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# Using Blockchain[1] Technology to Eliminate Selected Problems of the Tax System

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Owing to the distinctive features distinguishing it from traditional database solutions, blockchain technology has the potential to revolutionize the way taxes are settled: the way they are collected and refunded, the way transactions are settled and verified as well as the way compliance and invoicing are handled. Hence it may effectively help solve the fundamental problem of the tax system – the tax gap.

However, achievement of desired results will be contingent upon the use of specific mechanisms as well as the manner and area of their implementation. We are discussing and analysing six concepts of solutions within five areas: digitalisation of invoices; creation of a national cryptocurrency for tax settlements; settlement of dividends earned by foreign shareholders; compliance in terms of transfer pricing; and verification of active VAT payers.

We believe that the greatest benefits and at the same time the least deficiencies can potentially be offered by the introduction of the concept of Digital Invoice Customs Exchange (DICE) based on blockchain technology. Currently, the concepts that are supposed to support payment of tax liabilities are seriously flawed, which limits their effectiveness. Whereas other solutions are not developed enough to be able to serve as any real alternative to the existing tax system or potential solutions that are not based on blockchain technology.

Keywords: blockchain, public services sector, taxation, tax system, double spending, double taxation treaties, Value Added Tax, transfer pricing

JEL Classification: K34

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[1] The terms blockchain and distributed ledger technology (DLT) are often equated, however DLT goes beyond the framework of 1) blockchain data structure or 2) consensus mechanisms that are found within blockchain networks. Distributed ledger technology is a broader term than blockchain and blockchain is a type of DLT. All the solutions presented in this article use blockchain technology. Since there are numerous publications (including books) about this technology already available, we have decided not to provide an introduction deliberating on the technology itself. Some terms are explained in footnotes. The Polish reader is also encouraged to read: [Antonopoulous, 2018; Dhillon, Metcalf, Hooper, 2017; Drescher, 2019]

## Introduction

During the 2016 World Economic Forum in Davos, over 800 experts in technology and managers were asked when they expected to see the tipping points of selected phenomena. When asked what year we could expect to first see governments collect taxes with the use of blockchain technology, on average they answered – in 2023. Simultaneously, 73.1% of the respondents expected that this tipping point would have happened by 2025 [World Economic Forum, 2015, pp. 6–7] and merely 12.3% that it would never happen[2]. This shows that important decision-makers in the world of business are currently already aware of the great potential of blockchain technology, including blockchain.

So far such solutions have not been implemented in any country nor has the development of them been initiated. Theoretical concepts of the solutions are being developed in several research centres. Only a few potential solutions have been described in the relevant literature to this day. It does not, however, limit the potential of the technology or the benefits that implementation of tax systems based on DLT could bring about for economies and citizens.

Blockchain as a technology offering completely new functionality may simplify controls and compliance and hence limit abuse of the tax system.

When proposals for the solutions are polished and information about them reaches the highest authorities, it may be expected that the benefits arising from their implementation, which cannot be obtained with other modern solutions that are not based on blockchain technology, will outweigh the costs and risks (resulting from the fact that the technology is still slowly maturing). The benefits are likely to be the most pronounced in multi-national systems where differences between the tax systems are present on various levels (due to diverse tax regulations, the existence of different institutions, dissimilar organisation of the systems, and the use of various technologies and tele-information systems), which is the case in the European Union. Under such circumstances, implementation of the solutions based on blockchain technology into the tax system may offer substantial benefits. A Report from workshops conducted by EU Blockchain Observatory Forum published in July 2018 [Lyons, 2018] indicates that an important area where blockchain could potentially be used is VAT settlement.

It seems that using blockchain technology in a tax system could bring the greatest benefits. The reason for that is large quantities of data that administrations collect and analyse as well as numerous independent data centres that share information with one another. Exchange of tax information among countries, however, is not an easy task to accomplish since each country wants to protect sensitive citizens' data (which guards the interests of both the citizens and state security). Blockchain as a technology offering completely new functionality may simplify controls and compliance and hence limit abuse of the tax system. This is because blockchain technology is able to, among other things:

- supply mechanisms that guarantee inability to change, continuity of history, undeniably, and coherence of historical records in the ledger in a distributed environment;
- allow flexibility in establishing rules automatically executed by algorithms;
- ensure data transfer and registration security through maintaining a large number of copies and employment of robust cryptography;
- allow robust and detailed inspection of processes and access to the shared ledger.

These features are the result of placing independent devices (i.e., nodes) in the distributed environment (i.e., the network), which store an identical copy of a data ledger as data are se-

[2] the methodology for estimation of this answer has not been presented in detail; it was based on two options: indication of the answer 'never' and taking into consideration very distant future dates (e.g., in 50 years' time)

quentially supplied (and time-stamped). A distinctive feature of this ledger is a specific data structure (and manner of recording) that makes the outcome of the process of recording newest data (accumulated into transaction blocks[3]) contingent upon the data introduced earlier. Hence a change in any historical record will be reflected in the content that is recorded last. The technology's functionality is further extended with the so called smart contracts[4].

The purpose of this article is to assess the potential of blockchain as a technology that contributes to solving the problems of the tax system (especially in the European Union) through analysis and evaluation of the existing concepts of system solutions based on this technology.

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## Selected Problems of the Tax System

### General Remarks

On a macro scale, several problems frequently occur in numerous tax systems. The issues mostly boil down to difficulties with collecting taxes.

Usually tax collection is based on self-calculation made by taxpayers or taxable persons and it is assumed that taxable persons conscientiously and reliably declare the taxable amount and single-handedly settle the tax in accordance with the established rules. However, as practice shows, the rules governing taxation are not always clear due to their complexity, lack of harmonisation (otherwise integration), differences in interpretation, and technical and organisational limitations, which may be exploited to the detriment of the states, especially when it comes to cross-border transactions.

Exploitation of tax system deficiencies may be legal in character, that is, it may take the form of tax avoidance, or illegal and then it is referred to as tax fraud or tax evasion[5]. An example of exploitation of the tax system is the phenomenon referred to as treaty shopping[6], that is, such structuring of transactions that allows to use exemptions and facilitations arising from double-taxation treaties to the fullest. A similarly legal character is attributed to activity concerned with CIT (both as regards domestic and cross-border transactions): shifting debt, strategic use of transfer prices and distribution of intangible assets [FISCALIS, 2018a].

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[3] Transactions in blockchain systems are understood in general or technical terms as a collection of operations on a database that make up a whole, e.g., change in account status requiring several operations: a request digitally signed by the user to transfer funds from one account to another is: (1) selected from among unconfirmed transactions available in the network (and each node selects a request independently), (2) verified in technical terms, (3) verified in terms of correctness of access keys, (4) verified in terms of possession of funds on the 'source' account, (5) written-in a block of transactional data; and next incoming transactions are processed similarly; (6) a block is processed so that it will be associated with the outcome of a similar procedure of processing (see points 1–5) performed for the previous transaction block (that has already been confirmed by the network) and, simultaneously, so that all the network nodes could write-in a new block to the previous one, mutually establishing which block it should be (through the use of a method of establishing a common system version, which was chosen by system designers – the so called consensus mechanism).

[4] A smart contract is a computer protocol that verifies and executes contract performance; in other words, it is a contract whose terms and conditions are registered in computer language instead of the legal language. Smart contracts allow making credible transactions without third parties. Smart contracts have complemented and expanded the functionality of blockchain cryptocurrencies by, among other things, creation of applications placed and launched in a distributed environment (the so called Dapps). cf.: [Swanson, 2015]

[5] A. Nita pays particular attention to the difference between tax avoidance and tax evasion and points out the distinction, which is accepted within the doctrine of tax law, into tax savings, tax *avoidance*, and tax *evasion*. cf. [Karwat, 2002, s. 14; Nita, 2014].

[6] One of the actions of OECD within the BEPS package is devoted to treaty shopping (the so called Action 6 – Prevention of Treaty Abuse); cf. [OECD, 2015, 2019]

As far as income taxes are concerned, illegal character is attributed to the attempts to escape paying taxes by way of hiding or under-reporting income, over-reporting deductibles or requesting tax credit that the taxpayer is not entitled to.

Economic crime concerned with taxes mainly consists in striving to obtain undue tax return or not pay the tax at all. Among classic fraud types (considered tax evasion), there are several ones associated with VAT [FISCALIS, 2018b]: unreported sale; no registration, not applying tax to goods used for personal purposes; VAT collected but not paid; deduction of VAT from invoices that do not document actual transactions or deduction of input tax when no right of deduction is enjoyed. These types of fraud require neither sophisticated organisation nor construction of complex structures and processes. Nowadays frauds benefit the most (and states lose the most) from organized crimes that are usually international in character and make use of the specificity of a tax construction as well as system and logistic faults; and, in Poland, these types of fraud are jointly referred to as "carousel transactions" consisting in obtaining undue VAT based on the mechanism of the missing trader: MTIC – Missing Trader Intra-Community and MTEC Missing Trader Extra-community [Ainsworth, 2010], including various variants of those: cross-invoicer or contra-trading, triangular frauds or domestic sales reported as intra-Community supply. These crimes use the system of VAT deductions and refund, which is inherent in the fundamental principles of the VAT system, such as VAT neutrality and the resultant right of deduction.

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If we talk about profoundness, the biggest costs for state treasuries are generated by VAT. In 2016, the VAT gap was estimated to be 147 billion Euro for EU-28, which is about 12.3% of the total (potential) tax liabilities and about 1% of the GDP [CASE, 2018]. The gap in income tax is difficult to be estimated on the scale of the European Union due to the unavailability of sufficient data. Based on domestic estimations, it may be assessed that the gap in income taxes could be comparable to or even greater than the VAT gap. In Great Britain[7], this area represents half of the total tax gap [HMRC, 2018].

## Taxes on Income – Related Party Transactions

In recent years one of the main areas subject to analysis and control in terms of taxes (i.e., fiscal and tax and customs controls) were related party transactions and issues connected with correct allocation of income among parties within the same group, which may be discussed with reference to the general area of transfer pricing[8]. This area encompasses both correctness of prices and transaction terms and conditions in use as well as execution of the transaction itself (especially concerning intangible services).

Transfer pricing should be assessed from two perspectives – that of the organisation (i.e., the group) and of tax authorities. Though transaction verification methods are the same in both cases (as both tax authorities and taxpayers adopt the same methods to establish transaction prices), their intentions differ.

If we talk about profoundness, the biggest costs for state treasuries are generated by VAT.

Setting prices for services or goods sold by taxpayers is an inextricable element of running a business.

[7] On the day of submission of this text, Great Britain has not left the European Union so it is treated as its rightful member.

[8] This is observable in legislative changes in terms of transfer prices and activity of the Ministry itself, such as establishment of the Transfer Pricing Forum. Moreover, publications of the Ministry of Finance, such as the 2016 National Tax Administration Action Plan [Krajowy Plan Działań Administracji Podatkowej na 2016 r.] that particularly highlighted the necessity to verify transfer pricing [MF, 2015], also testify to the considerable importance of transfer pricing as far as controls are concerned.

Simultaneously, for tax purposes, it is assumed that these should be arm's-length prices, which is particularly significant in related party transactions. In principle, prices are considered arm's-length, if such prices would be used on a free market by companies in transactions with unrelated counterparties.

As far as complex economic processes, e.g., sale or production processes, are concerned, for the purposes related to establishing transfer prices it is necessary to correctly define the actual roles served by individual entities participating in the supply or production chain. It is also essential to track financial flows, verify settlements, archive documentation, and issue invoices on a timely basis. These issues are important not only from the perspective of taxation but also correct organisation of processes within organisations themselves. If processes are not planned appropriately, it usually leads to considerable financial loss that to some extent arises from replicating administrative tasks and reporting. This manifests itself repeatedly through perpetual searching for documents by employees of various departments (including the finance and accounting ones).

In practice, serious problems are frequently encountered with obtaining proper documentation and information from foreign related parties. Therefore, it is often not possible to present documentation of translations by the specified deadline (and the documents we refer to here are transaction documents and not documentation of transfer prices within the meaning of the Income Tax Act). The lack of a standardized way to present selected data within one group of companies leads to uncertainties as regards the manner of their settlement.

During controls, authorities verify the presented documentation and the actual course of transactions. Often consultation with the tax administration of another country is required. What is more, it is equally common that information on processes taking place in the whole organisation is incomplete as regards decision-makers in related companies (i.e., daughter companies), which results from the manner of operation of large groups of companies and information flow. Only full understanding of the processes, financial flows, and documentation used in a given group of companies allows to develop an appropriate transfer pricing policy in an organisation and implement an optimal reporting process for tax purposes. The last issue listed above will be of particular importance for entities that have to comply with the Country-by-Country Reporting (CbCR) obligation as well as during tax audits.

The attempts made so far in order to solve transfer pricing issues essentially boil down to imposing more duties as part of tax reporting[9] (understood in broad terms) and exchange of information among countries. Analytical activity of tax authorities follows in the wake of this. Simultaneously, owing to an international character of the problem, the reporting obligations being imposed are largely convergent. However, there are no convergent solutions for accumulation of and storing data that serve to compile financial and tax reports. In practice, this might influence the way the presented data are perceived and analysed by tax authorities.

An increase in the number of duties in terms of reporting entails more obligations not only on an international level but also the local one. An obligation to directly indicate information regarding the type of translation in tax declarations is being introduced. An example of that is the CIT/PIT-TP form where detailed data on transactions must be indicated.

## Turnover Taxes – VAT Fraud (the so called VAT Carousel)

"VAT carousel" [MF, 2018c, 2018d] is such action pattern that consists in making transactions usually in goods (which can be actual or fake), where goods are sold and bought by several parties that

[9] The issue of transfer pricing was raised in an international agreement as part of OECD activity within the framework of Action 13 of the BEPS package, which is concerned with Transfer Pricing Documentation and Country-by-Country Reporting.

have registered offices on the territories of several Member States or third countries. The goods are sold within a supply chain and both the parties that are aware of the fact that fraud is being committed and those that have no knowledge of that are involved in this chain. The fraud is based on entities using the mechanism of intra-Community supply of goods (ICS) to obtain undue VAT deductions as well as entities that serve as the missing trader, which stop running their business after they receive payment for goods (including VAT) – and pay no output VAT to the tax office. In carousel transactions, we most commonly deal with a closed circuit of goods – which means that in many cases the party selling goods in the first place is ultimately the last buyer of the goods. Goods "coming back" to the original seller are usually resold and become an object of subsequent transactions.

The parties involved in carousel transactions are both frauds and honest taxpayers that must face the consequences of the fraud. As practice demonstrates, the economic burden of the carousel fraud is shifted upon the honest parties that were not aware that they took part in a crime. The consequence of participation in a carousel, even if unwitting, is – first and foremost – questioning the right of deduction of input tax charged on an invoice documenting purchase of goods used in the carousel. Moreover, the right to apply the 0% rate in intra-Community supply is also questioned with respect to the goods involved in the carousel fraud. As far as the Polish regulations are concerned, an additional consequence is a "VAT sanction", that is, tax liability amounting to 100% of the established VAT liability. As regards income tax, it is a frequent practice to refuse classification of expenses incurred from purchasing the "carousel goods" as tax deductibles.

It is often highlighted in judicial decisions that a taxpayer may be refused the right of deduction, if based on objective circumstances, it is found that the taxpayer who received the supply (or service) was aware or should have been aware that by purchasing the goods (or service), they were taking part in a transaction whose purpose was to commit VAT fraud. On the other hand, in cases where the supply took place and the taxpayer did not take part in fraud but exercised due diligence (and acted in the so called good faith), they may not be denied the right of deduction (or analogously: the right to apply the 0% rate in ICS) [TSUE, 2014, 2018].

As can be expected, reference to such underdefined rules as "good faith" or "due diligence" has become the subject-matter of disputes between the taxpayers and tax authorities. So proving when due diligence has been exercised is thus becoming absolutely crucial. In practice, the burden of proving that the taxpayer acted in good faith lies with the taxpayer who must demonstrate precisely what measures did they take to verify the counterparty and the transaction itself. Disputes as to the scope of verification measures had been so serious that (following social consultation) the Ministry of Finance published a Methodology of how purchasers of goods in domestic transactions should exercise due diligence[10]. The Methodology offers guidelines as to the manner of verification of counterparties and lists verification tools made available by the Ministry of Finance. There are few information-based tools though which could confirm that comprehensive verification has been made, especially ones that would be affordable to micro and small companies. Although the services available on the websites of the Ministry of Finance do allow to verify whether at a given time an entity is listed in a register [MF, 2018a] or whether a given entity has been (or was) removed from the VAT register [MF, 2018b]. These services do not, however, offer the possibility to download digitally signed or print out credible confirmation[11]. It is possible to apply

[10] The Methodology is available on the archive website of the Ministry of Finance [MF, 2017] (in February 2019, the website of the Public Information Bulletin of the Ministry of Finance was moved to a new domain).

[11] It is worth adding that on the basis of an amendment to the Value Added Tax (VAT) Act, since 01 September 2019, the Head of the National Revenue Administration (NRA) has been obliged to share an electronic open-access list of entities registered as VAT taxpayers that encompasses, among

for an appropriate certificate but this is a time-consuming and payable process.

Verification processes themselves are not enough to eliminate the said abuse. Therefore, Member States also introduces system solutions in this respect. The solutions are universal in character and some of them are also being introduced in Poland[12]. These are, first and foremost, settlements based on:

- the reverse charge mechanism applicable to some products, which is a mechanism assuming that the entity purchasing the product is responsible for paying the tax (in practice, however, owing to the enjoyment of the right of deduction the tax is not paid to the appropriate office in an economical sense – this is because input tax is equal to output tax);
- split payment, which is a mechanism assuming that VAT will be paid into a separate bank account and there is a limited possibility to use the funds available on this account;
- electronic reporting of transactions in a form of a Standard Audit File for Tax (SAF-T).

A system solution adopted in Poland may also be the IT System of the Clearing House (ITSCH) – which analyses all flows on entrepreneurs' bank accounts. Based on the analyses, entities to be controlled are selected.

On the level of the European Union, proposals for changes in taxation of intra-Community supply (ICS) and intra-Community acquisitions of goods (ICA) and treating them as domestic transactions have been abandoned. The model would be based on a seller's obligation to report such supplies in the country where the purchaser has their registered office. In order to limit registration obligations in each EU country, the Polish enterpriser selling goods to a foreign counterparty could report and pay the tax in Poland but at the foreign rate. The whole settlement would be carried out within the One-Stop-Shop system (analogously to the currently operating Mini One Stop Shop – MOSS)[13].

The proposed solutions do not, however, offer a single and uniform in technological terms system to be created, which would allow reporting and settling transactions. It seems that only that kind of solution would make it possible to eliminate abuse while at the same time require no significant modification of the existing system and the mechanisms that govern value-added tax.

## Proposals for System Solutions

The relevant literature has so far offered several solutions based on blockchain technology, which are dedicated to tax issues. They are concerned with five areas: (1) invoice digitalisation; (2) creation of a national cryptocurrency for tax settlements; (3) settlement of dividends earned by foreign shareholders; (4) compliance as regards transfer pricing, and (5) verification of taxpayers as active VAT payers. Among others, solutions concerning stamp duty are being developed [Wijaya, Junis, Suwarsono, 2018]. Despite the fact that the relevant literature quotes potential benefits of adopting blockchain technology in the income tax system, no comprehensive solutions for this area have yet been developed.

### DICE + Blockchain (2016)

Currently, the system in use in the European Union is VIES (the VAT Information Exchange System) that allows European Union Member States to exchange information on intra-Community transactions and VAT payers. VIES allows tax administrations to access a database of VAT taxpayer identification numbers in another Mem-

other things, the records of registration and bank accounts of the entities (reported during registration). It is hard to say, though, whether the confirmations that can be generated will be any more credible than the ones obtained through the existing systems. Cf.: [WP, 2019]

[12] Some solutions need to be approved by the European Commission.

[13] You can read more about OSS in [KE, 2017b] and [Michalik, 2017]

ber State. This makes it possible for the supplier to use the national tax administration to verify if the purchaser from another Member State is a registered VAT payer for the purposes of intra-Community trade [Pisarek, no date].

VIES makes use of numerous centralized national data centres. It is not, however, an automatic system of data exchange and entails considerable involvement of the human factor in the process of sharing information. It is designed to make detection of fraud possible through tax jurisdictions sharing data. Nevertheless, there are several difficulties as: (1) the system is based on requests (so it is not automatic but only works when one side makes a relevant request); (2) it supplies aggregated data and not micro data at the level of invoices; and (3) the exchange of data (i.e., the VIES report) is delayed by several months following a suspicious transaction. MTIC fraud may be committed much faster than a report can be issued from VIES. Recapitulative statements and the current VIES do not allow for law enforcement in real time.

In 2013, R. T. Ainsworth put forward a new solution [Ainsworth, 2013], which he called the Digital Invoice Customs Exchange (DICE). Implementation of this solution is supposed to offer the tax office early access to any trade transaction on a disaggregated level.

DICE is a tax compliance system for VAT, which makes use of invoice encryption in order to secure transaction data that are exchanged between the seller and the buyer both in domestic and foreign trade, while simultaneously informing the interested jurisdictions about transaction details [Ainsworth, Todorov, 2013]. The system operates as follows: invoices are digitally signed and then encrypted invoice data are introduced back into data centres that single-handedly analyse transactions to subsequently carry out risk assessment on the whole uniform EU market. Within the framework of DICE transactions, data are shared automatically.

DICE is a tax compliance system for VAT, which makes use of invoice encryption in order to secure transaction data that are exchanged between the seller and the buyer both in domestic and foreign trade, while simultaneously informing the interested jurisdictions about transaction details.

DICE tracks neither the actual transfer of goods nor performance of service nor cash flows but it precedes them. DICE captures information and allows tax administrations to carry out risk assessment (e.g., with the use of artificial intelligence algorithms) of transactional data flows in order to prevent fraud before the transactions are even made.

The next stages of the invoice approval process are presented in diagram 1.

In the original proposals of the authors of DICE, it was assumed that tax bodies would cooperate with a centralized database. Two variant solutions were put forward, depending on whether the database contained transactional data of only one tax jurisdiction (as exemplified by the systems in Rwanda and the Brazilian Ceará State) or a single database collected tax data from numerous jurisdictions (such as the Brazilian SPED system) [Ainsworth, Shact, 2016, p. 11].

When a large number of tax jurisdictions are interconnected into communities (such as unions) but each insists on running separate central databases of its own tax data (e.g., in the EU), specific problems emerge. There are high-level security systems in place to protect the data, which makes the processes and procedures for granting external access to the data arduous and time-consuming. As far as centralized registers are concerned, there are three well-known issues. The fourth issue arises when centralized records are used for VAT. Centralized registers are:

- A single point of failure for the whole system;
- Susceptible to corruption since they consolidate power;
- Inherently uncertain and require considerable resources to be employed in order to protect data;

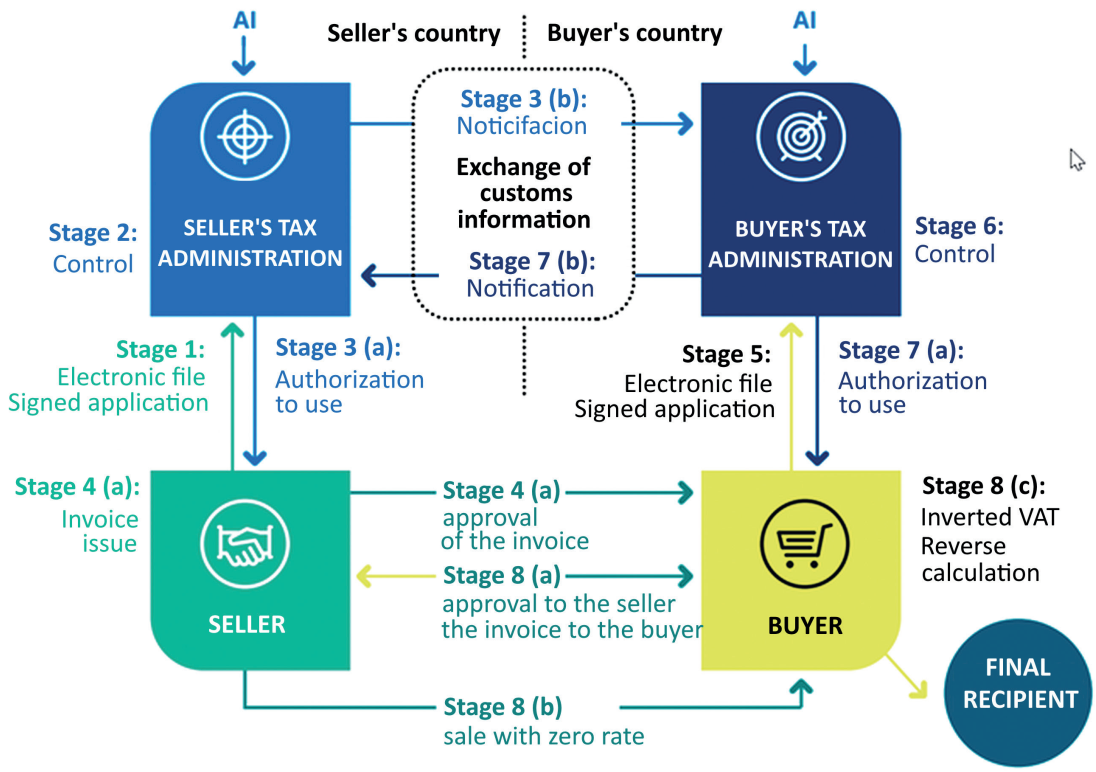


**Diagram 1. DICE operation mechanism**

Source: [Deloitte, 2017]

- Inherently insufficient as a comprehensive mechanism guarding adherence to the provisions of the law on VAT since a single database, which is connected with a particular jurisdiction, will not be able to capture all the significant transactional data [Ainsworth, Shact, 2016, p. 12].

The DICE solution (intended to be implemented in the European Union) assumes that the EU will not accept a central database for the whole Community. It was also assumed that each EU Member State would insist on controlling and sharing data stored in their own centralized database in accordance with its own rules and procedures. As a result, existence of 28 independent centralized databases was assumed. In line with the assumptions of the systems, files with transactional data of two counterparties (e.g., from Poland and Germany) are sent to separate data centres (in Poland and Germany) and access keys are shared with all the authorized parties. Each Member State has immediate access to appropriate taxpayer's data in another Member State. Access is limited to taxpayers and cross-border transactions with domestic taxpayers.

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Prior to issuing an invoice, the DICE system ensures that "Seller A", "Seller B", and the tax offices of both counterparties' are fully aware of the transaction. The whole process of analysis may take several seconds. Artificial intelligence (AI) may help detect high-risk transactions even before they are made (and not afterwards as the case with analysis performed on SAF-Ts). A suspicious transaction may be delayed or blocked by the authorities before VAT fraud is even attempted.

In 2016, R. T. Ainsworth and A. Shact [Ainsworth, Shact, 2016] proposed to implement DICE in an environment based on blockchain technology.

In a DICE system that would be enhanced that way, each product or service sold would have its own separate transaction record[14] showing who was the initial owner of the supply and in whose possession it currently is (as well as each intermediary in the course of sales and purchase). Each verified transaction of the supply would constitute a new "block"[15] added to the record. It would be inextricably related to all the previous "blocks" in the record, thus creating a chain of "blocks". The history of creation of added value and tax liabilities on behalf of VAT would be verifiable at any moment. If network nodes (e.g., national data centres) did not verify a transaction, it would not be possible to issue a VAT invoice. In other words, if a transaction were not recognized in a chain of blocks, it would not be possible to make settlement.

Blockchain DICE is a private, manageable, and limited-access system. It may not be a public (open) and unrestricted system, such as the blockchain of the Bitcoin cryptocurrency, as the computer network will have access to confidential taxpayers' information that are trade secrets (and often company secrets). Operators should be designated by the authorities. Considerable part of the work performed by each "node" would be automated, similarly to approval of transactions in the Bitcoin blockchain. In this case, however, a mechanism used in the majority of public blockchains would not be in place (i.e., mechanism based on the so called Proof of Work, PoW), consisting in solving resource-consuming mathematical problems. These mechanisms in open blockchains are an element of transaction approval processes, token emission, and reaching consensus (i.e., ensuring that each node has an identical copy of the register). Instead, consensus and transaction approval would be achieved by other means.

According to the authors of the concept, in the distributed VAT record the consensus mechanism should be based on objective criteria that would allow assessment of risk posed by VAT fraud *ex ante* and approval of "transactions" (i.e., introduction of invoices) after positive outcome of risk assessment is obtained. It should also ensure immediate and final approval of transactions in a system distributed among countries. The authors of the concept enumerate the following mechanisms that offer the desired features: "proof-of-identity" (which is more often referred to as "proof-of-authority" – PoA[16]), "proof-of-elapsed-time" – PoET [Rilee, 2018][17] or "quorum voting"[18]

[14] The register itself would contain all transactions but the transactions in a single chain of supplies would make up a single common "history" possibly inaccessible by the entities not involved in the chain of supplies of a given product.

[15] The term "block" and the derived term "blockchain" refer to the necessity of aggregating numerous transactions as "blocks" that could be approved jointly owing to the need for greater computing power required to approve each transaction separately, especially with the consensus mechanism of "proof-of-work" (PoW); blocking a transaction may delay its approval (so that reasonable certainty that it cannot be cancelled is ensured) by several minutes to a few hours; in the case of private (closed) systems that do not employ the PoW mechanism, it will be a smaller problem and will allow processing in the process of invoice issuing in real time, which is often essential in a system that is supposed to precede invoice issuance. It may not, however, be ruled out that blocking of transactions may in this case happen due to potential scalability issues of a solution without blocks. cf.: [Antonopoulous, 2018, pp. 21, 207].

[16] In networks based on PoA, transactions and blocks are approved by approved accounts, which are called validators. Validators set off software that allows them to place transactions into blocks. The process is automated and does not require the validators to constantly monitor their computers. It does, however, require that the computers are kept intact.

[17] In general terms, proof-of-elapsed-time (PoET) consists in each user of a blockchain network randomly waiting for some time; the first user that finishes waiting becomes the leader of the new block. It requires ensuring that nodes are randomly selected after some time passes and that there is no possibility to "claim" a block earlier.

[18] Quorum Voting is an adaptation of the consensus mechanisms Ripple and Stellar and serves to meet the needs of ap-

– based on permissions granted to nodes (or time passing by). Transaction approval in the whole system would in this case take place after the minimum number of required individual confirmations from nodes would be exceeded (e.g., if 75% nodes in the network approved the transaction independently in each country). Waiting for confirmation of all nodes could cause unnecessary prolongation of the processes as a result of, e.g., random situations (such as node failure), attack, an algorithm operating for a long time or inconclusive analysis results. In case the nodes that the network was not waiting for before official approval of transaction find that irregularities are possible, traditional reaction mechanisms may be triggered.

The computing power would be employed for the purpose of implementation of artificial intelligence (AI) algorithms that would associate transactions by indicating suspicious ones in a way learned through analysis of clues supplied by trained VAT auditors. That way validation would not be artificially hampered or costly for all the users (but it would remain costly only for the attackers) and the computing power would be used to produce functionality directly. Each country involved in the system would be obliged to supply an appropriate number of network nodes. The authors of the concept propose to base the distribution of the number of nodes on GDP distribution, however, it does not seem to be the key issue from the perspective of system operation. System users that have access to register records would be state administrations and institutions that they delegate or some other entities (not specified by the authors) and taxpayers but with dissimilar access permissions. In practice, entrepreneurs could enter a new invoice (having a "pro forma" status until approved and accepted by the recipient) using an official application or one that uses the official administration's API (i.e., a set of methods for accessing the administrations' system). A blockchain network would be approving this invoice (or transaction) and then the recipient of the invoice could accept it. Everything would take place automatically without direct intermediation of the tax office. The office though could have influence over "training" of the algorithms that are installed in domestic nodes and analyse transactions. Analytical processes could also be delegated to a specialized computer centre.

In order to illustrate its operation, the authors of the concept present an example that we provide below. Let us assume that an auto mobile manufacturer in France produces 100 cars to be exported, which are sold to a French intermediary, "Seller A", for 10,000 euros each (which is domestic sales). "Seller A" arranges with a Dutch intermediary, "Seller B", for him to purchase 10 of these cars for EUR 11,000 each (applying the ICS and ICA rules). Following the transaction, "Seller B" resells the cars to the dealer in the Netherlands, who then sells them to Dutch consumers. Let us assume that the distributed VAT record registers transactions with each of the ten cars starting from the manufacturer purchasing materials until production of ten cars (record in Block No. 1) that are handed over to "Seller A" (Block 2). The stage we are dealing with is cross-border sales to "Seller B" in the Netherlands (Block 3). When "Seller A" and "Seller B" accept the conditions of sale/purchase of ten cars for EUR 11,000 each, the rules of the distributed VAT record will require that both parties submit information about the contract as a pro forma invoice in an encrypted file handed over to appropriate tax administrations. It will be sent to the cloud from there and subsequently to each of the nodes assigned in each jurisdiction.

The artificial intelligence (AI) helps each node to decide whether to approve or reject a proposed transaction. In order for the network to approve a "transaction" (or contract), it is necessary to reach an appropriate consensus threshold – e.g., 75% of the French nodes and 75% of the Dutch nodes must give consent (having found no grounds for deferring the contract following risk analysis) to assigning a "transaction" (contract) to a blockchain. Approval process may take sev-

plications that require immediate and final transaction approval. [Mazieres, 2015] [Chris-j-h, 2016/2019]

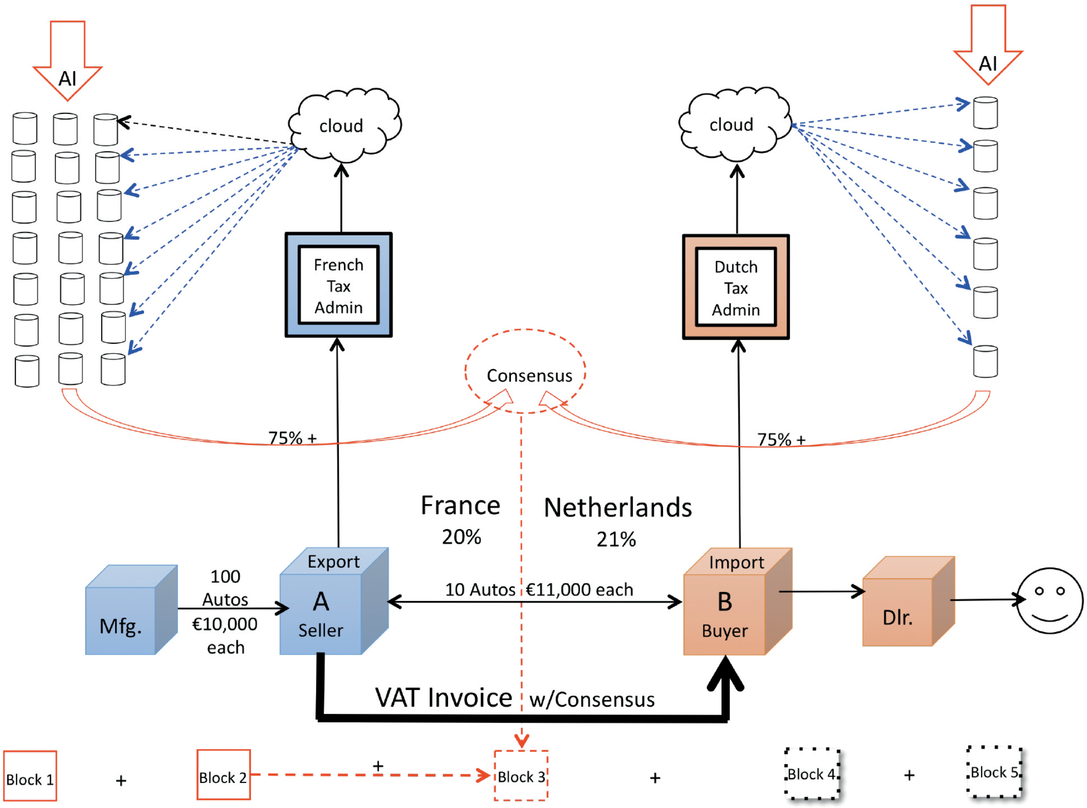


**Diagram 2. VAT Blockchain (based on DICE) with a 75% consensus threshold.**

Source: [Ainsworth, Shact, 2016]

eral seconds to a few minutes, depending on the manner of implementation.

## VATCoin (2016)

In 2016, R. T. Ainsworth, M. Alwohaibi, and M. Cheetham offered a solution complementing the DICE system, which also uses blockchain technology and is called by them VATCoin [Ainsworth, Alwohaibi, Cheetham, 2016][19].

VATCoin is similar to the Bitcoin cryptocurrency but it is designed for tax payments and so it complements the DICE system registering sales agreements prior to their execution. The transaction record in the Bitcoin blockchain is public.

[19] The VATCoin concept was developed as a result of face-to-face discussions between R. T. Ainsworth and Mike Cheetham following completion of the previous article. [Ainsworth, Alwohaibi, Cheetham, 2016]

Whereas VATCoin – similarly to the DICE blockchain – is private (i.e., closed and based on permissions). In contrast to Bitcoin, VATCoin is not a currency (or a crypto-asset) that is speculative in character. Its value will be determined based on a constant parity in relation to the national (or possibly international) currency. VATCoins – as a settlement currency – are obtained by way of purchase from the state Treasury and denominated in national currency units. VATCoins are exchanged into currency only by the same state Treasury that issues them. Each Polish VATCoin (VATCoin-PLN) thus represents one Polish zloty. Issuance (or exchange) of a VATCoin takes

VATCoin is similar to the Bitcoin cryptocurrency but it is designed for tax payments and so it complements the DICE system registering sales agreements prior to their execution.

place on request of a VAT payer purchasing goods from counterparties. During issuance, a smart contract is created that controls settlement of these VATCoins. During payment of tax to the tax office, VATCoins are "burned". VATCoins have no physical representation.

Tax payments are registered in a blockchain [Ainsworth, Alwohaibi, Cheetham, Tirand, 2018]. Possession and issuance of VATCoins requires that the taxable person (i.e., the VAT payer[20]) has a particular address. The taxable person (or the taxpayer) must digitally sign the transaction with a private key. If the private key is lost, the VATCoin network (in contrast to the Bitcoin network) should have mechanisms allowing identification of ownership of VATCoins.

VAT would be paid, transferred, and collected exclusively in VATCoins. Only the government (i.e., the state Treasury) can exchange VATCoins for real currency. VATCoin is not a currency and neither bank fees apply to its transfer and nor it is directly related to the real economy[21].

Validity of each transaction would be verified by the nodes owned by the public authority (i.e., tax administration) of each jurisdiction. In line with the authors' concept, the number of nodes contributed by a jurisdiction should be contingent upon the GDP of the jurisdiction (although this proposition has not been justified)[22]. Each company participating in a VATCoin transaction would have access to transaction records of all VATCoins it holds. Just as the case with the DICE system, the verification and consensus mechanism would require positive verification by a specified number (e.g., 75%) of votes to be obtained from the active network nodes.

Companies will be buying VATCoins to use them in their trade transactions. VATCoins are kept on an account in a blockchain network and transferred among companies' accounts as trade unfolds. VATCoins may be converted to local (i.e., national) currencies only on request of the authorities.

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For VATCoin implementation to be possible, it would be necessary to modify the provisions of the law on currencies (money) and tax regulations in countries interested in the implementation of this system. Countries should adopt such regulations that presume that on the whole territory where this settlement system is adopted:

- VAT must be paid (and received) only in VATCoins. Payments with VATCoins would be made through smart contracts that are built in invoice documentation (if VATCoin were combined with a digital invoice exchange system, such as DICE);
- VATCoins must be recognized as a currency that cannot be repurchased and can only be exchanged for cash by the authorities. The authorities would need to exchange VATCoins into zlotys, if a VAT return indicated a refund of an excess amount of input VAT over output VAT. VATCoins paid on the basis of a given invoice would be verified in real time and added to a distributed register;
- following the waiting period, a smart contract would pay out tax refunds every time the taxpayer's account showed a negative balance of VAT. VATCoin accounts would be balanced daily. Only risk analysis might in some cases delay instant refunds.

The authors provide an example [Ainsworth et al., 2016] of how the system operates based on the countries of the Persian Gulf associated

[20] In Polish Tax ordinance there is a difference between a taxable person and a taxpaye. To put it simply, we understand a "VAT payer" as an "active VAT taxable person"; cf. [Szymała, 2017].

[21] Classification of VATCoin in the light of the Act on Payment Services remains beyond the scope of these deliberations.

[22] An analogous proposition as regards the number of nodes is put forward in the description of DICE based on blockchain.

as the Gulf Cooperation Council (GCC)[23] as their proposal is directed at these countries in the first place. These countries have been pursuing implementation of a VAT system since 2018 – they strive to build a unified system in the whole region with a single 5% VAT rate[24]. So far (at the beginning of 2019), VAT has been introduced by Saudi Arabia and the United Arab Emirates. In January 2019, the system was also introduced by Bahrain [Taxamo, 2018].

In a subsequent publication [Ainsworth et al., 2018], the authors provided an example of a solution for EU countries, which is adjusted to the proposal put forward by the European Commission as regards changes in the treatment of cross-border B2B supplies of goods[25]. The proposal of the European Commission accepts, among other things, the above-mentioned one-stop-shop (OSS) mechanism that assumes the existence of an ICS/ICA settlement system governed by analogous rules as the VAT settlement system currently in place for sales of e-services for consumers (i.e., the MOSS system).

In the following example, the number of the step in the process is provided in square brackets and the number of the block that a transaction in a blockchain is recorded in – is provided in curly brackets.

Let us assume that a wholesaler (in jurisdiction B) wants to order goods from a distributor (in jurisdiction A); while simultaneously the wholesaler and the distributor will be selling the goods to a consumer. Since the necessity to pay tax arises, the wholesaler requests that his tax office issues VATCoins-B (in jurisdiction B) [1] by stating the number of VATCoins-B needed as well as the buyer's and the seller's identification information and the type of goods involved. The tax administration creates a new smart contract that is recorded in the first block {B1} of the chain. The smart contract creates the needed number of VATCoins-B and transfers them [2] to the tax office, which is recorded as the second transaction in the blockchain {B2}; and subsequently to the wholesaler's account in the next transaction [3] (which is recorded in {B3}).

The wholesaler uses the VATCoins-B to finalize the transaction with the distributor [4], which is recorded in {B4}. Transfer of VATCoins-B confirms a cross-border transaction and the distributor may apply for input tax return. The total VAT collected in jurisdiction B is 10 (the black dashed line starting at the distributor) but it should be 40. The missing VAT amounting to 30 is with the distributor in jurisdiction A awaiting submission of OSS return and formal transfer of 30 VATCoins-B through the agency of the OSS mechanism. The distributor sends VATCoins-B [5] to his tax office (in jurisdiction A), which is recorded in {B5}.

Following verification and aggregation of transactions and VATCoins-B available to the tax administration of jurisdiction A, VATCoins-B are transferred along with a request for OSS return to the tax administration of jurisdiction B [6], which is recorded in {B6}. The final step is transfer of VATCoins-B by tax administration B to the state Treasury [7], where they are destroyed {B7}.

Transactions are recorded individually and almost in real time, which means that a lot of data are processed. That should not be a problem for a private blockchain, however, manual analysis of the data or analysis with the use of traditional algorithms may not be sufficiently effective. Therefore, the authors suggest to implement algorithms based on artificial intelligence (AI) to analyse risk in real time (just as the case with the DICE system).

[23] The GCC is a regional intergovernmental political and economic alliance of 6 countries of the Middle East: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates (UAE)

[24] In June 2016, the GCC countries executed a Common VAT Agreement of the States of the Gulf Cooperation Council [GCC, 2016]; in May 2017, an official translation of the Agreement into the English language was presented [GCC, 2017].

[25] During export, the taxpayer will apply the rate applicable in the purchaser's country. Within the framework of intra-Community supply, the seller will thus be obliged to follow the regulations applicable outside the territory of his country. He will also bear the responsibility for making correct settlements and applying the right VAT. Cf. [EC, 2017a; Szulczewski, 2018]

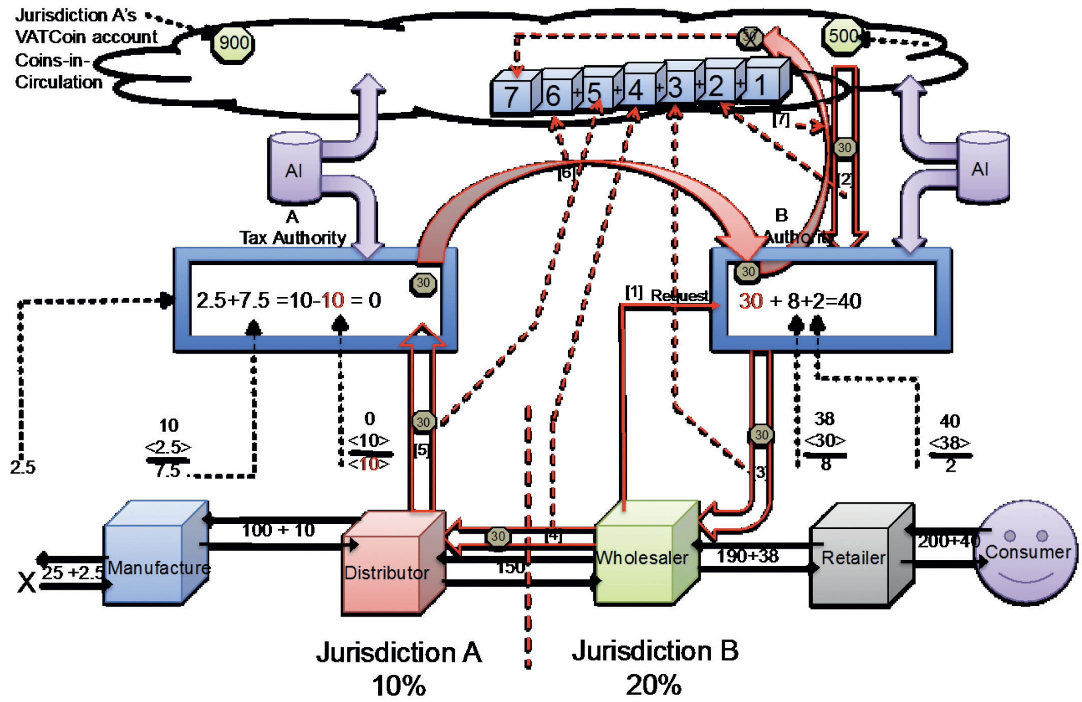


**Diagram 3. An Example of Tax Settlement Using VATCoin in the European Union in Cross-Border B2B Transactions**

Source: [Ainsworth et al., 2018]

According to the authors, the true potential of the VATCoin system is greater than international B2B transactions and may also encompass domestic B2B as well as B2C transactions.

According to the authors of the solution, the VATCoin system has several features:

- No entity is in possession of the funds received due to VAT payments (as the currency is held by the state Treasury), which hinders such crimes as MTIC/MTEC.
- VAT payments and settlements are possible in real time;
- "Code is Law" – the flows and settlements are legitimized by the provisions embedded in the code of smart contracts;
- The distributed VAT system is not susceptible to cyber-attacks (as there is no single point of failure, SPOF).

The whole VAT is stored in the cloud (a network) of the VATCoin system as a specific settlement token. Whereas the MTIC and MTEC mechanisms are based on the existence of an entity that "accumulates" the funds due in the relevant country. In case of transition to a settlement system based on VATCoin, there are only funds transferred between the taxpayer and the state. Such a construction creates no possibility to fraudulently obtain funds (de facto VAT) without any contact with the relevant tax administration body.

When the VAT system works as it should, companies do not bear the burden of VAT settlement (in economic sense as the tax is paid by the consumers). The VAT tax paid on input products is deducted from VAT collected at the time of sale of products. If there is profit, that

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The authors of the VATCoin and DICE concepts claim that a combination of both on a platform based on blockchain technology may be the most effective and fraud-resistant tax system.

is, a positive difference between output VAT and input VAT, net tax liability arises (so the tax is payable), which results from added value.

The common reasons for the lack of a positive difference are: a) in export, total cumulated VAT is returned to the exporter; (b) a company generates loss; (c) the moment of sale and purchase is inconsistent (but they should compensate in the long term). In the first two cases, negative VAT flows may become a financial burden (resulting in a negative cash flow) and foil the company's attempts to get out of trouble. The higher the negative balances and the longer the periods in which they are maintained, the greater the burden.

VATCoin goes around this loophole in the VAT system owing to daily balancing of taxpayers' VAT accounts in the blockchain register. Funds are transferred to the state Treasury every day (from accounts where the balance is positive). Refunds may be settled equally fast. With the VATCoin's blockchain, smart contracts may be easily constructed in such a way that allows immediate payout of returns. Consolidated daily VATCoin balances will impact the monthly profit and loss statement but daily burden on companies' liquidity will be lowered.

In the VATCoin system, all the parties are motivated to use authentic VATCoins in the exchange process. Stolen or fake VATCoins will immediately be identified by blockchains. An attempt to commit fraud would directly influence risk analysis and would most likely delay daily balancing, send the transaction for audit, and suspend the related refunds in a given trade chain.

The authors of the VATCoin and DICE concepts claim that a combination of both on a platform based on blockchain technology may be the most effective and fraud-resistant tax system. DICE ensures registration of trade transactions in real time at the level of invoices whereas VATCoin ensures that no taxpayer holds the funds (arising from the VAT collected) in the official currency. The authors enumerate several benefits from combining the systems. We quote selected ones:

- Transmission of tax payments to the government and companies is instant, liquid, safe, transparent, and highly controllable. Transfers are made without bearing any transaction costs.
- VAT returns are filled out by tax administration with the use of evaluation systems (where the administration prepares a refund based on the information available in the system) and not with the relatively more onerous self-calculation system (where the taxpayer prepares the refund to be verified by the tax body).
- The two systems (i.e., VATCoin and DICE) place burden neither on the business nor on the consumer. Compliance is more efficient thanks to the use of technology. A businessman or a consumer may easily download a free compliance application to any mobile device. The application creates a VATCoin account for the user, registers, encrypts, and sends an invoice to the VATCoin cloud.

### Pajakoin (2017)

In 2017, D. A. Wijaya, J. K. Liu, D. A. Suwarsono, and P. Zhang [Wijaya, Liu, Suwarsono, Zhang, 2017] proposed a Pajakoin system which is intended to offer solutions to two problems that the Indonesian e-invoicing system already in place is facing: creation of fake invoices in the e-Invoice system and other transactions related to them and lack of proper codification of types of goods and services listed on an invoice (as each taxpayer may create their own codification).

Pajakoin is a hybrid system (with a central administrator and distributed users) based on blockchain technology, which is administered by the Indonesian tax authorities – the Director General of Tax (DGT). The protocol that they offer reverses invoice processing – in order to generate a VAT invoice, the VAT payer (TPVP – Taxable Person for VAT Purposes) must first obtain valid PAKO tokens (i.e., tax credits). That means VAT is paid in advance.

Let us take a look at it by analysing the following example (there was no example provided in the authors' article). A Manufacturer wants to sell goods to a Wholesaler for IDR 100 million[26] + 10% VAT. Let us assume that 1 PAKO = IDR 1 million. The Manufacturer buys 10 PAKO from the DGT (through the agency of banks), which allows him to obtain the DGT's permission to send PAKO tokens to the Wholesaler and issue an invoice for the Wholesaler. The Wholesaler would not agree to make this transaction, if he were not to obtain PAKO tokens that will serve him to obtain permission for issuing an invoice for the Retailer. After an invoice is generated, the Manufacturer hands 10 PAKO tokens over along with an invoice (and the goods) to the Wholesaler. In a system based on blockchain, transfer of the tokens represents VAT invoice issuance (but it is not a digital invoice; although as the authors note, it may additionally contain information from the invoice[27]). The Wholesaler pays IDR 110 million. Whereas the Manufacturer[28] has already temporarily settled VAT. The Wholesaler wants to resell the goods to the Retailer (who is not a VAT payer) for IDR 130 million + 10% VAT. In order to obtain permission to make the transaction and send PAKO tokens to the Retailer, the Wholesaler buys 3 PAKO from the DGT (and thus has 13 PAKO in total as he has received 10 PAKO from the Manufacturer). The transaction with the Retailer is permitted by the DGT. The Wholesaler supplies the goods, transfers 13 PAKO to the Retailer and receives IDR 143 million as payment. The Wholesaler has temporarily settled VAT. The Retailer wants to sell the goods to the end customer for IDR 170 million + 10% VAT. The Retailer buys 4 PAKO tokens from the DGT. The Retailer does not hand over PAKO tokens to the end customer. Instead, he sends them to a special coin-eater address supplied by the DGT. Transfer of the tokens to this address means that the goods are sold to the end user (who received a receipt or a non-VAT invoice). The end customer receives the goods and a receipt and pays IDR 187 million to the Retailer. The Retailer has temporarily settled taxes.

Pajakoin is a hybrid system (with a central administrator and distributed users) based on blockchain technology, which is administered by the Indonesian tax authorities

Pajakoin is limited to authorized users only. The DGT may closely monitor and control PAKO transactions. Banks are the agents that "sell" PAKOs to taxpayers and receive the official currency from them. Subsequently, they create reports with the amount of money obtained and details of PAKO purchasers. The reports are sent to the DGT and will be used to match tax revenues to PAKO transactions. There can be monitoring bodies that act as independent third parties to audit the system (which are authorised to view transactions). Taxpayers may create transactions using PAKOs that they purchased from banks.

The authors used the Multichain service [no date] to create a private (managed) blockchain. The blockchain will be managed by the DGT. Banks, the monitoring bodies, and taxpayers will need permissions to view and create transactions. The consensus method will be proof-of-work and transactions will be validated by the DGT. The tax registration number is replaced by a Pajakoin address. Each taxpayer has one or more unique Pajakoin addresses. They correspond to private keys that can only be accessed by the taxpayers. A private key is used to sign transactions.

[26] IDR is a symbol of the Indonesian rupiah, the official currency of Indonesia. The rate of exchange at the time when the article was under creation was about IDR 1 million = PLN 270.

[27] Information about the VAT invoice may be added to PAKO transactions: commodity/service codes, prices, basis for assessing VAT, and VAT. For the purposes of periodical reporting, the authors propose to use transaction ID numbers.

[28] The actual flow of transactions is obviously longer and more complicated.

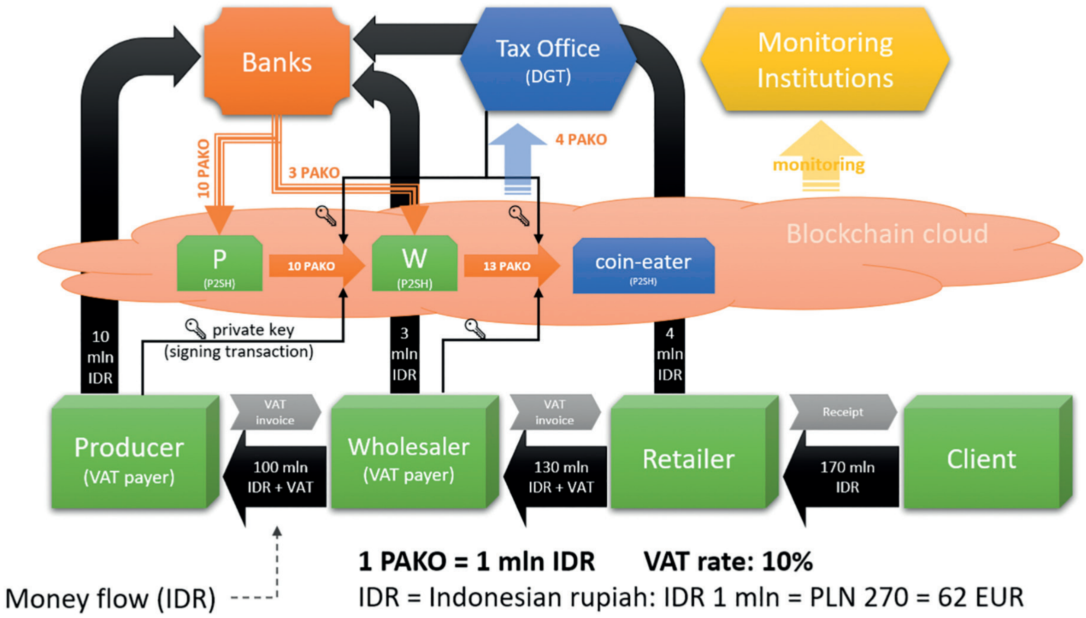


**Diagram 4. Funds Flow in the Pajakoin System (retailer is not a VAT payer).**
Source: [Wijaya et al., 2017]

A central body makes a list of all taxpayers' Pajakoin addresses for administrative purposes. In order to verify a Pajakoin address, the DGT may supply digital certificates for these taxpayers by signing public keys. A digital certificate proves that the DGT approves of the use of these Pajakoin addresses. As far as VAT payers are concerned, the Pajakoin taxpayer address is used to generate the VAT payer's address. The VAT payer may hand over his PAKO tokens to another VAT payer.

An additional unique address is generated for each VAT payer, which serves as an intermediary in transactions between VAT payers. It is a P2SH type address that requires that specific conditions be met in order to use PAKO funds accumulated on it (e.g., permission must be obtained from both the taxpayer and the tax office or only from the tax office after a specified time period has passed from the moment of ordering a transaction; which allows the DGT to control correctness of transactions and addresses). The DGT assigns such an address to each VAT payer. If they wish to send funds to their counterparty – they have to obtain the counterparty's address (which may be publicly available information).

In order for the proposed protocol to work, it is necessary to introduce some changes into the VAT payment procedure currently in place. Instead of paying input tax at the end of the settlement period, VAT payers are obliged to pay VAT (through buying PAKO tokens from banks) before the tokens are handed over to other VAT payers along with a VAT invoice.

PAKO rate of exchange for the official currency (which the authors refer to as the conversion rate) is determined by the DGT and banks in order to make sure that the value of PAKO tokens reflects taxes paid in actual transactions. VAT payers' Pajakoin addresses have a limited time (of 90 days) available to transfer the tokens as tax payments or exchange the tokens (which are overpaid tax) in banks. Transactions exchanging PAKO tokens into money require approval with the DGT's digital signature.

The authors express the need to develop the concept by using, among other things, a much more flexible solution based on smart contracts instead of scripts (P2SH addresses) and reducing the DGT's involvement (e.g., with an additional smart contract approving transactions).

### DPCS (2017)

The Dividend Payment Control System (DPCS) solution developed by H. Hyvarinen, M. Risius, and G. Friis [Hyvärinen, Risius, Friis, 2017] addresses the problem of "double payments" in Denmark. The problem arises from unauthorized applications for reimbursement of overpaid tax in the case of payout of dividends to foreign shareholders residing in countries with a lower income tax rate than the one in Denmark.

There are four categories of users in the proposed system: SKAT (the Danish tax office), VP Securities (a company rendering financial and investment services for investors and organisations), financial institutions, and shareholders. As an organisation allocating refunds; SKAT is the system owner and administrator. SKAT is the only user with full access to the information in the system and may receive tokens and reply to refund claims. Neither shareholders nor financial institutions have access to the information other than about their own accounts.

The Dividend Payment Control System (DPCS) solution addresses the problem of "double payments" in Denmark. The problem arises from unauthorized applications for reimbursement of overpaid tax in the case of payout of dividends to foreign shareholders residing in countries with a lower income tax rate.

All the user groups, except for SKAT, may use the basic common functionality: declaring transactions. VP Securities reports transactions made by the company with its shareholders (i.e., dividends); financial institutions report transactions that they make to the benefit of a shareholder (or, if the process is composed of several levels, another intermediary financial institution), and the shareholders apply for a tax refund by initiating a transaction with an appropriate number of SKAT tokens. Each time a transaction is initiated, tokens are transferred from the taxpayer's to the receiver's account.

VP Securities is the only user authorised to make dividend tokens, which ensures that the number of tokens generated in the system reflects the paid out dividends reported by companies.

Each financial institution and shareholder have an account that they can manage. Having a blockchain account is necessary for a shareholder to claim a refund. Financial institutions use their accounts to report dividend payments and shareholders may thus apply for a tax refund to SKAT (and permissions to do so are confirmed by documented payments in the system).

In DPCS, user IDs (which are their public keys[29] or their cryptographic abbreviations[30]) corresponding to shareholders' accounts may be used as unique IDs validated by VP Securities based on information disclosed by the company paying out dividends (in the cases where the dividend is paid out directly to a shareholder) or a financial institution (if the payment process is handled by intermediaries). Financial institutions receive user account information along with other personal details handed over by the shareholder as their client. It does not ultimately exclude the possibility that a fake bank might

[29] In asymmetric cryptography, which is frequently used in blockchain solutions for authorisation of system users (i.e., confirmation that a given user may manage the funds assigned to a given account), a set of two related keys are in use. One of the keys may be shared publicly without compromising data security. In a blockchain, a public key (which is a very long character string) is used to generate an address (which is a shorter version of the public key). A private key serves the role of an "access password" that allows to access an account – the system will only accept a transaction order that has been signed with a private key corresponding to a public key and the address generated on the basis of that key. cf. [Antonopoulous, 2018].

[30] Hashing (or the hash function) assigns a short and always fixed-size number to any large number (e.g., a digital version of any document); the outcome of hashing is non-specific and quasi-random, that is, its value changes in a near random way even with a small amount of input data and the original data cannot be inferred from the "hash". The same input data always produce the same outcome (with the use of the same function). cf. [Aumasson, 2018]

validate a fake person but a unique ID is still a considerable improvement in comparison to the current situation and allows processing user data from various countries in a uniform way, which additionally simplifies the whole process.

At the moment of dividend payout, information about this fact is sent to VP Securities. Tokens are created on the VP Securities' account. A shareholder that wants to claim a tax refund, creates an account and sends its identifier to a financial institution that manages his assets (or – if he received the dividend directly from the company – to VP Securities) for the purpose of granting due tokens. VP Securities transfers the tokens to an account of a bank that pays out dividends. The bank hands the tokens over to an investor who applies for reimbursement of overpaid dividends and transfers the tokens to the account of the tax office.

The correct amount on the tax return is calculated automatically. The whole mechanism may be implemented with a smart contract that issues tokens when payment is reported by VP Securities.

Shareholders may not transfer tokens to each other. The entitlement enjoyed by a shareholder may not be exercised by anyone else (as only he has access to the tokens sent to him in the course of this process). If he does not use the possibly to claim a refund following a specified period of time, the tokens authorising to a refund may be destroyed by a smart contract.

According to the authors of this solution, an approach based on blockchain ensures that several improvements are made to tackle the current problem of double payments. Firstly, the possibility of committing fraud is reduced due to the fact that traces of payments are documented, which means that claimants may no longer falsify bank documentation that would justify dividend payout. Secondly, the possibility of paying double is excluded because each token may only be used once in a refund claim. Thirdly, a blockchain solution facilitates SKAT's verification of the claimant's right to a refund on the basis of a token.

## Compliance in Multinational Corporations (2018)

There have been no such comprehensive solutions for transfer pricing and the problems described in the first part of this deliberation as there have been for VAT. The presented analyses are rather concerned with a general concept of collection of transactional information and the manner of data verification than coherent solution concepts. They are also mostly meant for the taxpayers themselves and intended to facilitate the so called compliance process regarding transfer pricing for them. These solutions have a principal advantage for tax authorities: their implementation may considerably speed up and simplify controls. Correctly implemented blockchain solutions will also provide irrefutable evidence of certain events.

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W. Zhang's [2019] proposal is noteworthy as it proposes to create a database solution based on blockchain in multinational corporations (MNC), which would be complementary to the currently existing system and allow to process transactions, settlements, register auxiliary documentation, and their automatic verification within an organisation. Such a system should link all the entities involved in transactions and all the departments of a given organisation (i.e., accounting, finance, purchasing, etc.) as well as internal auditors (i.e., compliance departments). External auditors and bodies of particular jurisdictions of companies within a group could be granted access to the data on the basis of an appropriate safe access. Within the framework of such a system based on a pri-

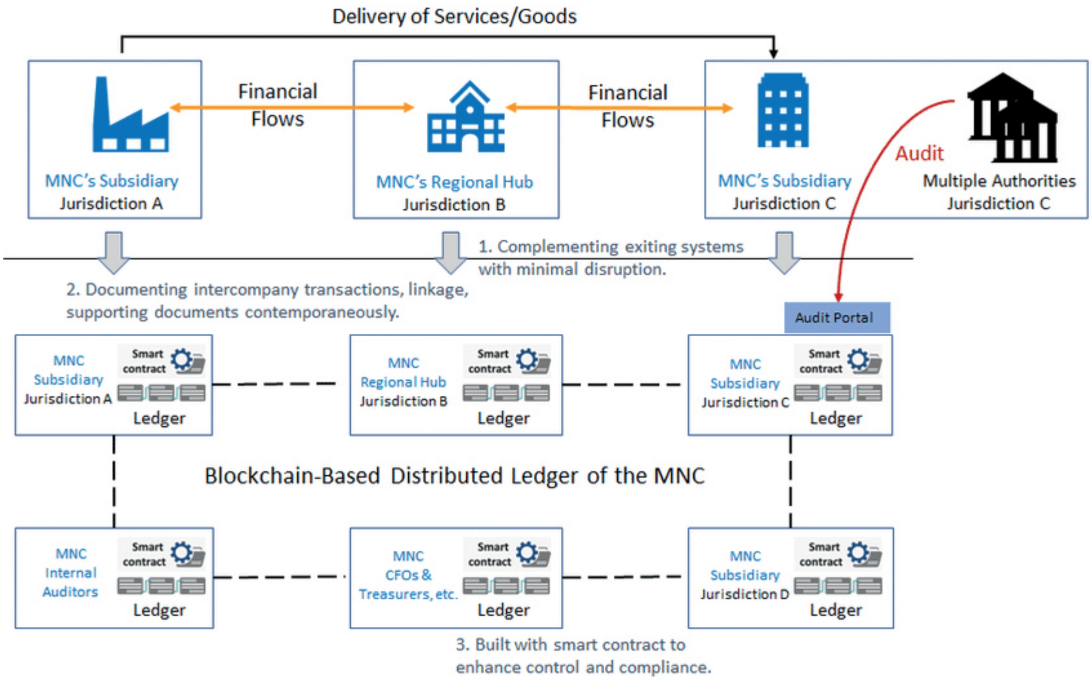


**Diagram 5. Simplified operation of "Blockchain for MNCs".**

Source: [Zhang et al., 2019]

vate blockchain, the authors suggest to also have external auditors and state bodies as the so called nodes in the system to a limited extent (as far as data collection is concerned), which would build up trust to the network.

A blockchain designed in such a way would be connected with the existing systems and internal company processes and coordinate execution of processes with smart contracts (e.g., such processes as payment approval or invoice issuance). It would also store transactional data and a given process status. What is more, in the system architecture and smart contracts, there would always be regulatory requirements of individual jurisdictions where special purpose vehicles operate.

The diagram below presents the functioning of the platform.

The relevant literature [Sim, Owens, Petruzzi, Tavares, Migal, 2017] indicates that solutions such as the ones described above can considerably influence:

- Improved understanding of economic processes within the framework of operating companies, which will make it possible for tax bodies to more fully verify settlements and economic processes in progress;
- The amount of comparative data that are necessary to run price benchmarking analyses;
- The way proceedings and controls are maintained – tax bodies will have access to undeniably original data that will be confirming transactional data (which is of utmost importance, e.g., in the developing countries).
- Resolution of disputes with tax bodies;
- Reduction of the costs of running a business.

## Taxpayer Verification with Blockchain (2018)

The above-mentioned VIES system partially solves the problem posed by verification of whether a purchaser from another Member State is a registered VAT payer for the purposes of intra-Community trade. However, credible accessibility of this information for the national administration does not guarantee that confirmation of counterparty (including domestic counterparty) registration generated by this administration will be credible enough – which we have also mentioned earlier – and it may turn out insufficient to prove "due diligence" in court.

In 2018, as part of a competition: Global Legal Hackathon 2018, A. Zadrożny, B. Goźlińska, and M. Zadrożna proposed a solution [Zadrożny, Goźlińska, Zadrożna, 2018][31] that was supposed to serve as credible confirmation for the court that the counterparty a company cooperated with had been verified by the company against the database of the Ministry of Finance at a given time. Hence evidence of "due diligence" is supplied and the entrepreneur obtains credible data.

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In the proposed solution, a blockchain network would be based on nodes maintained by lawyer's and notary public offices. On request of a client who needs a certificate from the Ministry of Finance's database, lawyer's offices generate certificates of such verification (in any file format in use in the office, e.g., a PDF, that may be printed out and signed traditionally, digitally or may be left unsigned). Next, the cryptographic hash function is used to generate a character string being a digital "print" of the file, which is introduced into a blockchain register. With an introductory transaction, such data as the following may also be provided as additional information: what entity carried out verification; which entity was being verified; and what was the status of the verification operation. An introductory transaction is approved by the network and the client may receive a certificate with a printed file print or the print only (regardless of the form in which the print has been handed over, even if a document gets lost, the client may confirm that he has verified the counterparty). Owing to the use of additional data – the entity might single-handedly (unless system implementation requires otherwise) read the information from a blockchain and generate confirmations of verifications.

Due to a relatively low cost of node maintenance, an office may share confirmations at a low price or free of charge (treating the service as an element of competitive advantage) by publishing an appropriate form on their website. As the authors point out, with a small change in code, a blockchain may also store confirmations for other types of documents.

Theoretically, a lawyer's office might generate a digitally signed certificate and issue it without using a blockchain system, however, keeping a print in a distributed network guarantees that the data will not be changed in the future and with appropriate implementation of the system the entity will be able to single-handedly obtain confirmation of a transaction.

## Discussion

### VATCoin and Pajakoin

The proposed VATCoin and Pajakoin concepts are systems supporting VAT payments. There are some similarities between the two concepts, however, they also differ as far as system mechanics are concerned. In particular, tokens are issued by the authorities in exchange for monetary funds to reflect the tax liability in both of the systems. Tokens flow in reversed directions,

[31] Description of the solution was based on a presentation for the above-mentioned competition as well as information provided by the authors (A. Zadrożny) and supplemented with potential detailed solutions.

which determines interpretation of a token's function.

PAKO is a document that has both the features of a digital invoice (although it is not one) and a tax token (although it is not a receivable). It certifies that VAT has been paid by entities involved in a supply chain earlier. It is information both for the client – that may verify a supplier in terms of his reliability as far as paying taxes is concerned – and for the tax office – that permits transfer of tokens to a counterparty. If a Supplier does not obtain a total number of tokens confirming payment of tax by entities involved in the chain earlier (as tokens can surely be aggregated from various sources and not only from the directly preceding link in the chain), then a client obliged to do the same may refuse to make payment that would be the source of a Supplier's "refund" of the tax overpaid (to their own supplier and the tax office). The problem arises at the end of the chain when the Retailer (that is a VAT payer) sells the product to the end customer. The customer[32] may have an account in such a system and expect confirmation of the Retailer's reliability as a VAT payer (i.e., expect that he sends over tokens), which may be a type of an electronic receipt for them. However, if the whole system was based on such a motivation, it would likely soon result in system failure, especially considering that the Retailer would have to learn the address of each of their clients. On the other hand, the Wholesaler that sells goods to a Retailer that is a taxpayer exempt from VAT (and has no account in the system) has no motivation to require the Manufacturer to send PAKO tokens unless an obligation to send PAKO to an address destroying tokens would be introduced (thus ending token trading). Without it, the Retailer might be willing to sell PAKO to other entities at a lower price. This issue has not been clearly explained by the authors of the concept. Furthermore, the Retailer will have to settle taxes in a traditional way, which means there will be a gap in the system and enterprisers who are taxpayers exempt from VAT may organise tax fraud. The use of a variable conversion rate of PAKO into an official currency is also not clear. Moreover, the current proposal is based on blockchain scripts (which is a fairly old mechanism), instead of the more flexible smart contracts. It also seems that the role of the tax authority (the DGT) in the system is too prominent as it would have to approve all transactions. It would be possible to automate this processes provided that algorithms analysing transactions in the blockchain register (and using other data sources) were adopted. This way or another, the system would still be a centralized solution and thus a single point of failure that the attacker may concentrate all their efforts on. It also raises doubts as to who would act as nodes to ensure decentralization and prevent data manipulation by the tax office?

The VATCoin system is more coherent and flexible. In this system, the "exempt VAT payer" will also be obliged to obtain tokens for payment of VAT along with the price of goods or services that are being supplied. If he obtains no tokens, it will be impossible for him to carry out the purchase transaction (and the supplier will probably not agree to make such a transaction as he will not be able to use the tokens later to pay VAT to his own supplier or possibly get a tax refund). However, he will use the funds obtained from the end client to purchase tokens. The system may function in any segment of the supply chain – encompassing both entities operating in a single economic community (using VATCoin) and their foreign counterparties. If a system operated at full length of the supply chain – some tokens would be obtained from clients and the remaining ones would have to be obtained from the tax administration (which was well-presented on an example in article from 2016 [Ainsworth et al., 2016]). VATCoin seems to effectively support the purpose connected with reduction of some fraud – as it separates tax payments from producer (net) price payment, which prevents undetected accumulation of funds arising from output tax collected along with the price.

[32] In accordance with an explanation provided by the author of the concept for the authors of this article with.

An effect similar to the one brought about by implementation of the Pajakoin system may be produced at a lower cost – by introducing appropriate regulations, e.g. required prior payment. It should be stressed, however, that Pajakoin has advantages that cannot be replaced with solutions that are not based on blockchain technology. This is because it guarantees almost full compliance, control over token flow, settlement in real time and clear-cut identification of users, and verification of their presence in the register as VAT payers. It does not separate payment of producer (net) price from tax payment though, which means that it opens up possibilities for committing fraud based on accumulation of tax payments (following appropriate adjustment of the mechanism of limitations in place in the Pajakoin system).

An effect comparable to implementation of VATCoin may in turn be produced by implementation of the split payment mechanism but VATCoin allows effectuation of this concept in real time and international data exchange as well. It also seems that implementation of the VATCoin solution could generate serious problems in case adjustments were needed – especially multiannual adjustments arising e.g. from erroneous classification for the purpose of input/output tax.

The key thing lowering the effectiveness of the potential implementation of both systems is that they require thorough amendment of the existing tax system and the acts related to it (e.g., on accounting). Doubts also arise over the influence of both systems on liquidity of companies – as in both of them payment of taxes is made in advance. Separating the moment of issuing an invoice (receipt of an invoice) and payment (both to the contractor and the payment of the tax) allows entrepreneurs to manage receivables and short-term liabilities. From the point of view of the seller, it would be disadvantageous in the supply chain to link the invoice issuing with the tax payment (while not complementing the system with an immediate payment for the invoice). Sales would mean the need to immediately reduce liquidity without having yet received funds from the buyer. This could lead to the resignation from the use of trade credit (deferred payments), which would, in fact, increase the liquidity security of entrepreneurs, but might also reduce the volume of trade. Only settlement in near real time does not make this single feature disqualify both the systems.

Improvement of the tax system as regards payment of tax liabilities may bring about real benefits, if it is integrated with the existing payment systems. In that case, payment of taxes (or possibly exchange of tax to tokens) could be handled automatically by settlement centres or banks on the basis of product codes sent to them at the moment of making a transaction. Settlement centres and payment operators would function as tax brokers that would manage additional tax accounts. This would be, in fact, implementation of the split payment mechanism but without the need for direct involvement of taxpayers who could focus on organizing their business activity. In order to ensure product code conformity, the system could also be integrated with a digital invoice system (e.g., DICE).

As far as payment of tax liabilities arising from all transactions made within the economy is concerned, it would be necessary to aggregate them into blocs (that would be approved, e.g., every hour or once in several hours) so that the system would remain scalable. However, development and implementation of such a system concept would absolutely require coordination of the actions taken by both tax administration and institutions responsible for issuance and regulation of money.

## DICE

The DICE system, which in fact is a digital register of invoices of the European Union, seems to be the easiest solution to implement and, at the same time the, one that promises the biggest benefits.

It allows registration of invoice flow at the level of individual documents in the system, which guarantees that the changes that have been introduced cannot be cancelled (and possible adjustments would be carried out just as the case with analogue documents, i.e., by way of issuing corrective invoices). Simultaneously, it makes credible verification of taxes possible on the basis of not only the current status of an identification number (i.e., account in the system) and rating (that could be based on risk assessment) but also on the basis of certification of actions taken (based on invoice history) – without the need to disclose the subject-matter of these documents. Furthermore, it would allow to carry out the first evaluation of transaction risk before the relevant invoice is even issued.

All these features make it hard to organise networks within such a system with an intention to commit tax fraud. Since the solution is concerned with invoicing and not payments, it would still be theoretically possible to have entities in the system accumulating funds from output tax. If the system were complemented with solutions for payments (such as VATCoin but also ones that are not based on blockchain technology, e.g., split payment), VAT fraud could largely be eliminated.

It would also be worth considering complementation of the solution with *ex post* transaction verification mechanisms (such as periodical reports; daily, weekly or monthly ones) in order to allow detection of fraud schemes that only just form (and are very difficult to detect with a system of *ex ante* transaction analysis).

### DPCS

As far as the DPCS solution is concerned, it seems that creation of a centralized dividend database managed by SKAT and to which VP Securities or intermediary institutions would introduce data would be an equally effective and at the same time less costly and simpler solution as regards implementation and operation. When applying for a tax rebate, SKAT (or the bank paying out dividends or handling refunds) would have a similar possibility to verify if a shareholder has claimed reimbursement in connection with the same dividend earlier.

### Compliance in Multinational Corporations

Here a blockchain system works as an integrator of transactional data that originate from various internal systems operating in companies within a multinational group of companies, which is supposed to allow financial and tax compliance (regardless of jurisdiction) mainly for the purpose of audit. Possible benefits for the tax system arise from the potential opportunity for tax administration and node suppliers or possibly suppliers of principles for smart contracts to join the system. An alternative would be to base the multinational corporation's system on a public blockchain and share system specifications with the administration. Another improvement would be a regulation requiring that such corporations develop and implement a blockchain system in accordance with central guidelines and share specific data with tax administration in line with a specified scheme.

### Taxpayer Verification

A taxpayer verification system based on blockchain technology is not flawless either. As soon as the Ministry of Finance introduces a tool that allows to download a digitally signed certificate (with an individual number and date of generation), the service ceases to make sense. What is more, a company must still use third party services – paid or not – and the process itself may partially be handled manually (e.g., introduction of counterparty's data on the Ministry of Finance's website) owing to the lack of an appropriate API (i.e., an interface between the Ministry's database and the lawyer's office application) that could automate this process.

## Conclusion

Implementation of solutions supporting the tax system, which are based on blockchain technology, has advantages as well as disadvantages. Many of their features are enumerated in Deloitte's report [Deloitte, 2017]. Potential advantages include, in particular:

- Reduction of the bureaucratic burden, saving time, and lower cost of accounting services (which is de facto a side effect of each process automation);
- Possibility of fast reaction owing to the fact that tax bodies have access to data in real time;
- Access to undisputed and transparent data;
- Minimization of fraud owing to advanced individual transaction verification and analytics; and in the case of VATCoin, practical elimination of the so called missing trader;
- Quick access to financial data;
- Faster VAT settlements and reduction of the negative influence on financial flows (especially if VATCoin is accepted and daily VAT balance settlement implemented);
- Faster procedure handling, e.g., as regards issuing certificates;
- Facilitated analytics for tax authorities;
- Facilitation of information exchange among various jurisdictions – no exchange of information in the standard sense – but access to data in real time granted to countries of taxpayers' residence;
- Lifting the burden off taxpayers as regards calculation of VAT rates on the level of invoices and output VAT on the level of VAT declarations as well as liabilities arising from income taxes and customs duties;
- Greater trust between the taxpayer and the tax administration;

Implementation of blockchain technology in the tax system brings about disadvantages as well, which have to be taken into consideration when the decision to implement the abovementioned solution or not is being made. The disadvantages include, in particular:

- It is relatively new technology and so there is a relatively small number of IT specialists in this field (i.e., programmers); durability has been verified to a small extent; system scalability; it is hard to develop reaction mechanisms in the case of disadvantageous events and circumstances that influence the systems based on blockchain technology, which have not occurred yet (owing to the immaturity of the technology);
- The necessity to introduce changes in the legal system (first and foremost) at the international level (as regards VAT – at the EU level);
- The costs of implementation, changes to system architecture, and maintenance of a large number of data centres that store complete register copies containing information on all transactions that are made;
- Time-consuming implementation owing to the necessity of taking into account the specificity of regulations applicable in various countries.

In our opinion, blockchain technology has the potential to revolutionize the way tax is settled. However, achievement of desired results will be contingent upon the use of specific mechanisms as well as the manner and area of their implementation.

Blockchain technology has the potential to revolutionize the way tax is settled. However, achievement of desired results will be contingent upon the use of specific mechanisms as well as the manner and area of their implementation.

We believe that among the areas covered, the greatest benefits may come from the implementation of solutions in the VAT system, in particular being the basis of the digital invoice system. This is due to the fact that it is the creation of these documents that is under the full control of companies and can therefore be manipulated. Giving the public administration control rights in the process of invoicing will be a more effective and simpler mechanism eliminating manipulation than interference with payment systems.

Looking at the development of the blockchain technology ecosystem, it is likely that ready solutions will be presented to tax administration by the companies themselves, which will be willing to become providers of applications and programming services (including for blockchain) and service the technical side of the system.

> Implementation of systems based on blockchain technology also requires evaluation whether a technical solution actually requires the use of blockchain technology – or perhaps the same purposes may be obtained with more traditional measures.

Nevertheless, apart from well-developed programmer competency (and there are currently not many programmers experienced in blockchain technology programming on the market), precise development of solution concepts encompassing a much wider scope of solutions than the one discussed in this article, implementation of systems based on blockchain technology also requires evaluation whether a technical solution actually requires the use of blockchain technology – or perhaps the same purposes may be obtained with more traditional measures.

> The concept introducing a digital invoice system (i.e., DICE) based on blockchain technology will offer the biggest advantages while simultaneously posing the least disadvantages.

It is worth noting that a system supporting the tax system, which has been implemented well, may not only seal this system but also serve as an additional verifier of the sources of products and value flows in the economy; speed up documentation flow; and simultaneously serve as a source of micro data for micro and macroeconomic research (as the use of blockchain technology allows the introduction of very specific principles of access to the data while appropriate cryptographic mechanisms[33] make it possible to maintain confidentiality of sensitive data while providing effective evidence of the existence of flows; whereas appropriate consensus mechanisms and blockchain systems[34] offer a possibility to keep certain data within a node private and other publicly available). Introduction of such a system in one country or community of countries (such as a union) may influence the robustness of the tax systems in other countries – through the use of various interfaces to the systems of those countries or appropriate markings (e.g., on invoices or import or export declarations) generated from a community system.

The presented examples of the existing solution concepts that support the tax system confirm that not every solution may bring about equally huge benefits. In our opinion, the concept introducing a digital invoice system (i.e., DICE) based on blockchain technology will offer the biggest advantages while simultaneously posing the least disadvantages. It is proposed to implement it within the area that brings major losses for state Treasuries and offers numerous benefits arising from the application of blockchain technology while simultaneously does not require profound changes in the tax and payment system.

> The solution concepts supporting payments of tax liabilities have serious flaws limiting their effectiveness.

Currently, the solution concepts supporting payments of tax liabilities have serious flaws limiting their effectiveness; although if modified they could complement the invoice system, especially by sealing the tax system effectively – both the national and the European Union systems (as well as those of other countries following appropriate modification).

The solution concept for transfer pricing is currently not developed enough (especially as

[33] For example, zero-knowledge proof allows one party to prove to another that they have a certain piece of information without disclosing it (and if the party does not have it, they cannot cheat the other by claiming that they do). Cf. [Schneier, 2006 pp. 149–161].

[34] E.g., Quorum, cf. [Chris-j-h, 2016/2019].

The solution concept for transfer pricing is currently not developed enough (especially as regards introduction of tax administration into the system) to make its implementation possible

regards introduction of tax administration into the system) to make its implementation possible; however, benefits both for companies and tax authorities may not be excluded, if the concept is developed further.

Other solutions are concerned with selected elements of the tax system and their implementation may bring about incomparably smaller benefits for the state Treasury than the ones mentioned above. Furthermore, it is relatively easy to replace them with systems that are not based on blockchain technology.

As enthusiasts of new technologies, we believe that the benefits from using blockchain technology will outweigh the costs and it will be possible to fulfil this kind of prophecy the experts made in 2016 in Davos when they judged that blockchain technology could be used to collect taxes for the first time already in 2025.

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