would be required, which would pose a considerable challenge.

Nevertheless, the main obstacle for blockchain adoption is perhaps the turmoil it would entail, as skepticism would be likely to arise between several stakeholders. Still, benefits largely outweigh the disadvantages. As the digitalization of taxation speeds up, it is only a matter of time that the implementation of blockchain in taxation becomes a reality.

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