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Challenges and Opportunities for a Fiscal Blockchain

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Abstract

The development of Blockchain applications is still at an early stage, considering that, after 13 years of the Bitcoin introduction, cryptocurrencies remain an example of a well-established Blockchain system. The digitalization of taxes and its underlying processes is gaining speed worldwide, with not only developed countries adopting it. This trend can be the foundation of a Blockchain integration to the tax system, so that this domain could take advantage of desired inherent features offered by the technology, such as transparency, security, immutability and real-time information. Consequently, tax authorities would achieve higher revenue levels and improve compliance tracking, reducing tax evasion and fraud. At the same time, taxpayers would benefit from reduced tax compliance costs and better experiences through more efficient processes. This work aims at investigating the state of the art within the field of Blockchain application on taxation, in order to drive new research that could close current gaps and support the development of new applications.

Keywords: Blockchain; Tax; Taxation; VAT; Auditing.

1. Introduction

After the Bitcoin publication release in 2008, its underlying technology, Blockchain, remained for years associated strictly to Bitcoin. Lately, Blockchain has been spread across different domains and it is seen as a technology that can potentially revolutionize the way we conduct payments, store data and perform transactions [1]. Research in other fields can boost Blockchain technology even further, since it will aggregate dedicated studies and resources to develop specific models and applications in different industries, which, in turn, will contribute to the evolution of the technology. This can be accomplished by exploring Blockchain use in other environments beyond the Bitcoin, such as *Ethereum*, which can support smart contracts. Blockchain adoption is suitable for governments, since it offers the opportunity to improve transparency, prevent fraud and stablish truthful relationships with citizens and private sectors [2].

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Particularly, tax administrations can be considered as prime candidates for the kinds of efficiency improvements offered by this technology [3]. The digital age is challenging tax administrations in many aspects. The first one is related to the taxation structure itself, as it faces new products and services that do not fit traditional tax bases. Besides, open challenges include integration to new tax payment solutions, and the provision of an environment to submit and store ancillary obligation data. In both cases, taxpayers expect digital solutions, designed to deliver an easier experience, less time-consuming. At the same time, tax authorities seek to gather and analyze information digitally, to improve the auditing process efficiency and induce better compliance. Current solutions rely on centralized environments, which have high maintenance overhead and are more exposed to Denial-of-Service (DDoS) attacks and single point of failure [4]. A Blockchain-based tax system could reduce operational costs and mitigate security and privacy risks, due to its decentralized structure [5]. Blockchain is also considered a secure and immutable network, i.e. once a transaction is registered in the Blockchain it cannot be tampered [2]. Another issue is that current integration to payment systems is still burdensome, depending on conciliations that hind real time tax settlement. This limitation leaves space to fraud, since it encourages dishonest taxpayers to forge fictitious tax documents, which do not represent actual transactions [6]. A real time payment system can undermine this *modus operandi*, and cryptocurrencies can play a key role in providing a seamless architecture, especially considering the emergence of Central Bank Digital Currencies (CDBC). A survey conducted at the World Economic Forum in Davos, in 2015, revealed that 73,1% of the respondents reported that taxes will be first collected using a Blockchain by 2025 [7]. This information shows that Blockchain technology deserves the attention of tax authorities, as a powerful tool to face ongoing barriers. Its ability to deliver reliable real-time information can trigger a more productive system, able to raise government income and offer better services to taxpayers. This systematic review aimed at identifying, in the relevant literature, current research topics, challenges, use cases and trends related to Blockchain adoption in taxation, in order to provide a comprehensive background and guide to future research. The structured approach allowed the grouping of the main proposals, associating each of them to the tax authority problem that is addressed and to a research process stage assessment, which goes from a conceptual phase to an evaluation after real-word implementation. In section 2, the details of the methodology followed in this systematic review are presented, covering the research question, the search string, inclusion and exclusion criteria, quality assessment and search strategy. Section 3 discusses the main results, section 4 discusses the main challenges and section 5 presents the conclusion and proposes future works.

2. Methodology

Given the increasing quantity of publications on the Blockchain technology, which turns a free review into a complex and likely biased approach, the systematic review was selected as the research methodology for this study. The objective is to provide a proper overview of the target area, summarizing the ideas of the most relevant works. The process described in this section was based on the guidelines provided by [8].

2.1. Research Question

The research question considered for this systematic review is presented in Table 1.

Introducing Blockchain to the tax authorities is a complex task, which goes beyond technological aspects, given the multiplicity of interfaces to deal with. The answers to the proposed research question can provide an understanding of the intended applications and map current proposed initiatives and approaches. This will lead to a clearer scenario to position further studies on a topic already explored, or even to kick off a brand-new research line on a detected opportunity.

Table 1: Research Questions.

Research Question	Description	Objective
RQ1	What topics have been addressed in current researches on Blockchain regarding the tax area?	To understand the main topics discussed in related publications. From this research, it will be possible to identify proposed applications, specific challenges and current research gaps.

2.2. Search string

The search string was derived from the research question, following the steps below:

- Identify keywords;
- Combine terms to obtain candidate search strings;
- Run trial searches with candidate search strings, using the following repositories: IEEE Xplore, ACM digital library, ScienceDirect, SpringerLink and AIS. These repositories were chosen because they are among the most used in mapping and systematic reviews [9]. Besides, Association for Information Systems (AIS) was also included, not only due to its relevance on the financial field, but also due to the potential presence of taxation subject;
- Check trial research strings against a list of already known primary studies and evaluate the effectiveness of the search strings.

As the result of the described procedure, the search string, which is presented in Figure 1, was defined.

"Blockchain" AND
("Tax" OR "VAT" OR "Invoice" OR "Taxation")

Figure 1: Search string.

2.3. Inclusion and Exclusion criteria

Since the inclusion criteria determine which studies will be included in the systematic review, they were based on the research question, so that they could increase the likelihood of selecting appropriate studies. The following inclusion criteria were applied to the studies obtained from the search string:

- (IC1): The article addresses the research question;
- (IC2): The article is related to difficulties, critical issues or challenges on the tax area;
- (IC3): The article proposes some methodology, conceptual model or framework of study related to the tax area;
- (IC4): The article presents an application, lessons learned, case study or best practices;
- (IC5): There will be accepted primary and secondary studies;
- (IC6): If several journal articles report the same study, the latest one is included.

Likewise, the following exclusion criteria were defined:

- (EC1): Work is not available to full download;
- (EC2): Work is clearly not related to the research question;
- (EC3): Primary focus is not related to the research question;
- (EC4): Language was not English or Portuguese[a].

2.4. Quality assessment

In addition to general inclusion and exclusion criteria, it is considered critical to evaluate the quality of the studies [8]. The following quality questions were used in the selection process, only keeping in the systematic review the studies for which all answers were affirmatives.

- (QQ1): Are the research objectives clearly stated, including the motivation of the study?
- (QQ2): Is there a clear description of the research environment and background?
- (QQ3): Are the results or conclusions clearly explained?
- (QQ4): Are the obtained results or conclusions related to the research question?
- (QQ5): Is the study plan adequate for answering the research question?

2.5. Search Strategy

The base set of studies was obtained from the application of the search string on the previously defined scientific databases – the same ones used to test the search strings. A total of 4407 works were returned. However, not all papers were necessarily related to the research questions, then they went through a filtering process, where each layer of assessment and decision-making narrows down the original articles set.

At the first screening phase, papers were evaluated based only on the title and key words, applying the exclusion criteria. The following information was recorded for the 69 pre-selected papers of this step, in an Excel spreadsheet: Authors, Title, Repository, Year and Place. This set was also classified by repository as follows: IEEE Xplore (13), ACM digital library (10), ScienceDirect (7), SpringerLink (37) and AIS (2).

In the second phase, the abstracts of the articles were read and used to apply the inclusion criteria. In a few

[a] Portuguese is the author's native language.

cases, it was difficult to determine whether the paper was out of the scope of this systematic review. In these cases, the selected papers were evaluated again in the next stages. The exclusion criteria were also applied, with more refinement, since it had been applied on the previous stage based on title and key words only. After running this phase, 48 articles were selected, which were recorded in *Mendeley*® [b], a reference management application.

The next stage consisted of the identification and removal of any duplicated articles. A total of six duplicated works were removed. Additionally, some relevant missing articles were manually included, based on the snowballing technique, which refers to using the reference list of a paper or citations to the paper to identify additional references [10]. This stage was completed with a total of 55 studies.

The last stage was an evaluation based on the full reading of the articles, which applied a new round of inclusion and exclusion criteria, on an even more comprehensive basis. Besides, more in-depth analysis was performed, with the introduction of the quality assessment. This resulted in the selection of 31 papers, which were included in this review. The described search and selection process is illustrated in Figure 2.

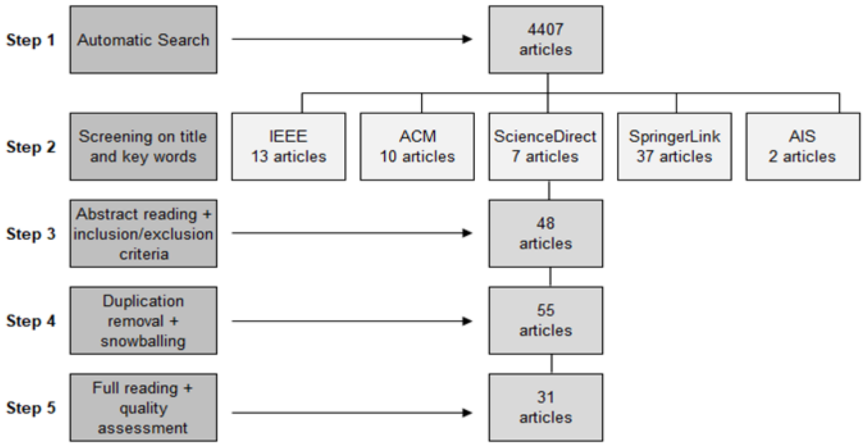

Figure 2: Search strategy and results.

3. Results

3.1. Data Analysis

Thirty-one articles were analyzed as part of the systematic review, following this distribution along the selected sources: IEEE with 10 articles (32%), Other with 10 articles (32%), SpringerLink with 6 articles (20%), ACM with 4 articles (13%) and Science Direct with 1 article (3%). The *Other* category consists of papers introduced through the snowballing technique, which were not found on any of the considered sources.

As Fig. 3 shows, most of these articles were conducted by researchers located in Europe, followed by Asia. It is important to highlight that only one of the selected articles was published in South America, although Brazilian digital taxation products, such as the Public Digital Bookkeeping System – SPED – and the digital invoice, are

[b] https://www.mendeley.com/

recognized as one of the most advanced by some of the studied papers. Relevant topics have been investigated in Brazil regarding the operation and functionalities of the local tax system. For instance, the work [11] proposes a data model based on XBRL taxonomy to improve the quality of the information shared through SPED. Nevertheless, this scenario is not reproduced when it comes to Blockchain research.

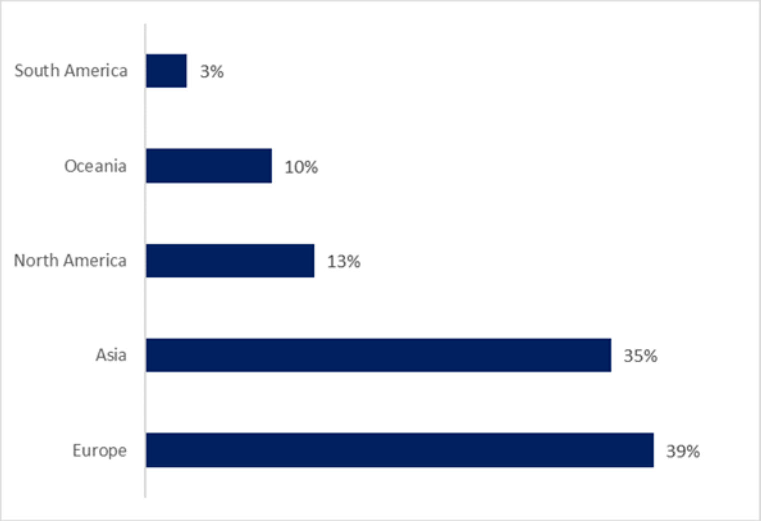

Figure 3: Accepted articles per Region.

Another aspect that should encourage researches in South America is that developing countries could take special advantage of the potential benefits of Blockchain application, such as trust and transparency, since they are more vulnerable to corruption and fraud than developed countries [2].

Fig. 4 presents a yearly analysis. From there, it is worth noting that even though the Blockchain technology was first introduced with Bitcoin in 2008, the studies on the specific tax application domain have taken place in the last 5 years only. It took some time for the research community to become aware of the full Blockchain potential and to envisage that other areas could also take advantage of its benefits.

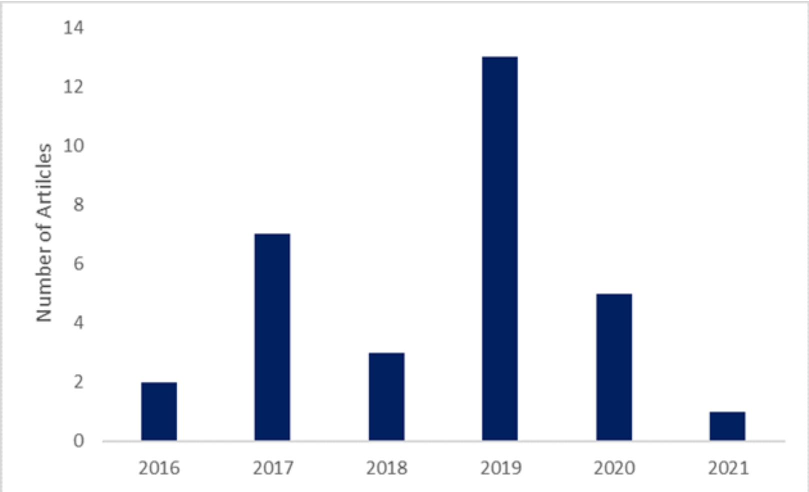

Figure 4: Accepted articles over time.

3.2. Findings

The selected set of 31 articles contained both primary (25 articles) and secondary (6 articles) studies. In general, primary studies presented a concrete application proposal and went deeper on technological aspects of the implementation, as well as on the specific challenges to be addressed. Secondary studies focused more on the application context, the design requirements and on the general suitability of Blockchain technology to the taxation domain, also including summaries of main challenges, benefits and key applications already presented by primary studies.

To understand the focus of the primary studies, a category was assigned to each of them, based on the main goal defined by the authors. Five categories were defined:

- Tax collection management: the article aims at automating a current manual system, or at improving the efficiency of an existing system in some aspect (security, operability...). The work has a general approach, which covers the whole tax collection environment and cycle;
- Fraud prevention: the solution proposed by the article intends to face a clearly identified fraud schema or to redesign a process that facilitates illegitimate behaviors;
- Tax data sharing: the focus is on exchanging information among actors of the tax environment, such as governmental institutions, companies, taxpayers and banks, with collaboration or business purposes;
- Tax auditing: the work aims at redesigning the auditing process, based on a real-time and integrated perspective;
- Tax compliance: the study focuses on automating or improving the efficiency of some specific tax compliance requirement.

Figure 5 summarizes the percentage proportion of articles on each category. This view highlights that 56% of studies are focused on tax collection management. As such, they present a broad system proposal, normally including an operation tracker at transaction level, followed by tax calculation, verification and payment. The second most popular category is fraud prevention, with 24% of participation. These studies designed their proposal with a more restricted approach, to address the identified focus of illegitimate actions. Tax data sharing has 8% of participation and reflects the digital age impact on the social interactions. As tax authorities worldwide engage on digitizing taxes and its related processes, they build rich datacenters, whose value and importance go beyond audit scripts. Actors such as financial institutions use this information to feed their credit analysis systems. Other classic clients of tax data are government agencies responsible for monitoring the economy, and academic researchers.

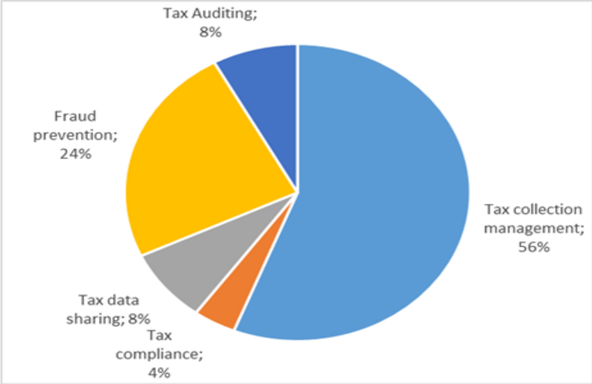

Figure 5: Primary studies classification.

Tax auditing also represents 8% of total articles. Many related studies state that auditing can be significantly impacted or even replaced with the advancement of Blockchain [12]. Another viewpoint is that this technology will redefine the auditing cycle with an important paradigm change: from a *post facto* evaluation to a *real-time* and continuous process. The papers included in this group explore the development of a platform [13] and an information system [12] to integrate the participants of a typical auditing cycle. Finally, the studies under the category tax compliance have 4% of sharing and focus on a specific phase of tax collection, in order to deep dive on a compliance procedure.

Another analysis carried out on the set of selected primary studies was based on the system development research process defined by [14]. Figure 6 shows that, among primary studies, the majority does not reach a prototype phase, adding up to a percentage representation of 64%, distributed on Conceptual Framework, System Architecture and Analysis and Design phases. These works develop a conceptualization, but do not implement the frameworks that they proposed. Consequently, technical details are overlooked and the feasibility analyses of the ideas lack materialization. The whole scenario is completed with the Prototype phase, which reaches 24% of the studies, whilst only 12% get to Observe and Evaluation phase. This overview indicates a trend already identified by the paper [2], that Blockchain adoption in the public sector seems to represent a more theoretical view than a practical approach.

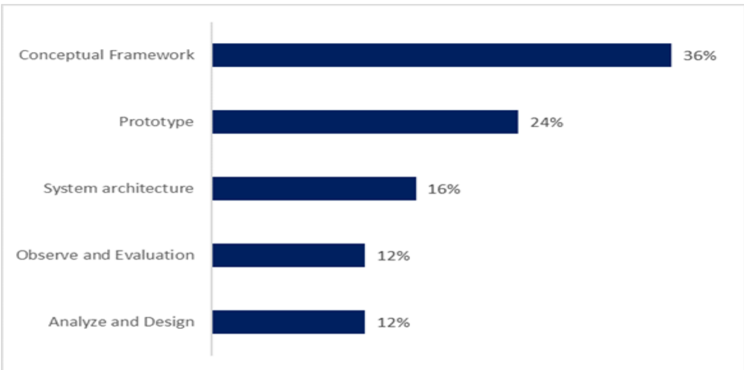

Figure 6: Research process stage.

Another outcome of the preliminary analysis conducted on the selected articles was the tax type. Figure 7 shows that primary studies focused on the Value Added Tax (VAT), which is an indirect tax, paid along each step of the business chain, but eventually charged to the end user, who will pay an accumulated tax included in the final price of goods and services. Other articles worked on different tax types, such as income-tax, representing 16%, and stamp duty, dividend-tax and cross-border related taxes, which are aggregated on the group Other. Lastly, seven articles do not focus on any particular type of tax. Additionally, it is worth mentioning that some secondary studies also envisaged the possibility to apply the Blockchain technology on the payroll taxation process and on transfer pricing taxation. However, they describe current issues, linking them to the main characteristics of the technology, without any further development on the design proposal. For instance, the authors of the work [15] state that Payroll compliance is an ideal space for Blockchain, because of the complex calculation, which involves matching the contributions from employers, and, mainly, due to the data collection and central storage by multiple regulatory agencies. Demirhan [16] considers that using Blockchain technology will reduce transaction costs both for the state and employers.

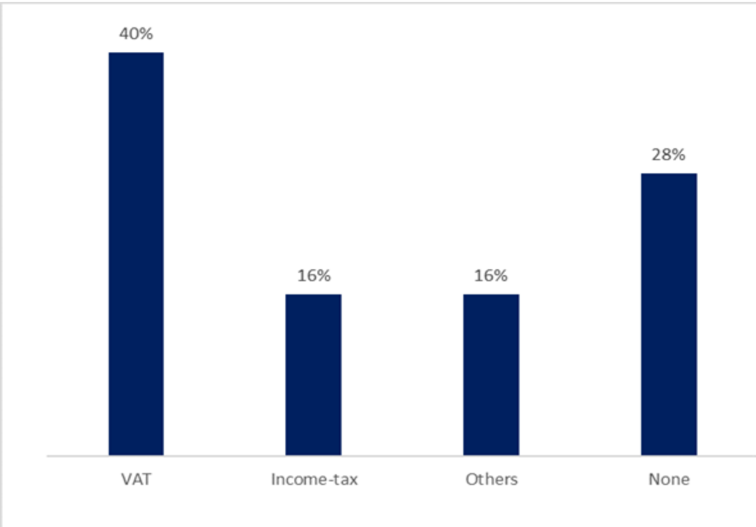

Figure 7: Referenced tax types on primary studies.

3.3. Discussions

Permissioned vs. Permissionless

The first important implementation aspect is the type of Blockchain to be used on tax related applications. Most studies clearly state that a private/permissioned model is more suitable. A few articles simply do not explore this topic, and none endorses a public/permissionless approach. In this regard, the work [17] provided a broader perspective, studying the Blockchain application in a more comprehensive governmental context. The findings are the same: a private, restricted or permissioned distributed ledger works best. The authors in the study [18] consider the private/permissioned model as a proper choice due to two aspects; the first one is the requirement of an unambiguous identity of companies or those acting on its behalf; the second is related to the need of access management and data protection.

This fundamental design choice between permissionless and permissioned Blockchain impacts directly the performance and the efficiency of the network [3]. Hoffman [19] compares both types considering the different levels of effort required to assure the consistency of recorded information. On the one hand, the permissionless kind depends on heavy computation to create trust [19], since the ledger is potentially accessible by every internet user. On the other hand, the second option restricts the participants of the network through a tax authority control, that determines who is allowed to participate in the validation process and in the protocol itself. As a result, developers of restricted Blockchains can choose less expensive consensus algorithms [3], which leads to advantages in terms of cost and throughput.

Some authors consider the existence of a third Blockchain mode called consortium. Vitalik Buterim, the creator of *Ethereum*, defines it as “a hybrid between the low trust provided by public Blockchains and the single highly-trusted entity model of private Blockchains, whereas the latter can be more accurately described as a traditional centralized system with a degree of cryptographic auditability attached" [20]. This concept allows a shared control of the network in situations where different authorities must preserve their own taxation rules in a multi-jurisdiction environment, such as international commerce or cross-border operations among states of the same country, if there is a state-level tax system in place.

An important discussion is raised by the study [21]: they claim that the technology can only be used for transparent data, whereas almost all data related to the taxation context are confidential. Then their proposal is limited to a Tax Invoice Serial Number (TISN) delivery and tracking system, considering that these data are not confidential [21]. According to the same reasoning, the information broadcasted across the nodes must not contain all transaction data, but only the headers of those transactions.

Nevertheless, the same work considers that the nodes of the network should see only the transaction that have connection with them. The authors count on smart contracts to comply with this restriction and assure that only core participants of an operation - seller, buyer and tax authority - have access to transaction data. Besides, Hoffman [19] explains that *Hyperledger Sawtooth* implementation provides an on-chain governance feature that can be used to replicate real world taxation structures, so that only participants of a transaction could see its sensitive information. Additionally, Ainsworth and Alwohaibi [22] present *Ethereum Quorum* as a platform that supports smart contracts as enablers to provide data privacy, using cryptography to prevent all except transaction participants from seeing sensitive data. The *Quorum* whitepaper documentation also confirms that the validation process is modified so that all nodes validate public transactions and any private transaction they are party to [23]. For private transactions associated to others, a node will simply skip the code execution process. This process seems to address the privacy concerns raised by Setyowati and his colleagues [21].

An interesting discussion that was not raised by any of the selected articles is the similarity of permissioned and consortium Blockchains to intranets and extranets, respectively. Both models are indeed very comparable in terms of control, privacy and increase of overall efficiency through a customized network. Then, depending on the application, it may be technically hard to decide between them, so that other factors, such as cost and legacy, must be considered. Intranet and extranet concepts are normally associated with poor user experience, due to ineffective search features, outdated information and difficult navigation. The implementation of a permissioned or consortium Blockchain can be totally transparent to the end user and, at the same time, provide simplification and cost savings. As an example, reference [24] presents a project carried out by the Secretariat of the Brazilian Federal Revenue, to improve information sharing of its citizen and enterprise registration databases with other government agencies, under formal agreements. As a result, they achieved a cost saving of 4000%, compared to the old service structure, proving the success of the implementation of an innovative simple model.

Ethereum vs. Hyperledger

Another important design decision is the Blockchain platform to be adopted for a tax related application. From the selected articles, 36% chose *Ethereum*. At first glance, it might seem inconsistent with the recommendation to use private/permissioned solutions, because *Ethereum* is a public platform and there is a perception that, as such, it cannot be used to build permission scenarios or to control access to data. However, the public nature does not mean that the default design cannot be modified [25]. A permissioned model can be created on originally public platforms, and this process will typically involve some kind of identity management system. *Quorum* is a good example of a private/permissioned Blockchain that modifies the standard *Ethereum* in order to support desired privacy functionalities [23]. This implementation is proposed by 8% of the selected studies. In the paper [26], the authors highlight that *Ethereum*-like platforms are preferred because of the following: (1) a consolidated community of contributors and software developers, which provides confidence for future improvements; (2) the existence of myriad peer-reviewed research works conducted in terms of security, so that many vulnerabilities have been well-discussed and documented; (3) the resilience of the *Ethereum* system, which has been submitted to severe attacks and exploits. The remaining articles propose the *Hyperledger* implementation which is a private Blockchain by design. Hoffman [19] explains that *Hyperledger Fabric*, proposed by 20% of the selected studies, is an implementation of a permissioned Blockchain able to run smart contracts on top of a modular pluggable architecture. Wibowo and Sandikapura [27] point out that its core feature of channel management can be utilized as additional Blockchain logical infrastructures so that other services can be deployed as needed. Finally, the option suggested by 8% of the articles, *Hyperledger Sawtooth*, is a newer solution and shares many capabilities with its *Fabric* predecessor. Additionally, it implements on-chain governance, *Ethereum* compatibility and broader programming language support [19]. It is worth mentioning that, although the selected studies stay on the oldest and most established platforms, this discussion has evolved and there are many other options available and deployed on real-word applications, such as EOSIO, IBM Blockchain, Stellar and Tezos. The increasing interesting on Blockchain pushes the developing communities to release continuous upgrades, in order to provide practical value for different business uses. The enhancements include improved performance, increased size limit of smart contracts and support to governance features.

Consensus Mechanisms

Only six out of the 21 articles mentioned the consensus mechanism to be adopted. Søgaard [18] choses the Azure Blockchain Workbench as a development environment and it offers an *Ethereum* implementation with Proof-of-Authority (PoA) consensus mechanism. In this paradigm, the validators are pre-approved by trusted authorities and then become responsible for validating transactions and blocks within their networks [18].

Wijaya and his colleagues [6] propose the use of Proof-of-Work (PoW), the most traditional mechanism, used in Bitcoin. The main disadvantage of this model is that it requires a massive commitment of computing resources and energy consumption, because the nodes need to run complicated algorithms to verify the transactions. However, the authors suggest that the transaction validation will be entirely conducted by the tax authority, so that other participants do not need to provide any mining equipment. Hoffman [19] points out that this approach is redundant and prohibitively expensive for the tax domain applications.

Alkhodre and his colleagues [28] point out that PoW is not very efficient, since the transaction throughput is too small (21 transactions per second). Their proposed VAT architecture is designed and implemented on Practical Byzantine Fault Tolerance (PBFT) consensus model, in which the most agreed block is committed to the network. Nevertheless, they encourage further studies using other consensus models, in order to achieve more interesting results on performance, security and storage.

Ainsworth and his colleagues [29] consider that it is possible to use a less costly private consensus mechanism than the ones used by public ledgers. They argue that, in the taxation circumstances, taxpayers cannot be anonymous when remitting taxes, so a related system is not compelled to use the costly PoW consensus mechanisms. Some options are mentioned, and the Proof-of-Identity (PoI) is highlighted as the most likely one. In addition, the authors advert that these alternative mechanisms must relax anonymity, openness and equalitarian distribution verification.

The work [3] point out that there is no universally acceptable consensus mechanism in Blockchain, and that such mechanism should not be all-purpose; instead, the consensus mechanism should tie directly to the application being considered. This is also aligned with the previously discussed idea that restricted Blockchains do not need to impose a heavy and costly validation process to all users, considering that an authentication barrier was already responsible for identifying the potential attackers, or at least for making their access more difficult. The suggested mechanism was the Proof-of-Elapsed-Time (PoET), developed for the *Sawtooth* model, which consists in a lottery protocol, where every single node is equally likely to be a winner. Finally, Ainsworth and Alwohaibi [22] proposed the QuorumChain consensus mechanism, a majority voting protocol, where a subset of nodes within the network receive the ability to vote, whilst others are responsible for making the data blocks.

The choice of the consensus mechanism leads to another important aspect of the application design: the definition of the nodes that will participate on the validation process. Two articles define that the involved businesses are authorized to (1) take part in the consensus-building and (2) propose transactions to the Blockchain. Fatz and his colleagues [30] point out that businesses are more interested in submitting transactions than in validating them, so it is necessary to integrate an incentive into their solution, such as a condition that imposes the validation of two transactions to be able to submit a new one to the network [31].

Reference [22] propose that large enterprises and tax authorities of all member states should participate as nodes in the network, with different roles: the member states would be responsible for making data blocks, whilst the private enterprises would be charged with voting on the blocks, in accordance with the already mentioned

QuorumChain consensus mechanism. This process can be compliant with privacy requirements, thanks to Quorum's ability to keep some data private and yet allow all participants of the network to receive a complete copy of the ledger [22]. Nevertheless, the authors recognize that it is necessary to encourage the companies to dedicate computer resources to receiving and saving the full distributed VAT ledger, instead of keeping only their portion of it, as per regular processes. The traditional way of compensating the nodes is the use of cryptocurrencies. However, this mechanism can change and incorporate a crypto tax currency, the VATcoin for instance, as incentive [22].

A group of studies proposes that the business should not participate on the consensus-building. Søgaard [18] states that buyers and sellers are the key actors within the ecosystem, as they carry out the transactions. They interact with the Blockchain through a software application, but do not validate transactions, as that would require them to have access to all transactions. As already discussed, Wijaya and his colleagues [6] propose a mining process using PoW, considering that the transaction validation will be entirely done by the tax authority. The taxpayers and banks can create transactions, and those are sent directly to the controlled nodes. The authors in [26] consider a consortium-based permissioned Blockchain model where only the tax authority together with other trusted participants, such as governments auditing bodies, validate new transactions and secure the Blockchain, also excluding taxpayers from the validation process. The paper [29] designed the VATcoin network, where the nodes responsible for the validity of each transaction will be government-owned computers running the VATcoin client software. Since a multi-jurisdictional application is considered, the number of nodes will be distributed among different authorities, considering the Gross Domestic Product (GDP) proportion of each jurisdiction relative to the aggregated one. The enterprises involved in the VATcoin system will not validate transactions, but will have access the records related to their own VATcoin balance. This approach is very similar to that presented by [3], which also assumes the trading volume as an indicator that determines the number of nodes that a country (or any other unit of authority) must hand over to the network. The idea behind is that the groups that places more transactions on the system should bear a proportional share of the compliance burden [3].

Other studies do not clearly specify the nodes that will participate on the consensus-building. As an example, the paper [28] establish that all stakeholders in the supply chain system must be part of the Blockchain network, however it does not cover the details about the participation on the validation process, such as each one's role and the challenges related to the incentive mechanisms, in case business are required to validate the transactions and store a copy of the distributed ledger. Diversely, Hossain and his colleagues proposed application [32] does not affect business, since it consists in an income-tax verification system. Therefore, the Blockchain will take place with government agencies only, and the taxpayers – individuals in this case – will submit the tax return through a Web application.

Tokens

The studies that explore the concept of tokens on a Blockchain-based system use two main approaches: the first one is the use of tokens to represent tax credits; the second one is to represent an asset in a non-fungible way. Exploring the first idea, Wijaya and his colleagues [26] define tokens as numbers stored in a smart contract that can be moved from an address to another. The authors emphasize that the tokens are not intended to replace the national currency. The proposed application uses them as a proof that the taxpayers have purchased tax credits and then have enough balance in their account to pay the due tax, which is the stamp duty in this case. This work covers in details the subject and presents some activities related to tokens: the token creation, which is restricted to the tax authority; token distribution and sales, also performed by tax authorities to authorized participants, such as banks and post offices; and stamp duty payment, in which the smart contract will check the user's account and reduces the equivalent amount. In a similar proposal, but this time focused on VAT, the paper [6] defines tokens called PAKO that also fall in the first category. The proposed system works as follows. The taxpayers have to buy PAKO tokens prior to an invoice creation. Therefore, when they want to sell something and need to issue an invoice, a PAKO transaction is created to transfer the correct amount of tokens to the buyer, who, in turn, will pay the seller the same amount of money as the VAT represented by the transferred PAKO. This strategy turns around the mechanism of fake invoice issuance or at least discourage it, by requiring a real tax credit cash flow beforehand. The last study to explore tokens as a payment tool was conducted by [29], and the concepts are similar to the PAKO system. VATcoin is defined as a digital currency, but meant only for VAT payment and, contrary to Bitcoin, is not susceptible to changes in value. Business will purchase VATcoins for use in their commercial transactions. With VATcoin, no tax is paid or held in real currency and only the government can convert it to real currency. This system will work together with a second Blockchain, which contains the Digital Invoice Customs Exchange (DICE) information. Only one of the selected articles explored the second application of tokens – representation of an asset in a non-fungible way. Hossain and his colleagues [33] aim to face the issue of illegitimate apply for tax returns on the taxation of dividend payment context. To achieve that, they propose to conduct and track dividend payment on the Blockchain, using tokens to represent the dividend originally issued by a company. This way, the designed Dividend Payment Control System will control the token flow since its creation by a financial service company that provides security for investors and organizations, until it arrives to the stockholder's account. Only at this moment the tax refund application can be sent to the tax authority.

Tax payment solutions

Besides the use of tokens, other solutions were proposed for the tax payment. Demirhan [16] considers that smart contracts play a key role on VAT calculation and payment. According to this study, the total amount of the invoice payment made by the buyer could be split into non-VAT and VAT parts. Then, the VAT portion could be sent to the tax authority in real time, whilst the non-VAT part would be transferred to the company´s account using a smart contract. As a result, this system can reduce transaction cost as well as reduce the risk of fraud. Similarly, Søgaard [18] considers a smart contract conducting split payments within every transaction as opposed to every month or quarter, as in current VAT systems. He points out that, in doing so, the smart contract removes the administrative burden of declaring the VAT and ensures the VAT revenue flow to the tax authorities. The proposed ecosystem considers that banks operate outside of the Blockchain system, but provide payment services. Diversely, other studies split invoice and VAT payments, but leading to a non-real time VAT settlement. Nguyen and his colleagues [34] propose a model where a smart contract calculates the VAT based in the value of goods uploaded in the Blockchain by the seller. Periodically, the tax authority controlling the network requests the VAT payment. Then the smart contract consolidates all invoices from corresponding payers. After tax authority's approval, the banks, which are also part of the network, trigger the flow of payment from payer bank account to the tax authority account.

4. Main challenges

Nemade and his colleagues [35] consider that the main issues Blockchain has yet to overcome are the complexity of the system and a limited number of IT specialists with the ability to create a business Blockchain. Similarly, Wang [36] points out that this limitation is reinforced when the new information technology and taxation fields are combined, since there is a lack of a large number of personnel with expertise in both areas. Moreover, since the consolidated know-how of the technology was stablished for cryptocurrencies, it is a challenge to transfer its concepts to more complexes systems, such as the tax domain [35]. Setyowati and his colleagues [21] point out that the use of Blockchain technology is influenced by infrastructure, capability and government policy factors. Additionally, the infrastructure that supports the application of this technology, such as internet networks, server computers and digital identities, has to be fulfilled. Hyvärinen and his colleagues [33] add some general Blockchain limitations, such as throughput, latency, size, and bandwidth of transactions, but also consider that some researchers discard these concerns as transient inefficiencies which will soon be overcome. Hoffman [19] alerts about reversibility. By default, all transactions on Blockchains are final, which is a desirable design principle, since it provides trust through non-repudiation and fraud traceability. However, it also poses challenges when trying to correct a careless mistake, because Blockchain's immutability capabilities do not allow participants to delete content. According to [36], Blockchain technology cannot prevent wrong information from being entered into the system by the participants during system's operation. However, the full transparency and immutability of the data allow errors and fraud detection. Fatz and his colleagues [30] state that any non-compliance facts can be automatically identified, by adding intelligent sanity checks in smart contracts. These sanity checks could be provided by tax authorities since they have the proper access to detect anomalies based on the entire Blockchain data. Besides the mentioned general challenges, other most frequent challenges raised in the selected articles are covered next.

Scalability

Reference [18] states that his design proposal meets the scalability requirement for the considered Denmark's case, since it is able to manage approximately 230 million invoices per year (130 –150 transactions per average peak second). However, he highlights that extensive scalability tests are recommended if the solution is to be extended to other countries. The relevance of this item depends on the considered application. For example, in the use case presented by [33], the scalability concern is considered a minor issue, since dividend payments only occur periodically, are not frequently exchanged but rather transferred to a final recipient, and are not subjected to time critical transactions.

Balancing Privacy and Transparency

According to Hoffman [19], there is an inherent trade-off between privacy, which is required by many legal frameworks, and transparency, which is a design principle of distributed ledgers. Fatz and his colleagues [30] observe that this conflict has been detected in the context of cryptocurrencies, where the money flow exposure, necessary to validation of transactions, leads to privacy problems, since it allows a tracking of wallet activities and map them to real individuals. Hossain and his colleagues [33] state that privacy issues could arise when the tracking of the transactions is able to create or map profiles, leading to a pseudo anonymity break. On the tax context, the degree of privacy provided by a Blockchain architecture highly depends on the product portfolio of a participating business [30]. Business that have a small and homogeneous product portfolio are more likely to reveal their turnovers. Some sophisticated network algorithms can identify individual users even if a turnaround mechanism is used, such as a third-party transaction pooling services that disguise the flow of transactions [33]. Hoffman [19] highlights that to overcome this issue, the entire content of a transaction must become private. In this case, the considered framework should be able to provide parallel and on demand documentation. Blockchain applications will benefit from progress within the research field of zero-knowledge proofs, which represents promising solutions to address the dilemma of verifiability and privacy [30]. They enable a party (the prover) to prove a statement to another party (the verifier) while revealing nothing but the validity of the statement itself [37].

Legacy

Transition to a new, potentially disruptive technology is likely to be both resource and time-intensive [38]. As stated by [15], Blockchain implementation on a nationwide governmental context cannot be faced as a segregated piece of the national IT infrastructure; rather it requires a high degree of coordination and should be part of a strategic arrangement of tax administrations. According to [38], it is also important to consider if the Blockchain is indeed necessary, because when operations are already based on highly integrated process, the marginal benefit of Blockchain implementation may not justify the high transition costs. Finally, Frankowski and his colleagues [1] point out that besides the integration of IT systems on many levels, implementing Blockchain would also require far-reaching changes to the regulatory environment, including reforming laws on databases, intellectual property and legal identity.

Incentives

Owens and Jong [38] discuss the network effect, that can be summarized as follows: the value of Blockchain increases as the number of participants increases, and the risk of colluding between them reduces. This is relevant for the applications that consider the business as participants of the network. In this case, for the network to grow and protect the robustness and immutability, the participation in the validation process has to be rewarded. As previously mentioned, the development of a mechanism able to attract users to participate as miners in growing a network that is used for tax administration purposes is a challenging issue.

Maturity of Technology

Owens and Jong [38] consider that Blockchain technology is still in its infancy. Therefore, they recommend starting with small scale proof-of-concepts with a high degree of standardization. Ainsworth and Shact [3] followed this guideline, when addressing the Missing Trader fraud issues faced by intra-community trading operations within the European Union. Instead of modeling the full commercial chain, which would cover the domestic operations inside each member state, the study focused on the cross-border stage, in order to simplify the model, and recommended follow-up articles to consider the whole scenario.

Data storage

Setyowati and his colleagues [21] highlight that the distribution of the data blocks chain in the Blockchain network assumes that all nodes have adequate storage capacity, so that the data size does not exceed the capacity of each node. Then when designing a Blockchain that counts on the participation of taxpayers as nodes, it is crucial to assess if the participant can provide enough storage capacity. Otherwise, the taxpayer – being an individual or a business – will not be able to participate in the network. The same article also considers that this aspect prevents the system from placing the full invoice data into the network, since this would require a huge storage capacity from the nodes. Nguyen and his colleagues [34] provide a good solution for this storage issue, using a Decentralized Storage Network (DSN) on their VAT management model. On this paradigm, all information of invoice is encrypted and stored in the DSN and only the hash code, which is returned from DSN, will be uploaded to the Blockchain network.

Security

Because the data held and processed by government agencies, specially by tax administrations, are highly sensitive, data protection and security are critical aspects for Blockchain implementations [38]. The security requirement on the taxation domain can be split into two main design principles: 1) high level of user access security and 2) high level of data access security [18]. In general, security was considered as one of the main strengths of Blockchain technology, provided that the digital ledger cannot be altered or tampered with once the data is entered. However, Hyvärinen and his colleagues [33] mention that Blockchain is subjected to security threats whenever a single entity or a group of individuals/entities holds 51% of the computing power. This is the worst case scenario, since attackers would be able to modify the transaction data, which can lead to double spending. Dey [39] points out that this sort of attack particularly raises security concerns in Consortium Blockchain, in which the consensus process is controlled by a set of previously selected nodes. In this case, the nodes who have more computer power can collude to take control over the ledger and benefit from it. Ekramifard and his colleagues [40] conducted a systematic literature review of integration of Blockchain and Artificial Intelligence. This study demonstrated that security increase is the main research topic related to this integration – 43% of the selected studies covered the theme. The combination of these technologies can monitor the network, detect malicious behavior and develop prior knowledge of the likelihood of an attack.

5. Conclusion and future work

This paper summarizes key information about Blockchain application on the taxation domain, based on a systematic literature review. The potential impact of the technology is recognized in all studies. Frankowski and his colleagues [1] consider that in the long run Blockchain can be a driving factor in implementing real-time, automated tax processes for both small and large enterprises. Nevertheless, it is also clear that challenges and limitations must be taken into account. Owens and Jong [38] point out that prior to any proposal of taxation based on Blockchain, it is mandatory to pursue an in-depth understanding on how the technology actually works, what problems it can solve, and what issues may be better addressed by other information technology.

Admittedly, this study focused on technical design decisions, even though it is well known that regulatory and legal infrastructure are also responsible for the cautious attitude of many tax authorities towards Blockchain implementation [38]. Besides, since the research domain was restricted to works related to tax applications, the technical knowledge itself might be more advanced on some of the discussed topics. Therefore, if a few of the presented design decisions are to be further explored, it is important to revisit the literature on the specific topic, without limiting the search to the tax domain.

In terms of current proposed applications, the VAT system was the most explored use case, and the studies agreed that this tax can benefit from increased transparency, compliance and reduction of transactions costs. However, it is important to consider that in countries where an electronic indirect tax system is already well established, a full shift to Blockchain may not be worth it. In this case, Blockchain initiatives seem to be more suitable if placed on a well delimited roadmap, such as a proof-of-concept proposal, followed by a *Minimum Viable Product* implementation.

As far as the research gaps are concerned, it is possible to deep dive on any topic discussed in Section 3 or to propose new applications. For future works, a special attention can be addressed to payment solutions, since one of the expected outcomes of the re-organization of the taxation system at a global level is to make the payment of taxes not only automatic, but also inevitable [15]. A Blockchain tax system could integrate cryptocurrencies or Central Bank Digital Currencies (CDBC) as payment methods, resulting in a full Blockchain-driven solution. This approach represents an alternative to traditional physical currencies, which, in turn, can also be further explored thanks to the increasing offer of innovative electronic payment services.

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