

Blockchain technology: Challenges and opportunities in public finance



Tecnologia blockchain: Desafios e oportunidades em finanças públicas

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Abstract

Purpose: This article aims to analyze pioneering public finance initiatives based on blockchain technology, identifying the Brazilian context amid the international. Additionally, this study seeks to present opportunities for blockchain technology applications and the challenges encountered for their expansion.

Originality/value: Few studies have covered the public sector, especially public finance, despite using and testing this technology in different areas. The development of these innovative applications is limited, particularly in Brazil.

Design/methodology/approach: Public documents, such as reports and official websites of public agencies, associations, and institutions, were identified and selected from the unit of analysis “pioneering public finance initiatives based on blockchain technology.”

Findings: Blockchain technology has been used in government projects related to research, identity, economic development, and financial services, among others. Blockchain initiatives have been led by Brazil’s financial, technology, and education/media sectors. Finding technology applications in public finance was one of the difficulties in the research. The number of projects in this category involving blockchain and the public sector is scarce in Brazil and internationally. However, this scenario has shown signs of change. Although reduced, public sector participation has increased in recent years. Blockchain has much to offer the public finance sector, but governments have been cautious and insecure about introducing the technology. It happens because of uncertainty about whether the technology is developed enough to withstand critical problems in the public system or what unique issues could arise from that technology.

Keywords: blockchain technology, public finances, public administration, government, Brazil

Resumo

Objetivo: Este artigo tem como objetivo analisar as iniciativas pioneiras de finanças públicas baseadas na tecnologia blockchain, identificando o contexto brasileiro em meio ao internacional. Além disso, o estudo busca apresentar oportunidades de aplicações da tecnologia blockchain, bem como os desafios encontrados para a sua expansão.

Originalidade/valor: Apesar de a tecnologia ser empregada e testada em diferentes áreas, ainda são poucos os estudos que abrangem o setor público, em especial as finanças públicas. No Brasil, em particular, o desenvolvimento dessas aplicações inovadoras é limitado.

Design/metodologia/abordagem: A partir da unidade de análise: “iniciativas pioneiras de finanças públicas baseadas na tecnologia blockchain”, foram identificados e selecionados documentos públicos, como relatórios e sites oficiais de órgãos públicos, associações e instituições.

Resultados: O emprego da tecnologia blockchain foi identificado em projetos governamentais relacionados a pesquisa, identidade, desenvolvimento econômico, serviços financeiros, entre outros. No Brasil, as iniciativas de blockchain têm sido lideradas pelos setores financeiros, tecnológicos e de educação/mídia. Uma das dificuldades na pesquisa foi encontrar aplicações da tecnologia nas finanças públicas. O número de projetos dessa categoria, envolvendo a blockchain e o setor público, é escasso, no Brasil e internacionalmente. No entanto, esse cenário tem dado indícios de mudanças. Apesar de reduzida, a participação do setor público tem aumentado nos últimos anos. Observa-se que a blockchain tem muito a oferecer ao setor de finanças públicas, mas há cautela e insegurança dos governos na introdução da tecnologia. Isso porque não há como saber se a tecnologia está desenvolvida o suficiente para suportar problemas críticos no sistema público ou quais problemas singulares poderiam originar-se dessa tecnologia.

Palavras-chave: tecnologia blockchain, finanças públicas, administração pública, governo, Brasil

INTRODUCTION

Blockchain technology has received significant attention as the object of a series of tests and applications in several countries and companies (Tan et al., 2022; Government Office for Science, 2016; WU GTPC, 2017). Considered innovative, it has enormous potential to transform the business world and governments (Kassen, 2022; Iansiti & Lakhani, 2017). Bitcoin is the most well-known application of blockchain technology, but cryptocurrencies represent just one of many possible applications.

Both blockchain technology and Bitcoin were developed by Satoshi Nakamoto (a pseudonym). This character is shrouded in mystery and speculation because its identity is still unknown, even if it concerns a group of people. Bitcoin is a decentralized digital currency, that is, implemented without a central administrative authority. Transactions are based on cryptography, with network information sent back and forth without third-party intervention. Therefore, transparency is guaranteed through blockchain technology, which creates a reliable system (Boucher et al., 2017).

Despite the recent success of Bitcoin, studies have indicated that blockchain will have an important impact on the economy in a few years (Abadi & Brunnermeier, 2018; Ahluwalia et al., 2020; Zhang et al., 2020), as it is a transformative technology, which guarantees the integrity of information, authentication of data origin, confidentiality, and availability of information. Thus, it enables security and transparency in data storage. Blockchain will impact contracts, audits, and product validations in the short term, leading to structural changes (Fanning & Centers, 2016; Martinovic et al., 2017).

Blockchain is a distributed and shared database on a peer-to-peer network with a growing list of data records protected from tampering. This list grows as complete blocks are added to existing blocks. Each block is encrypted to protect its information. Blockchain is often described as a public ledger that contains all executed transactions (Fanning & Centers, 2016).

Therefore, its application covers the most diverse areas. Considering public administration in particular, applications include automating the management and sharing of any type of government record, such as identification, tax collection, property registration, and control over the distribution of social benefits (WU GTPC, 2017). In general, this technology will allow for better control of public accounts and greater integration of government data.

In this context, blockchain technology's even greater impact is expected in developing countries. The applications of this technology can contribute

to strengthening institutions, allowing the monitoring of the public budget, higher transparency, and better governance (Schmidt & Sandner, 2017). Despite the growing interest in technology worldwide, few studies have addressed the potential of technology in the public sector, especially for public finance.

This research aimed to analyze the pioneering public finance initiatives based on blockchain technology, identifying the Brazilian context amid the international. In addition, the study seeks to present opportunities for blockchain technology applications and the challenges encountered for their expansion.

This article is divided into five sections. The first section consists of this “Introduction” and presents the context and objective of the study. The second one, called the “Theoretical framework”, addresses the rise of blockchain technology and its relationship with public finance. The third section, “Methodology and action strategy”, describes this study’s methodological approach. The “Data analysis” is found in the fourth section, in which national and international initiatives for using this technology are presented. Finally, the fifth and last section presents the “Conclusions”.

THEORETICAL FRAMEWORK

Historical factors for the rise and characteristics of blockchain

Bitcoin was created in 2008, after the global financial crisis, and is considered a significant contribution to the world and pointed out by some experts as an alternative to the centralized monetary system (Chuen, 2015).

According to Cechin and Montoya (2017), the financial crisis of 2008, also known as the subprime crisis, was originated mainly due to the deregulation of the financial system and the low-interest monetary policy practiced for an extended period by the Federal Reserve Bank (FED), which caused an increase in the supply of credit.

Beginning in 2003, the US housing market stepped up high-risk lending, while banks increased subprime lending to customers who mortgaged their homes without the buyers being risk-assessed. As a result, after the increase in interest rates by the FED in the following years, there was a significant increase in defaults on subprime mortgages, which went into foreclosure. Thus, real estate prices fell, and bank investments became unprofitable (Cechin & Montoya, 2017).

The decline in real estate prices produced a severe weakening of the real estate market, which spread to various parts of the financial market in the United States and the world. The series of bankruptcies, interventions, and sales under pressure spread distrust in the financial market and society in general, which began to fear for its savings. Emerging countries gradually felt the impact of the 2008 crisis basically on two fronts. First, credit has become more difficult in the interbank market and the flow from banks to businesses. Second, there was a reduction in the prices of exported basic products, such as raw materials and food (Dulci, 2009; Cechin & Montoya, 2017).

Nakamoto's article "Bitcoin: A peer-to-peer electronic cash system" (2008) was first published during this period on the cryptography mailing forum and released as a solution for people to no longer depend on banks and have control over money. There are no fractional reserves in Bitcoin; therefore, there would be no loans that exceed the amount that institutions have, unlike what happens in banks. This promise of a unique service raised the curiosity of many about Bitcoin's operation and possibilities for success, which partially explains its rapid growth.

Satoshi Nakamoto thought about and elaborated on Bitcoin and blockchain in 2007 and 2008 (Aquino, 2019), which were applied in 2009 (CPQD, 2017). The aim was to eliminate third-party elements necessary for conducting financial transactions and reduce intermediation costs, the time to complete transfers, and the risks of reversibility of transactions and fraud (Nakamoto, 2008). Nakamoto developed the blockchain system described in his article despite not mentioning this term for the functioning of the Bitcoin cryptocurrency.

Nakamoto (2008) described the various features of blockchain aimed at giving maximum reliability to virtual transactions. First, the transactions had to be public to prevent owners from spending the money more than once. It allows observing the history of transactions and the timestamp of the record. However, the parties involved in Bitcoin transactions remain anonymous, as the exchange of information is encrypted with an asymmetric key. Thus, only the holder of the private key, the owner of the "wallet," can access information about the act, business, amounts, and people involved (Follador, 2017).

The term "proof of work" was also introduced, referring to the analysis of computers to discover a unique code to open the file, called "nonce" in cryptography (Nakamoto, 2008). The Central Process Unit (CPU) that manages to decipher the mathematical calculation validates the process and

passes the information to the other computers. This process became known as “mining” (CPQD, 2017). Each computer has a vote to determine which transaction is valid, and the purpose of this mechanism is to prevent fraud through the multiplication of internet protocols (IPs) (Nakamoto, 2008). Each file is introduced to a block of data called a ledger and is linked to the others through a hash value. After this “chaining” process, the information can no longer be changed (Treleaven et al., 2017). Finally, the longest chain wins, as chains with fake transactions would have to rework to change processes, while honest chains would continue to grow. Thus, it is almost impossible for fraudulent transactions to reach honest ones (Nakamoto, 2008; Morgayar, 2017).

The technology had such growth that it is considered a distributed ledger technology (DLT) (Burgos et al., 2017). DLT is a category that includes different technologies. In addition to blockchain, one can mention Dag, Hashgraph, Holochain, and Tempo. It is characterized by distributing databases in a decentralized way, and each node maintains a copy of the records independently and with updates made after approval by most nodes (Panwar & Bhatnagar, 2020).

Public and private institutions worldwide recognize the potential of blockchain and consider it a revolutionary technology. Several changes have occurred, and other versions have emerged or have been developing since the technology came into operation to meet needs other than those involving cryptocurrency (Burgos et al., 2017). Many of these platforms can be used to improve the functionality of public institutions.

Public finance and blockchain

Public finance is not only related to the financial activities of the State but is also seen as a subject that addresses revenues, expenditures, budgets, and public debts. The execution of financial activities, such as public health, education, security, and housing, must benefit society. Thus, public finance is related to social well-being, as it tries to correct market failures and expands tangible and intangible public goods to provide for collective needs (Nesi, 2010).

The government acquires revenue through taxes and fees required from the taxpayer to meet the expenses arising from conducting these activities. However, public sector spending must be monitored and controlled in a democratic society considering the principles of legality, legitimacy, and economy. This process begins with the approval of the budget presented by

the executive, while the inspection occurs later, with the budget execution (Nesi, 2010).

This responsibility is “also [of] society in general in the exercise of its rights. The objective of this inspection is related to the government’s activity and the confidence that society gives to the so-called welfare state” (Nesi, 2010, p. 34). To this end, public spending cannot suffer from opacity. In this context, public spending management tools, such as the Fiscal Responsibility Law (2001) and the Fiscal Transparency Law (2009), have been developed to support broader social control. However, the availability and structure of fiscal information are still not satisfactory. In this scenario, blockchain technology can help in the control, transparency, and information speed of public accounts, for instance, by tracking the origin of taxes and their destination and distribution of information responsibility.

METHODOLOGY AND ACTION STRATEGY

The documentary research method was used in this study. This method consists of analyzing documents containing information about the phenomenon to be studied (Bailey, 1994; Guba & Lincoln, 1982), possibly resorting to different sources (Godoy, 1995). The documents include institutional reports and government publications (Denscombe, 2017; Bailey, 1994).

The terms “government blockchain projects” and “blockchain in public policy” were searched in Portuguese and English in search engines from the unit of analysis “pioneering public finance initiatives based on blockchain technology.” More consistent information was found only from 2018 despite some previous discussions about the use of technology in the public sector. This study identified and selected public documents, such as reports and official websites of public agencies, associations, and institutions. Initially, two groups of documents were used as a basis for the identification of cases:

1. *International initiatives*: the guide *Blockchains unchained: Blockchain technology and its use in the public sector* by the Organization for Economic Cooperation and Development (OECD), published in 2018, presented discussions and global initiatives on the technology. This work systematizes the database of “The Illinois Blockchain Initiative,” a project by the Department of Innovation and Technology of the State of Illinois in the United States (Illinois, 2018). Survey at OECD iLibrary cites blockchain technology in initiatives from May 2018 in specific applications for transport.

2. *Brazilian initiatives*: “BlockchainGov Forum – Blockchain contributions to the digital transformation of governments”, particularly the study presented by Maranhão (2018) entitled “Blockchain initiatives map” conducted by the Brazilian Development Bank (BNDES) – Blockchain Team. This document identifies initiatives utilizing blockchain technology in Brazil. The first mentions of the technology on the official BNDES website are from 2018. The survey carried out by the Central Bank of Brazil (BCB), entitled “Distributed ledger technical research in BCB: Positioning report,” published in 2017, was also analyzed. A survey conducted on the official website of the BCB allowed identifying the very brief first mention of technology in the “Financial stability report” of September 2016, with the title “Financial innovations.”

The choice of these two groups of documents is justified as relevant to the research. The OECD has supported research and implementation of innovations in public management and public policy since its inception. For this reason, the report coordinated by this institution was considered representative of international initiatives. Regarding Brazilian initiatives, the public agencies BCB and BNDES pioneered the discussion on blockchain in Brazil.

Then, after analyzing the documents mentioned above, new searches were carried out for cases not yet contemplated. Other documents were analyzed at this stage, such as reports from digital security companies, government agencies, and public projects in progress in Brazil, such as the Blockchain Network Brasil, CPF, and metered parking (TCU, 2022; Dataprev, 2018; Belo Horizonte, 2018), and abroad, such as Real Economy Currency (REC) and e-Residency (REC, 2018; Kotka et al., 2015), in addition to private projects, such as Alastria (2020), which has a large territorial coverage and has democratization of technology among its main goals.

DATA ANALYSIS

Opportunities and cases

A study on blockchain technology developed by the OECD presented several elements that can have a transformative impact on the public sector, such as decentralization of payment systems, reliability, resistance to Byzantine

errors¹, immutability of data, and transparency in transactions. The study points to the reduction of financial and operational costs, such as the reduction in the printing of documents and the prevention of total anonymity due to the registration of transactions conducted in the user's profile – even using pseudonyms. Also noteworthy is the solution to document integrity problems since document sharing, as it currently occurs, allows to change the content of copies and makes it difficult to confirm which document is true (Berryhill et al., 2018). A BCB report highlights other technology functions, such as storing smart contracts, health records, and identification records (Burgos et al., 2017).

According to Berryhill et al. (2018), despite the technology being more extensive in the financial sector, the public sector has invested in research to analyze the potential of blockchain, mainly through public-private partnerships, as information about this topic in the public sector is still limited. Table 1 shows some of the main government initiatives developed in the world using the technology. The projects were grouped into categories, but each should be considered to fit into more than one category. The projects were also grouped according to type (industry). Of the 203 projects, 174 are government services, and 74 are financial services (Table 1). The other types of projects have less participation and are linked to tourism, education, health, telecommunications, and energy.

Table 1

Main categories of government projects using blockchain technology surveyed by "The Illinois Blockchain Initiative"

Project category	Total	Type*	
		Government services	Financial services
Strategy/research	42	39	12
Identity (accreditation, licenses, certificates)	25	24	5
Personal records (e.g., health and financial)	25	21	4
Economic development	23	19	5
Financial services/market infrastructure	20	13	20

(continues)

¹ It is a condition of a distributed computing system in which failures occur and it is not possible to identify which components have failed and whether the system information is correct (Li et al., 2021; Driscoll et al., 2003).

Table 1 (conclusion)
Main categories of government projects using blockchain technology surveyed by “The Illinois Blockchain Initiative”

Project category	Total	Type*	
		Government services	Financial services
Land title registration	19	18	10
Digital currency (Central Bank)	19	18	19
Benefits/rights	13	13	2
Compliance/reports	12	11	4
Research/standards	12	8	2
Others	44	37	7

Note. Each project can fit into more than one category.
 *Project types: Financial services, government services, supply chain, defense, education, energy, industry/manufacturing, real estate, media/property rights, recreation/tourism, healthcare, technology, telecommunications, transportation, and retail/consumer goods.

Source: Updated from Berryhill et al. (2018) and “The Illinois Blockchain Initiative” (<http://bit.ly/blockchain-govt-tracker>).

There is a greater participation in projects related to strategy/research among the listed categories, totaling 42. Several of these projects explore the applications and medium- and long-term impacts of blockchain technology on society, such as the power of technology to reduce fraud and the costs of public processes.

Projects related to the issue of identity are focused on accreditation, licenses, certificates, and personal records. As a result, they would inhibit identity theft, make it less costly to issue documents involving multiple government entities and circumvent accessibility issues for information such as health records. In the latter case, the records could be interoperable across hospital networks or the country.

Another 24 projects are aimed at economic development and involve applying blockchain technology in various sectors. This category includes, for instance, projects that seek to create centers of excellence in using the technology.

The financial services/market infrastructure category stands out. The projects aim to streamline processes and documentation, improve reports and operate efficiency, reduce errors, and facilitate the charges associated with

national and international transfers. There are projects related to digital currencies, digital securities, credit, interbank transactions, and imports/exports.

Permissioned digital currency projects supported by central banks correspond to 19 projects. In this context, China has stood out by announcing the creation of a Central Bank Digital Currency (CBDC), the e-CNY, also known as Renminbi. It was launched in 2022 during the Olympic Winter Games Beijing. However, the People's Bank of China (PBoC) has been conducting internal tests with the digital currency in Shenzhen, Chengdu, and Suzhou. Unlike Bitcoin, e-CNY is a currency centrally controlled by PBoC and pegged to the Chinese currency (Li & Huang, 2021). The idea of creating a digital currency is not exclusive to China, as in the case of the United States and South Korea (Chorzempa, 2021; Alonso et al., 2021). Recently, the Covid-19 pandemic accelerated the downward trend in the use of physical currencies and intensified the use of other forms of payment. Faced with digital transformations, over 80% of the world's central banks have discussed the possibility of offering a digital currency. Part of these projects is already in the test phase (BIS, 2020). In Brazil, the Central Bank set up a working group in 2020 and is considering launching the digital Real in the coming years.

Another prominent category in the survey carried out by "The Illinois Blockchain Initiative" of government projects using blockchain is the registration of land titles, totaling 19 projects. The technology would help in the historical and chronological registration of property titles, reducing the expenses with third-party services in carrying out transactions. In turn, benefits/entitlements correspond to 13 projects that can help with government programs, such as pensions and health care benefits, through smart contracts to verify beneficiaries' eligibility and avoid benefit diversion. As for compliance/reports, 12 projects that plan to mitigate and identify fraud in paying taxes, for instance, were recorded. The research/patterns category comprises 12 projects that seek innovative approaches to leverage and explore blockchain technology, including platform development and partnership with universities and other entities.

Some projects are categorized into smaller groups but are essential to public finance, such as tax collection, procurement, and government finance. The projects include audits, monitoring the billing/purchase process, management of the taxation system, regulation of subsidies, issuance of electronic invoices, adoption of smart contracts, and tracking government spending at the initial stages. These measures ensure accuracy and security and provide a better real-time view of the state of public finances.

The mentioned projects are located in Australia, the United States, the United Kingdom, the Netherlands, Russia, China, and the United Arab Emirates, among other countries. Only two of the 203 projects in this report are located in Brazil, and both consist of government service pilot projects. One employs the technology to verify the legitimacy of personal documents, and the other to register property.

Brazilian initiatives

In Brazil, BNDES surveyed public and private sector initiatives in the national territory (Maranhão, 2018). The result comprised 357 categorized initiatives, of which the financial sector covered 33%, education and media 25%, consultancy and technology 23%, industry 9%, and public interest almost 9% (Table 2). It shows that despite the OECD concluding that blockchain in public services has the potential to improve efficiency, reduce inter-agency conflicts, reduce bureaucratic barriers, better share knowledge, and foster automation through intelligent contracts (Berryhill et al., 2018), only a fraction of the initiatives have been developed in the public sector.

Table 2
Main sectors of blockchain initiative in Brazil in 2018

Blockchain initiative sector	Quantity
Financial	119
Industry	33
Public interest	32
Technology	82
Education and media	91

Note. Each project can fit into more than one category.

Source: Maranhão (2018).

Eight of the 32 public interest initiatives deal with transparency and control of government spending, such as BNDESToken and TruBrudget. Also, six information-sharing initiatives were identified, including the Federal Revenue Service, the Federal Justice Council (CJF), and the Platform for Regulatory Entities' Data Integration (Pier). Other public interest initiatives include certificates, digital identity, civic innovation, notary systems, and transport.

The financial sector has initiatives to share information, payments/transfers/financing, brokerages/investments, and Tokens. Initiatives include the SALT project of the Central Bank, the Digital Financial System at Federal Savings Bank (Caixa), and two BCB projects (Digital Financial System and Flurbos). However, most projects are from private companies.

Table 3 shows some Brazilian blockchain-based initiatives expected to impact the public sector. Regarding projects in an application, there is the BNDESToken. This project is a BNDES creation whose pilot was applied in 2019. It is a tool for tracking public loans using tokens for financing public entities and non-refundable operations. With blockchain, the bank was looking for an efficient way of “[...] account management, transaction monitoring, and association of accounts to companies or people”² to make the destination of these resources and their contribution to the country’s development more transparent. The tool uses contracts from the Ethereum network. Therefore, customers must have an account on the platform and associate it with the Federal Tax Identification Number (CNPJ) through a digital certificate. As presented at the BlockchainGov Forum, held by Arantes (2018), the idea of using blockchain technology came from an internal selection of innovative ideas to combat the global confidence crisis propagated by the internet. BNDESToken is not the only bank tool based on blockchain, as there is also the pilot project TruBudget, created by the German development bank KfW and adapted with BNDES. The purpose of TruBudget is to make the destination of the Amazon Fund’s resources more transparent.

Table 3
Some of the Brazilian blockchain-based initiatives

Initiative	Institution
BNDESToken	BNDES
TruBudget	BNDES
Brazilian Blockchain Network	BNDES/TCU
bCPF	Federal Revenue/Dataprev
Pier	BCB
Identity management	BCB

(continues)

² Retrieved from <https://www.bndes.gov.br/wps/portal/site/home/imprensa/noticias/conteudo/bndes-lanca-consulta-publica-em-busca-de-componentes-blockchain-para-o-bndestoken>

Table 3 (conclusion)

Some of the Brazilian blockchain-based initiatives

Initiative	Institution
SALT	BCB
SOL	State
BH metered parking	Municipal

A cooperation agreement (no. D-121.2.0014.22) was signed between BNDES and the Federal Court of Accounts (TCU) in April 2022. The agreement's purpose is to create and maintain the Brazilian Blockchain Network (RBB). The network will provide more security and control of public administration actions, reducing costs and eliminating entry barriers. The first decentralized application is expected to go live in 2023 (TCU, 2022). Another Brazilian public project, which had little publicity, is the bCPF. It complies with Ordinance no. 1,788 of 2018 and was developed by the Federal Revenue in partnership with Dataprev. The bCPF aims to "[...] simplify the process of providing data stored in the CPF database" of information not protected by tax secrecy by the Special Secretariat of the Federal Revenue of Brazil (RFB) through the blockchain permissioned network³ (Dataprev, 2018). Although the project is restricted to agencies and entities of the direct federal, autarchic, and foundational public administration and agencies and entities that have an agreement with RFB (Dataprev, 2018), bCPF represents an initiative for a new public system that is less bureaucratic, more economical, faster, and democratic. Ronald Cesar Thompson, tax auditor and project manager, explains that using blockchain solves the risk of centralizing data and replicating information. However, the adopted model is adapted to the needs of governance, and, therefore, the network is not entirely horizontal, as the Federal Revenue is the central node and manages its data (Thompson, 2019).

The Pier, implemented in 2018, is a collaborative and decentralized network for exchanging information between BCB, the Superintendence of Private Insurance (Susep), and the Securities and Exchange Commission (CVM). The tool was created using blockchain as a service (BaaS) resources from Microsoft Azure. Thus, entities do not need to resort to e-mail, telephone, or paper letters to establish decisions related to the financial system. This

³ Private blockchain whose characteristics are as follows: requires permission to participate in the network; there is already a relationship of trust between the participants; the network is controlled by one or more entities; and it is faster to implement changes.

makes the process safer, more efficient, auditable, and less subject to control failures.⁴ The TCU also held a technical meeting in 2018 on the use of blockchain in a pilot project to take advantage of the characteristics of the speed of processes in the registration and analysis of information and documents in the accountability in the audiovisual sector. The objective is to improve the internal standards of presentation and the analysis of accountability of the resources applied in the National Film Agency (Ancine) audiovisual projects through direct or indirect funding.⁵

The BCB has already shown interest in projects that rely on blockchain. The BCB Information Technology Department analyzed “identity management,” a mechanism that aims to create a single customer record. It allows the user to select which data to share and with whom. The financial system is interested in optimizing these systems, as knowing its customers’ processes and compliance with anti-money laundering laws consume a considerable amount of resources (Burgos et al., 2017). Another platform analyzed was the System for Transactions Settlement (SALT), perceived by the group as a great backup resource and preventive tool for bank collapse. In the latter case, given the inability of the BCB to function, SALT would act, enabling the nodes to share information on the institutions’ reserves to carry out transactions in the Real-Time Gross Settlement (RTGS) system, recorded and confirmed reliably without the direct involvement of the bank (Burgos et al., 2017).

An application aimed at bidding on family farming is the Online Bidding Solution (SOL). It was launched in 2019

[...] by the Brazilian states of Bahia and Rio Grande do Norte so that beneficiary organizations of the Productive Bahia (BA) and Citizen Government (RN) Projects can carry out bidding processes for the purchase and/or contracting of goods, services, and works.⁶

In this sense, the technology allows for transparency, integrity, and auditability of recorded data, as it facilitates verification by the auditor of bids on the compatibility of transactions with those carried out between the parties.⁷

⁴ Retrieved from <https://news.microsoft.com/pt-br/banco-central-desenvolve-projeto-de-blockchain-com-recursos-do-microsoft-azure/>.

⁵ Retrieved from <https://portal.tcu.gov.br/imprensa/noticias/tcu-discute-o-uso-blockchain-em-prestacoes-de-contas-da-ancine.htm>.

⁶ Retrieved from <https://www.sol-app.net/sol-o-que-e>.

⁷ Retrieved from <http://www.ba.gov.br/noticias/governo-lanca-1o-aplicativo-de-licitacoes-do-brasil-e-coloca-tecnologia-servico-da>.

Other public projects in application do not fall directly into the financial sector but are linked to it, as they help in governance and reduce public spending. Metered parking is an initiative that directly impacts the daily lives of the people of Belo Horizonte. It was launched in 2018 and created by the city of Belo Horizonte in partnership with the Municipality Informatics Company (Prodabel). Instead of paper tickets; drivers can use the app on their cell phones to buy credits and park in metered parking spaces in the capital. According to the City Hall of Belo Horizonte (2018), “the capital of Minas Gerais [was] the first city in the world to use blockchain technology to implement this type of service.” As a benefit, the application brought more quality, agility, economy, and transparency to the public service because the user can use the service even at home or work, reducing the use of paper and registering transactions on the Transparency Portal. Also, most of the collection is destined for municipal companies to improve the local road system.

Other international initiatives

As for other projects developed around the world, the e-Residency has become popular among successful public initiatives. According to the project’s official website,⁸ the initiative, created in 2014, made Estonia a pioneer in offering electronic residency. e-Residency is an electronic government infrastructure code system that allows foreign entrepreneurs to access the country’s electronic services through a digital identification card. The cardholder can digitally sign documents, such as legal contracts, and verify the authenticity of documents. Thus, it enables establishing and managing companies in the European Union even if the entrepreneur lives in another country (Kotka et al., 2015). According to Kotka et al. (2015, p. 4), the smart DI card allows a cardholder to digitally sign documents (including legally binding contracts), verify the authenticity of signed documents, and encrypt confidential documents, which can be directed to a specific person or group. Moreover, the eID can be used to establish and manage an Estonian company anywhere in the world. The eID, by providing access to Estonia’s extensive e-banking privileges, also enables digital payments to service providers and online tax filing.

The project’s success was possible due to several factors, such as solid legislation and a political environment favorable to its development, technical infrastructure, partnership, and mutual effort between public and private

⁸ Retrieved from <https://learn.e-resident.gov.ee/>.

sector entities, and expansion of internet connectivity to rural areas. However, despite the government not making risk analyses public for national security reasons, the authors also point out precautions to be taken with e-governance initiatives. Among them is the possibility of cyber-attacks. Estonia is dynamic in creating security precautions, but the country fell victim to this type of attack in 2007 by politically motivated Russian hacktivists. After the event, Estonia strengthened the protection of digital services and databases, making it a pioneer in cyber defense, and started its investments in blockchain. Currently, the platform is consistently secure but requires commitment and constant updates by policymakers to keep it that way. However, it is related to another risk, which concerns the need for political integration to maintain the e-Residency's legislative priorities amid power coalitions. Otherwise, government agencies' lack of commitment would jeopardize the initiative's functioning (Kotka et al., 2015).

Furthermore, this technological project is not isolated, as Estonia provides other services using blockchain. E-healthcare, a decentralized medical record project, uses the technology (Kassen, 2022).

Real Economy Currency (REC, 2018), bearer of the official website rec.barcelona/, is a fully digital social currency from Barcelona launched in 2018 and supported by blockchain technology (Pires, 2018). Barcelona City Council, Novact, and the Taula de Canvi bank developed it, and it is part of the B-MINCOME project. The objective of the social currency is to encourage local consumption because "large stores, supermarkets, and e-commerce are having an effect on local trade, which is in decline. Without local shops, streets become deserted, there is a greater feeling of insecurity, and social relationships deteriorate" (REC, 2018). The project is recent, limited to the Besòs Axis area for local retailers and a small part of the population. However, depending on its performance, it can be expanded and used for wholesale markets.

The European Blockchain Services Infrastructure (EBSI) was created in 2018 with 29 countries (all members of the European Union, Norway, and Liechtenstein). The European Blockchain Partnership (EBP) was created with the European Union Commission to promote blockchain to develop services across the region for public administrations, companies, citizens, and their ecosystems to verify the information and make services reliable (EBSI, 2022).

In turn, Alastria is a project with an international scope that both the public and private sectors can enjoy. The Alastria Consortium is a regulated, not-for-profit organization that advances the digital economy through the

availability of a common collaborative platform. It is a pioneering project born in mid-2017 in Spain that aims to anticipate the possible interest of society in the use of services and products based on blockchain, which is why it tries to democratize access to this technology (Alastria, 2020). It became “[...] an international reference due to its collaboration and multi-sectoral concept and its purpose of the solution ‘as a country’ to the challenge of digital transformation of the economy and society” (Minsait, 2019, p. 27).

This platform created a digital identification (DI) standard that allows citizens to control their personal information transparently. In turn, companies can create a digital representation of their assets, called tokens, to develop new products and services with legal validity. Transactions are conducted faster, more efficiently, and at a lower cost. At the end of April 2020, 45% of the partners were small and medium-sized companies, 43% were institutions, and 12% were large companies. Some of the ongoing projects are: “Reciclo,” a system that promotes recycling and encourages it through virtual currency and digitized lotteries; “CLAUDIA,” which allows the performance of government activities, such as voting, surveys, and evaluations in a decentralized and transparent manner; “Clockchain,” which aims to record employee hours easily and prevent fraud (Alastria, 2020).

Another private initiative, designed by rapper Akon, is the construction of Akon City, a futuristic city in Senegal. The singer aims to make it fully managed through cryptocurrency, Akoin.⁹ Dubai is another city that has been investing heavily in blockchain technology. Emirates Blockchain Strategy 2021 was created by the United Arab Emirates government in 2018. The aim is to transform 50% of government transactions. The government estimates savings of about AED 11 billion in transactions and printed documents, streamlining resources and working time. The Dubai Blockchain Strategy program, which aims to implement initiatives in the city with blockchain, was also created. The strategy is based on “government efficiency, industry creation, and international leadership.”¹⁰

Challenges: Blockchain threats and weaknesses

The *Blockchain Threats Report*, by McAfee – an American computer security software company – analyzes the risks present with the use of blockchain in

⁹ Retrieved from <https://akoncity.com/>.

¹⁰ Retrieved from <https://u.ae/en/about-the-uae/digital-uae/blockchain-in-the-uae-government>.

private networks. In this sense, these threats in the public sector are insecure, as the experience and dynamics in applying permissioned technology in public services differ. However, the report can be used as an alert. According to McAree, the decrease in successful attacks on Bitcoin brings a false sense of security, but other platforms that use the technology, especially small ones, have been recurring victims. Below, some of the threats present in the blockchain will be explained.

Cyber-attacks on users of cryptocurrency technology are notorious because they are more vulnerable, given that “[...] security is often overlooked relative to growth [...]” (McAfee, 2018, p. 5). Furthermore, even well-known attacks are regularly functional, as many machines have not been updated to be immune. Attacks can be from phishing, ransomware, mining software, cryptojacking, deployment vulnerabilities, and technology. These attacks can aim to steal data, steal cryptocurrencies, exchange wallets, or even turn the machine into a bot to mine without the user’s consent.

Intending to improve security, the report points out assumptions that led to unique blockchain vulnerabilities. Among them is the conjuncture of contributory distribution to the network, assuming that a group or organization cannot have more than 50% of the network. A significant attack can occur if this percentage is reached. However, many entities choose to own more than 50% of the network because they process blocks faster and have more freedom to create them. It facilitates “[...] attacks, such as double spending [...]” (McAfee, 2018, p. 14) and data retention. Bitcoin, for example, has a large distributive network. Consequently, no majoritarian attack has been successful, but other small or internal platforms that use blockchain are easy victims, such as the theft of US\$ 1 million in tokens in 2018 from Verge (XVG). Not only that but according to the MIT Technology Review website, the increase in “hashrate marketplaces”¹¹ has created opportunities for hackers to invest in attacking large companies (Orcutt, 2019).

The conjecture of decentralization makes it difficult to recover stolen values because it is not enough to know who stole the cryptocurrencies, which makes the situation worse. It is also necessary to have access to the private key to return it to the rightful owner, as only the holder of the key of a private wallet can change the value they have. McAfee (2018, p. 25) states that “recovering from a cryptocurrency theft is more difficult and more complicated than with other currencies due to its decentralized nature.”

¹¹ On-demand virtual market, which rents CPU power capacity for mining.

The third assumption concerns the idea that most nodes are honest. However, a local node can have its connection surrounded by malicious nodes, thus starting the Sybil attack.¹² Thus, the attacker can control the information the victim has access to, such as the ledger. Only one honest node would be enough to thwart the attack because the true ledger chain would be longer than the attacker's. The report states that "as with the mass attack, a smaller network is an easier target, particularly when no additional countermeasures are built into the system" (McAfee, 2018, p. 15). The fourth conjecture refers to the uniqueness of the hashes; that is, they are created so there is no collision between the property keys. However, this security is perceived in systems that respect the complexity of creating the hashes, such as Bitcoin, which uses hashes with a length of 256 bits. On the other hand, people who use brain wallets¹³ or companies that improperly implement algorithms for creating keys facilitate collisions and the discovery of third parties by attempt.

The OECD guide states that technology would not solve all government problems, as some of its main characteristics would be limiting factors in the public sector. In this sense, data immutability could be unfeasible in cases where updating and deleting information are recurrent. Another example is transparency, reliability, and decentralization. Despite being characteristics that would allow perfect transparency of public actions, they would conflict with the need for confidentiality and privacy in situations of private data storage (Berryhill et al., 2018). Regarding the blockchain characteristic that there is no need for a third-party intermediary in transactions, which is very important, especially in transnational relations (Burgos et al., 2017), the OECD argues that this statement is not complete, as

Blockchains do not appear out of thin air – they must be built and governed by code developers, engineers, and other decision makers who have been entrusted with key roles for the development of a blockchain platform. These developers are a de-facto central authority, and their composition and actions and underlying decisions coded into a blockchain may not be as transparent as the transactions themselves (Berryhill et al., 2018, p. 30).

¹² An attacker creates multiple false identities on the network, becoming malicious nodes, which multiply the workforce to propagate fraudulent information.

¹³ It is a Bitcoin option for using a memorable key to avoid the user having written it somewhere and needing to access the private key from random algorithms.

The cost-benefit is not yet evident, as operations with the technology are financially high in the short term while the visibility of benefits is limited in the long term. It is one factor that hinders the popularization of the technology in projects (Berryhill et al., 2018). BNDES also raised possible factors that interfere with the applicability of the technology in Brazil. The main ones are: 1. legal difficulties; 2. lack of labor; 3. difficulty in accessing markets, which can be justified by technological monopolies and lack of regulation, among others (Inter-American Development Bank – IDB, 2019); 4. lack of capital; and 5. cultural barrier, as the traditional financial system resists changes. Also, they propose stimulating actions, such as strengthening the regulatory environment, incubators combined with tax exemption, training professionals, creating a national identity standard, strengthening access to markets, and implementing a national permit network (BNDES, 2018).

In addition, the IDB (2019) highlights the need for an ecosystem for the inclusion and development of projects involving blockchain. It identifies that some of the main obstacles to the growth of this ecosystem are: 1. coordination failures and a low association between the actors of the ecosystem, which makes it difficult to promote new governance techniques that democratize access to the benefits of the technology; 2. limited infrastructure technological resources and lack of standards that allow scalability,¹⁴ cost predictability, and legal validity of transactions; and 3. lack of information analyzed and made available to public and private decision-makers about the impacts on financial, economic, and social inclusion of this technology and lack of standardization in technological, regulatory, and usage aspects across countries.

Despite the potential of blockchain technology in public finance, its large-scale adoption is viewed with caution. Initiatives of profound impact on the financial system proposed by governments that initially considered its adoption sought other technologies for implementation. It was the case of PIX in Brazil, an instant payment method created by the BCB that uses a centralized and unique infrastructure to settle payments. According to statistics on the agency's official website, the number of users and transactions has been growing, replacing other means of payment (BCB, 2021).

In Brazil, only 2% (eight initiatives out of 357) of the total projects are directly related to public finance, similar to the international situation.

¹⁴ Limitation that the technology has in conducting a large number of transactions due to the block size limitation in the decentralized consensus mechanism. The scalability problem is highlighted in Bitcoin, as the limitation of 1 MB per block and the high demand made the transaction processing time far below the stipulated in theory.

Despite the caution in adopting high-impact initiatives by governments, there has been an increase in cases in recent years in the most diverse areas, including public finance.

CONCLUSIONS

Blockchain technology emerged associated with Bitcoin in 2008, in a scenario in which the global financial market was fragile. Since then, the technology has mostly been applied to alternative cryptocurrencies. However, the perception that blockchain could be disconnected from the digital currency and the possibility of bringing security, reliability, transparency, and inviolability in transfers created interest in using it for other purposes, such as inter-organizational cooperation, data storage, medical records, school records, voting, commodity tracking, and smart contracts.

One of the difficulties in the research was finding applications of the technology in public finance. The number of projects in this category is scarce in Brazil and internationally. But this scenario has shown signs of change. According to Berryhill et al. (2018), despite the technology being more extensive in the financial sector, the public sector has invested in research to analyze the potential of blockchain, mainly through public-private partnerships, as initiatives on this technology in the public sector are limited.

In theory, the technology can be used to collect taxes, prevent tax evasion, misappropriation, and manipulation of records, prevent fraud in public projects by tracking funds, and record immutably. However, it requires a blockchain ecosystem in all government circles, which requires research and planning, infrastructure, investment, and political-legal and social support. In Brazil, the Financial Inspection and Control Commission has already held a hearing to discuss the feasibility of the technology in public finance (Câmara dos Deputados, 2017), and there are already platforms created by private companies aimed at solving government problems in finance, such as EY OpsChain Public Finance Manager (EY, 2019; Nordgren et al., 2019).

The use of technology to assist in the functioning of financial institutions, such as data sharing, self-service, and facilitation of communication between organizations or between organization and user – which enables a reduction in expenses with employees and office materials, higher agility and modernization of service, and reduction of bureaucracy – is what has been observed in practice for the time being. In turn, public projects that

foster the economy and stimulate the social acceptance of digital currencies generally have a small geographic extension, as in the case of REC.

In this context, blockchain has a lot to offer the public finance sector, but governments are cautious and insecure when introducing the technology. It occurs because there is uncertainty about whether the technology is developed enough to support critical problems in the public system or what unique issues could arise from this technology. In addition, creating an infrastructure for information management, with clearly defined procedures so that information can be connected between different agencies and levels of the State, is necessary.

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