The Consequences of Blockchain Architectures for the Role of Public Administrations

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Abstract:
Blockchain technology is an innovative technology that enables the provision of e-government services in a more direct and distributed way, challenging the intermediary role of public administrations. This technology is both an institutional and technological innovation, and the socio-technical consequences of the implementation of blockchain technology in governments are often overlooked when exploring use cases in the public sector. Different blockchain architectures are often overlooked when investigating governmental blockchain implementations, while these architectures impact the socio-technical system of e-governments differently. A comparative exploratory case study on the consequences of using two main blockchain architectures for an EU-wide system that monitors the movement of excise goods under duty suspension is conducted to demonstrate the differences of using a *permissionless* and a *permissioned* blockchain for the role of public administrations. It is found that the role of public administrations can change depending on the blockchain architecture and that blockchain technology alone cannot be an alternative for the current data quality controls provided by public administrations. Future research is suggested to focus on developing blockchain technology towards being able to provide semantic validation by the network and using Value Sensitive Design for the architecture of blockchain technology for e-government.

Keywords: *Blockchain Architecture, Intermediation, E-government, EMCS, Comparative Case Study*

I. Introduction

The development of information technology has enabled governments to deliver services more directly to citizens, in a phenomenon called e-government. E-government is the "the use of information and communication technologies, particularly Internet, as a tool to achieve better government" (Field, 2003, p. 63). The concept of e-government originated from the need of cost-reduction and effectiveness enhancement by governments. Now, a technology has emerged that opens up a world of possibilities in the field of e-government, called *blockchain* (Ølnes, 2015).

Blockchain is a technology that allows two actors in a system (called nodes) to transact digital assets in a peer-to-peer (P2P) network and that stores these transactions in a distributed way across the network (Back et al., 2014). The blockchain registers the owners of the assets that are transacted and the transaction itself (Warburg, 2016). Every transaction is validated by the network by a 'consensus mechanism', which is a mechanism that allows users in the P2P network to validate the transactions and update the registry in the entire network (Warburg, 2016). The definition of blockchain technology that is used in this paper is the following, provided by Meijer (2017):

> *"A blockchain is a distributed, shared, encrypted, chronological, irreversible and incorruptible database and computing system (public/private) with a consensus mechanism (permissioned/permissionless), that adds value by enabling direct interactions between users."*
> (Meijer, 2017, pp. 6-7)

The distributed nature of this information infrastructure emerges in three ways. First, the transactions in the system occur directly peer-to-peer instead of via one central actor often referred to as the 'intermediary' or 'trusted third party'. Second, the validation of the transactions in the system is performed by the network instead of by this intermediary. Lastly, the transaction log is distributed as it is stored at every node in the system instead of in one central database. This distributed nature is fundamentally different from traditional information infrastructures, causing the blockchain to be seen as a General Purpose Technology (GPT) that is highly disruptive, as it affects how value is exchanged and how transactions can be executed.

This disruption can be seen in the first and most famous application of blockchain: Bitcoin (Antonopoulos, 2014). Bitcoin was introduced in a paper published by an anonymous (group of) author(s) called Satoshi Nakamoto. In this paper, the idea of the Bitcoin blockchain was introduced as a purely peer-to-peer (P2P) electronic transaction network that allows for direct financial transactions instead of via a financial institution (Nakamoto, 2008). The Bitcoin system initially lead to resistance of regulators, legislators and the media, as it became clear that the cryptocurrency was often used for criminal activity given its mathematical guarantee for anonymity. Nowadays, more and more countries are legalizing the use of the currency, as for example Japan. Japan now officially accepts Bitcoin as a payment method (Garber, 2017), displaying the increasingly positive sentiment regarding this cryptocurrency.

Blockchain is not only a disruptive technology in the financial sector, but it is also argued to enable the provision of e-government services in a more direct and distributed way. Public administrations can use this technology for the distributed registration of documents and assets instead of solely registering in a centralized way. In addition, blockchain technology can be used as an information infrastructure to provide the exchange of information by public administrations, for example the exchange of criminality information, the distribution of grants and the exchange of information regarding academic degrees (Davidson, De Filippi, & Potts, 2016b).

The benefits of blockchain technology for e-government services are argued to be the ability to provide tailored services for specific citizens, increased trust in governments and improved automation, transparency and auditability (Atzori, 2015; Norta, 2015; Swan, 2015; Van Zuidam, 2016). While an increase in scientific research into this technology can be seen, research on blockchain in e-government literature is scarce. In a literature review of public sector related blockchain papers, Ølnes (2015) concludes that still very little research is dedicated towards the potential of this major technological breakthrough in the public sector and what it can do for future development in e-government. He calls for e-government researchers to *"start researching ways this technology can be utilized by [the] public sector"* (Ølnes, 2015, p. 9).

The distributed nature of blockchain systems can create uncertainties regarding the control in the network and the alter governance structures and institutions as we know them. Therefore, blockchain is not only a technological innovation but an institutional innovation as well. With blockchain, systems are able to function without intermediaries like banks, notaries and governments, challenging the role of public administrations in the area of e-government.

E-government initiatives have traditionally focused on providing services more directly, decentralized and tailored to the needs of the citizens (Molnar, Janssen, & Weerakkody, 2015). Yet traditional e-government initiatives never truly changed the intermediary role that public administrations have in recordkeeping and administration. There are several definitions for 'intermediation', but in general intermediation refers to the brokerage function of an actor or firm that brings together providers and seekers of any goods (Ávila, Putnik, & Cunha, 2002). Intermediation in governments occurs when certain governmental agencies position themselves as the channel to provide governmental services like facilitating *information exchange* and *registration* (Klievink & Janssen, 2008). *Figure 1* outlines the intermediary role of public administrations in information exchange and registration processes.

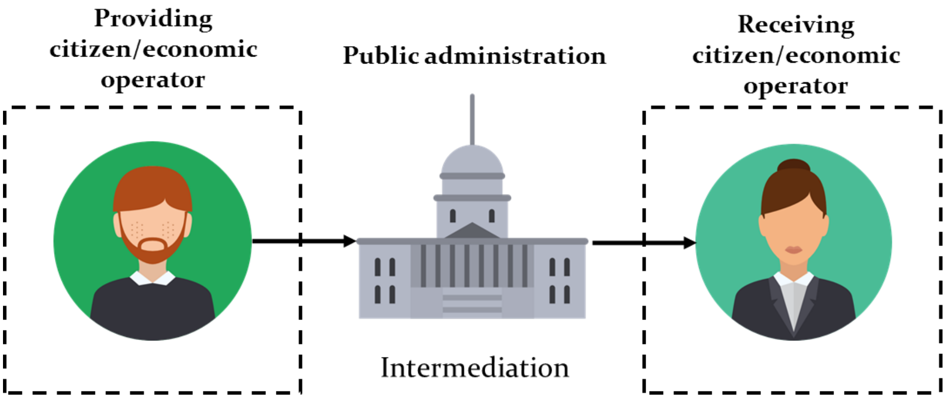

Figure 1. The intermediary role of public administrations

An increase in governments exploring use cases for blockchain can be seen, but much attention is focused on displaying the technical and short-term benefits. In literature, there is only limited attention given to the impact of blockchain architectures within the socio-technical system of e-governments. Governments should consider the socio-technical impact of blockchain implementations given their fundamental differences with traditional information infrastructures. In addition, blockchain technology is currently often viewed as a one-size-fits-all solution, as the different blockchain architectures are ignored or overlooked. Governments should look beyond the advantages of the technology alone and deepen the discussion towards the architecture of blockchain technology as well.

This paper explores the socio-technical impact of two different blockchain architectures for the role of public administrations, to deepen the discussion on the impact of blockchain in governments and add the analyses of different blockchain architectures to this discussion. The research question that this paper answers is:

What are the consequences of the implementation of different blockchain architectures for e-government services for the role of public administrations?

We investigate the consequences of the implementation of different blockchain architectures for e-government services for the role of public administration for two main blockchain architectures: *permissionless* and *permissioned* blockchain systems. We use the Public Choice and New Institutional Economics (NIE) perspectives and a comparative exploratory case study of an EU-wide system that monitors the movement of excise goods under duty suspension to demonstrate the different consequences of using the two blockchain architectures for this system for the role of public administrations.

We structure this paper as follows: Section II introduces the research approach. Section III outlines the theoretical background, using a Public Choice perspective to reflect on why we have governments and a NIE lens to explore the consequences of blockchain technology implementation in public administrations. Section IV presents the comparative exploratory case study where the different consequences of using the two blockchain architectures are demonstrated. Section V provides a conclusion, a reflection on the findings and recommendations for future research.

II. RESEARCH APPROACH

In this paper, we use a literature review to analyze the potential of blockchain technology in governments and investigate the consequences of the implementation of different blockchain architectures for the role of public administrations using Public Choice and NIE perspectives. A comparative case study approach is used to explore the consequences of the implementation of two blockchain architectures for the role of public administrations for two blockchain architectures in an information exchange process (Yin, 1989). This case study approach is used because it allows for the analysis of the differences between two cases, as two different blockchain architectures are explored for the same system. The comparative case study first outlines the current process, after which each blockchain architecture is explored for this process. It is investigated what the impact is the blockchain system has on the validation, data quality and control in the network. The comparative case study is performed using a combination of desk research and an expert interview with an employee of the organization involved. The comparative case study demonstrates the socio-technical impact of the implementation of the two mayor blockchain architectures for the role of public administrations.

III. THEORETICAL BACKGROUND

In this section, literature on the implementation of blockchain technology in governments is introduced. First, a Public Choice perspective is used to reflect on why governments are created. Second, a NIE perspective is used to explain why public administrations function as intermediaries. Third, literature on the consequences of blockchain technology implementation in governments is presented. Last, the two main blockchain architectures are presented: *permissionless* and *permissioned* blockchains.

III.I PUBLIC CHOICE THEORIES

Public Choice theory refers to the perspective of using "economic tools to deal with traditional problems of political science" (Tullock, 1987, p. 10). From this perspective, the main reason why public administrations are originally created is to maximize some sort of welfare function for society (Tullock, 1987). Also, public administrations are created to protect social values, promote the common good and protect collective right (Atzori, 2015; Green, 1991; Scammell, 2000). Governments facilitate coordination in society to smoothen the tensions between the short term individual interest and the collective good, with the goal of finding compromises between the two (Atzori, 2015; Dahl, 1989). To provide coordination in the most efficient way, public administrations have developed towards bureaucracies.

Bureaucracies, as introduced by Weber (1992), are administrative systems governing any large institution and are characterized by predefined processes and organized hierarchies to provide governmental services for citizens (Weber, 1992). Opponents of bureaucracies highlight the inefficiencies and limited flexibilities of these bureaucracies to provide services that are requested by civilians, leading to a gap between the governmental services that citizens desire and the governmental services that are provided (Atzori, 2015; Johnson & Libecap, 1994). The hierarchical structures of these bureaucracies are also argued to facilitate the centralization of power towards a few top civil servants, bringing about a lack of transparency, the possibility of corruption and the potential misuse of power (Antonopoulos, 2016). On the contrary, proponents argue that rational and systematic control is needed to facilitate coordination between humans (Weber, 1992). Weber (1992) argued that this is essential in order to avoid chaos in society and that using bureaucracies can avoid favoritism and enhance the efficiency of interactions in society. Various trends towards the decentralization of governments can be distinguished from this perspective, including *Proudhon's social contract, Marxism, Decentralization* *of the State* and *IT as source of governance decentralization.* Blockchain builds upon these trends as this technology can lead to the disintermediation in public administrations institutions and decentralize e-government services.

III.II New Institutional Economics

Another theory that can be used to explain why public administrations function as intermediaries in registration and information exchange processes is the Transaction Cost Theory that is part of the NIE perspective (Malone, Yates, & Benjamin, 1987; Sarkar, Butler, & Steinfield, 1995). This perspective analyses the costs of transacting between two parties. If these transaction costs are too high for a transaction to occur, then intermediaries can emerge to bring these parties together and lower the transactions costs. In this network setting, three actor types can be distinguished. These three actor types are defined by Janssen (2009) as the *intermediary,* the *service provider* and the *service requester* (Janssen, 2009). Service providers in this research are citizens or economic operators providing a service that requires compliance with the authorities, like sending a package across borders, building a house or selling land or property. Service requesters are citizens or economic operators on the receiving end of this service. Janssen (2009) defines an intermediary as "an organization aimed at bringing together demand and supply" (Janssen, 2009, p. 1320). Public administrators traditionally take on the role of intermediaries in a network to facilitate coordination between citizens/economic operators, in order to protect the common good, reduce opportunism and avoid the abuse of the network (Atzori, 2015; Klievink & Janssen, 2008).

There are generally three roles of public administrations in the coordination between the providing citizen/economic operator and the receiving citizen/economic operator: as a complete intermediator, as a supervisor or no role in the coordination at all (Janssen & Sol, 2000). This is presented in *Figure 2*. The public administration is often not involved in the actual transaction of a real-life product, but can also just facilitate the market transaction by providing the registration or by assisting in the progress of information exchange (Garbade, 1982).

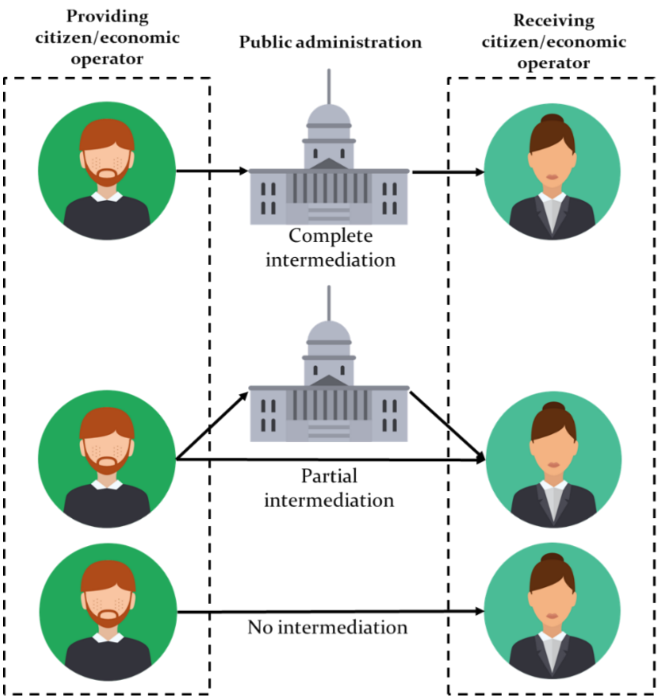

Figure 2. Levels of intermediation by public administrations [based on Janssen & Sol (2000)]

From a NIE perspective, blockchain technology can present the next step in the discussion of the re- and disintermediation of electronic intermediaries, as the role of public administrators in the field of registration and data exchange will change through this technology. Based on the Public Choice and NIE perspectives, it is presented that governments are created to protect the common good and facilitate interaction between citizens/economic operators and to enable consensus and coordination between heterogeneous or distant citizens/economic operators. Public administrations function as intermediaries to (1) provide this coordination as the transaction costs are too high to have direct transactions, and (2) to regulate networks in order to provide continuity of governmental services as they are critical to citizens' rights, welfare and the common good.

III.III Consequences of blockchain technology in governments

A number of researchers investigating the potential of blockchain in governments expect blockchain technology to lead to a changing role of public administrations in society. Davidson, De Filippi, and Potts (2016a) argue that this technology can reshape the way governments are able to interact with citizens, economic operators, and each other. This technology is considered to hold the fundamental promise of facilitating direct interaction between citizens, providing administration without a governmental administrator and tailoring services provided by governments (Keyser, 2017). Shrier, Larossi, Sharma, and Pentland (2016) state that blockchain technology enables us to rethink the current institutions in society, especially as this technology has the ability to redefine the relationship between government and the citizen in terms of data sharing. They argue that the distributed nature of this technology can ensure the integrity of government records and services, without the need of a central administration (Shrier et al., 2016). Atzori (2015) concludes that blockchain can provide governmental services in a more efficient and decentralized way, allowing for a less hierarchical and more horizontal and distributed diffusion of authority.

Current blockchain systems that are successful, like Bitcoin, do not require semantic data validation on top of the consensus mechanism. Given the relative simplicity of a payment system that includes one currency like Bitcoin, these systems are able to provide full data quality validation disintermediation. In these systems, the blockchain system is able to provide the data quality validation in a network setting. The way this works is, very simply put, that each transaction is validated if the following two conditions are met:

I. The sender has sufficient amount of funds to send the amount of Bitcoin
II. The sender knows the address of the receiver

Looking at a more complex data or asset exchange system, where also the semantics of the data is of value, there is still a need for an intermediary to provide this data quality check (Boucher, Nascimento, & Kritikos, 2017). The verification on the blockchain is only done on the technical requirements of the protocol, so it records the time and details of the transaction. In current blockchain systems, if the transaction ticks all the technical requirement boxes, then the transaction will become part of the transaction history that is immutable. The semantics of the content of the transaction are not checked in this process (Boucher et al., 2017). Therefore, the quality of the data in the system cannot be verified with a blockchain system alone in more complex information exchange processes.

III.IV Blockchain architectures

Blockchain technology can be divided in two main blockchain architectures: *permissionless* blockchains and *permissioned* blockchains. The difference lies in the openness of participation in the consensus mechanism of the blockchain system. The blockchain types differ in who can participate in validating the transactions, resulting in two main blockchain architectures:

I. *Permissionless blockchains* allow all nodes to participate in the consensus mechanism.
II. *Permissioned blockchains* have the transaction consensus mechanism performed by a given set of participating nodes, based on criteria determined by the architect of the *permissioned* blockchain.

To demonstrate the consequences of the implementation of these two blockchain architectures for public administrations, a real-life governmental information exchange process on both a *permissionless* and a *permissioned* blockchain is explored in the next section.

IV. CASE STUDY

This comparative case study investigates the consequences of the implementation of the two blockchain architectures for the role of national authorities in the monitoring of excise goods under duty suspension within the territory of the EU. It is investigated what the impact is of the different blockchain architectures on the validation, data quality and control in the network. First, the current EMCS is explained. Then, both the *permissionless* and the *permissioned* blockchain architecture are explored for this process. Last, an overview of the consequences of an EMCS using the two blockchain architectures is presented.

Currently, to facilitate the information exchange between traders and national authorities in both countries of the trade, the Excise Movement and Control System (EMCS) workflow management system is used. It is used to complete a digital declaration form that moves from the trader in the country of dispatch, to a receiver in the country of destination. Each country currently has their own National Excise Application (NEA), in which the sender and receiver complete the dispatch data. The national authority of each country has to validate the data input in the transaction, after which the digital document is send to the other national authority. *Figure 3* presents a simplified visualization of the EMCS that is used for cross-border trading of excise goods in the EU.

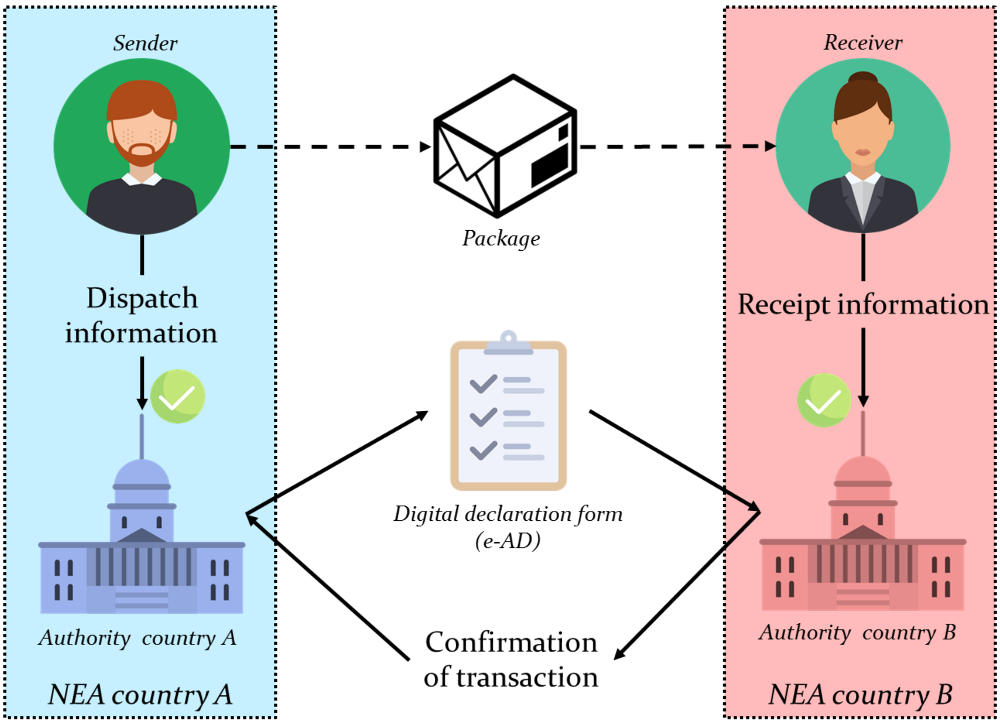

Figure 3. The current situation of the EMCS

IV.I Permissionless blockchain

Looking at the consequences of a *permissionless* blockchain architecture for the EMCS system, the peer-to-peer transactions would reduce the effort for both the traders and the national authorities as data only has to be entered once instead of multiple times. In addition, it will also cause the system to be less human-error prone. However, *permissionless* blockchains would enable transactions to be validated without complying with regulations, as anyone can participate in the consensus mechanism. Traders can for example pool together and combine for more than 50% of the verification power in the network, shifting the control to this group that might have malicious intentions. In addition, the reason why national authorities are validating the data input in every transaction, is to make sure all taxes are paid and thereby promoting the common good. Shifting the validation control to the network, the majority of the traders are responsible for the correctness of the data input and thereby the fact that all taxes are paid. Traders are argued to be primarily economically driven, so it can hardly be expected that the whole network will feel responsible for making sure all taxes are collected and the common good is protected. This *permissionless* blockchain system leads to the disintermediation of the public administrations, which could increase the potential of fraud and present a threat to the common good. The national authorities involved would be completely sidelined, as they will only be able to see the transaction log but not be able to provide any supervisory or facilitating role. *Figure 4* presents a visualization of the EMCS system using a *permissionless* blockchain.

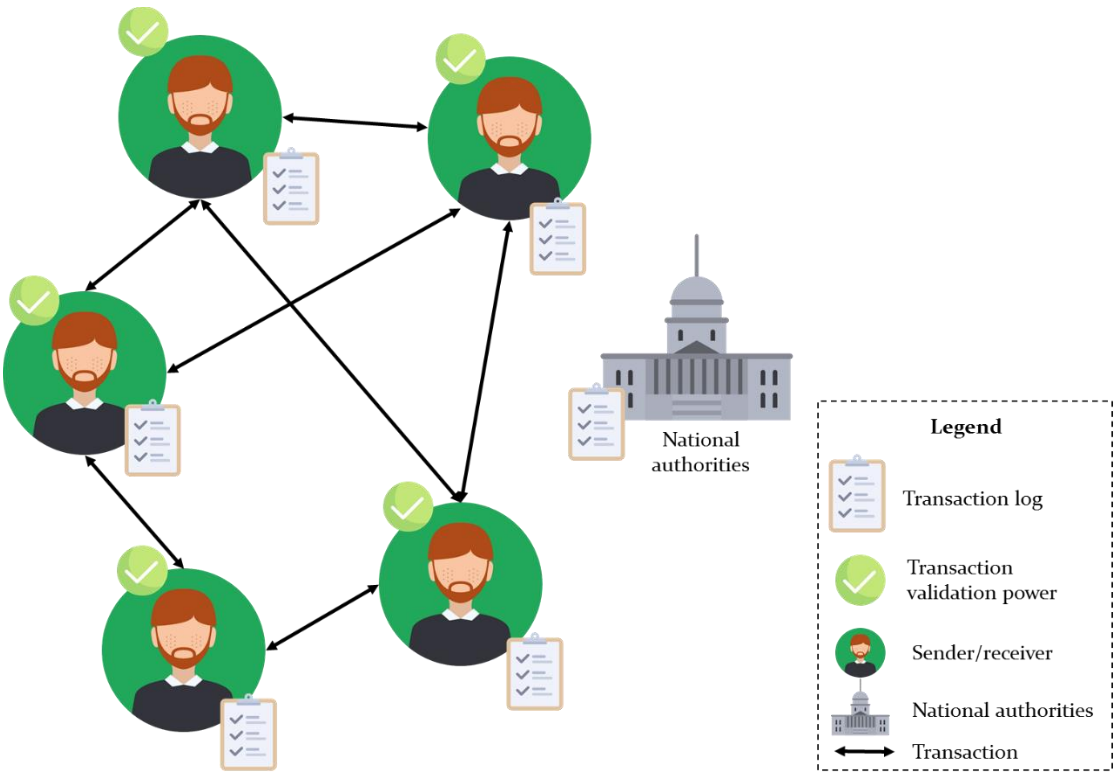

Figure 4. The EMCS using a permissionless blockchain

IV.II Permissioned blockchain

If the EMCS system would use a *permissioned* blockchain, the system could also benefit from the enhanced data integrity as is the case in the *permissionless* blockchain system. A *permissioned* blockchain system can however also regulate who can participate in the system and who can participate in the consensus mechanism. To ensure the right amount of tax collection and to reduce fraud, the system should ensure that traders provide the right data in the monitoring system. A *permissioned* blockchain system for this process would not completely remove the need for semantic validation by the authorities in the process, which can be provided if the validating nodes (the actors performing the consensus mechanism) are the national authorities. This would change the role of the national authorities involved. They would move from being the facilitator of the data exchange process in every transaction (as is currently the case in the National Excise Applications), towards a role where they have the ability to check and control when necessary. This enables the regulation of the data input in the system, which leads to the appropriate amount of tax collection and thereby the promotion of the common good. This *permissioned* blockchain system leads to a changed role of the national authorities from a facilitator to a supervisor, as it would facilitate peer-to-peer transactions between the traders, while regulating the critical input in the system. *Figure 5* presents a visualization EMCS using a *permissioned* blockchain system.

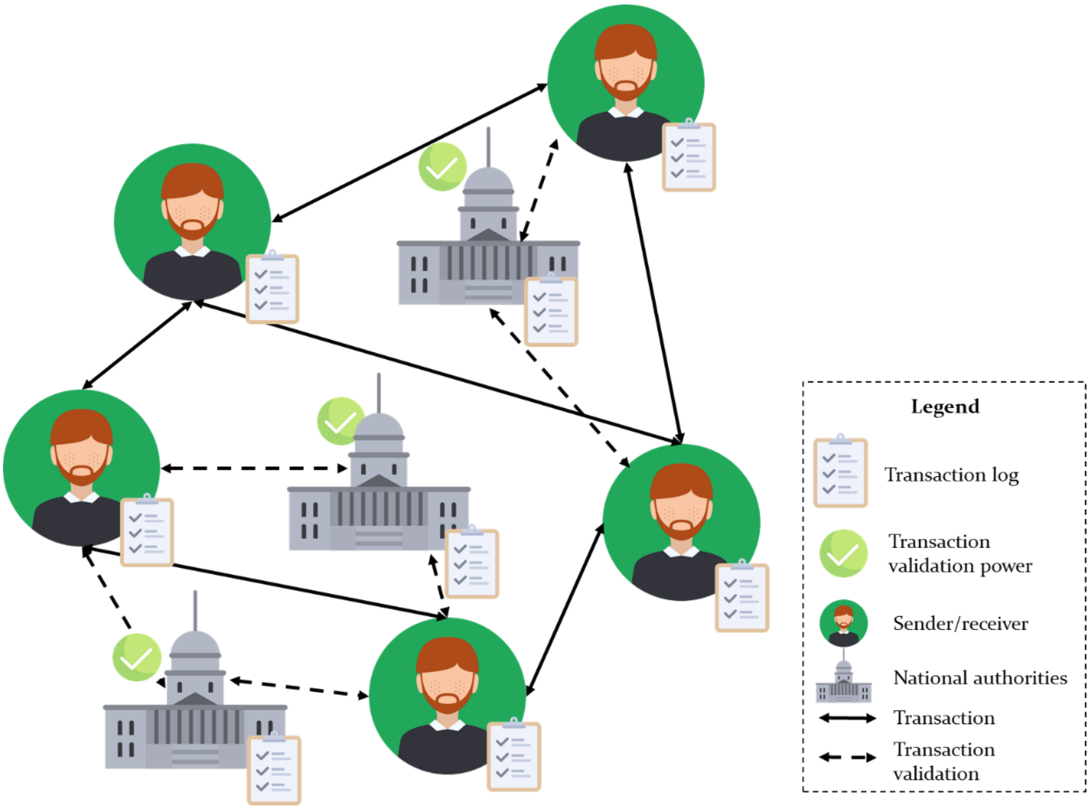

Figure 5. The EMCS using a permissioned blockchain

IV.III Consequences of an EMCS on blockchain

In the case of a system that monitors the trading of excise goods under duty suspension within the territory of the EU, it can be seen that there are consequences for the role of the public administration based on the blockchain architecture that is used for the blockchain implementation. In the case of a *permissionless* excise duty system, this could lead to completely side-lined national authorities, increasing the potential of fraud and presenting a threat to the common good. In the case of a *permissioned* excise duty system, the role of public administrations could shift to a more supervisory role. The *permissioned* blockchain system would enable peer-to-peer transactions and enhance data integrity, while the national authorities would still be able to provide semantic validation and thereby regulating the infrastructure.

V. Conclusions

The comparative case study that explores the two blockchain architectures for the information exchange process facilitated by public administrations displayed that *the consequences of the implementation of* *blockchain technology for e-government services for the role of public administrations are dependent on the architecture of the blockchain system*. Blockchain therefore requires a completely different perspective to assess at the way governmental services can be provided. The focus of public administrations can move to providing the right data quality checks in the process instead of processing every individual transaction, presenting a new role for public administrations enabled by blockchain technology.

Permissionless blockchains present a complete disintermediation of public administrations in information exchange or registration processes, with limited ways of interfering in the process as a government. The control of the governance in the network will be completely distributed and in the hands of the validating nodes in the network, giving them significant power over the governmental service. In many governmental services, continuity is required to protect the common good and facilitate interaction in society, which cannot be automatically guaranteed in *permissionless* blockchains.

Permissioned blockchains enable a changing role of public administrations: from a facilitator towards a supervisor, presenting re-intermediation in public administrations. These blockchains are still somewhat centralized in terms of control, as they are closed systems and the architect of the system can impose participation rules, which is necessary to ensure the protection of the common good and facilitate interaction in society. The implementation of *permissioned* blockchains can allow public administrators to provide this level of trust and protect the common good while *largely distributing the control* to the network. *Permissioned* blockchains allow for the necessary semantic data quality checks to ensure the appropriate data quality in the system, which is not provided by the blockchain technology itself. Therefore, *permissioned* blockchains present the next step in e-government as they provide benefits to governments that were not feasible with traditional information technologies while ensuring continuity of governmental services.

V.I LIMITATIONS

This research has focused on the consequences of the implementation of different blockchain architectures for e-government services for the role of public administrations. The two most important limitations are presented below, after which future research directions are suggested.

First, this research has investigated two major blockchain architectures: *permissionless* and *permissioned* blockchains. The difference between the two types originates from the openness of the consensus mechanism. However, many other categorizations of blockchain architectures exist. The way the validating nodes are rewarded for example or the openness to external actors to see the transaction log. The results of this study can therefore not be directly generalized to all blockchain architectures, as they only apply to *permissionless* and *permissioned* blockchains.

Also, this research assumes the fact that blockchain systems cannot provide semantic checks for data input. This highlights one shortcoming of blockchain technology: the inability of fully distributing the control to the network in *permissioned* blockchain systems. As this technology is still evolving, it might be possible that this shortcoming might not be applicable anymore in the near future.

VI.II FUTURE RESEARCH

Because blockchain technology on its own does not provide semantic data validation, further research is suggested exploring the possibility of adding semantic validation by the network in these systems, moving away from technical validation alone. This would pave the way for *permissionless* blockchains to provide governmental services as well. In addition, we suggest to incorporate Value Sensitive Design in the design of blockchain systems in governments. Value Sensitive Design is a design approach that can account for the human values that governments want to protect and it could potentially be used to design a *permissionless* blockchain system that is still able to protect public values.

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