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Research Article

Empowering Democracy: Does Blockchain Unlock the E-Voting Potential for Citizens?

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The adoption of blockchain technology continues to grow, a direct result of its potential to provide new solutions to old problems in several industries, including the electoral sector. Blockchain technology is proposed to have the potential to address and overcome the traditional pen and paper scheme's challenges and limitations, as well as trust concerns around more modern e-voting systems. Ultimately, with the aim to revert the recent downward trend in voter turnover, despite the interest and potential, there remains a significant research gap in understanding citizen response to this technology. This research is aimed at investigating whether citizens would be willing to embrace blockchain technology, as well as at exploring the factors that influence its adoption. A model designed to combine the extended unified theory of acceptance and use of technology methodology with an experimental approach is applied. The results of the study ($N = 416$) show that the intention to use blockchain-based e-voting systems can be predicted by five of seven constructs, that is, citizens are more likely to adopt e-voting systems when they perceive them to be effective, socially endorsed, enjoyable, trustworthy, and low in perceived risk. However, we do not find a direct influence of blockchain technology, over cloud-based e-voting, on voting intentions indicating that the benefits of this approach may not be well understood by consumers or may not drive the desired increase in voting intention. By understanding citizens' willingness and concerns to adopt new voting technologies and the factors influencing this disposition, policymakers are better equipped to develop strategies on the development and implementation of electronic voting systems and can make informed choices about the use of blockchain technology.

Keywords: blockchain; digital democracy; e-government; electronic voting; technology adoption; voter turnout

1. Introduction

In a democratic society, voting is a vital act of citizenship, being both a right that should be protected and a responsibility that citizens should fulfill to ensure the legitimacy and effectiveness of democratic institutions.

Despite the growth in the global voter population and the number of countries that hold elections, the global average voter turnout rate has been decreasing significantly since the 1990s. The percentual decline in Europe is more significant than in the other regions. In Asia and in America, the trends in voter turnout appear more stable over time. However, in both continents, the voter turnout has been much below the global average [1, 2].

Lower turnout rate presents severe consequences such as underrepresentation, disproportionate influence, and vulnerability. Understanding the main reasons for these actions and encouraging active participation is crucial for a more inclusive, representative, and accountable democracy [3]. A great number of empirical studies have been conducted to try to understand how various factors may affect voter turnout. The elements most commonly cited are socio-economic—population size, stability, and economic development; political—closeness of elections and perception of political issues at stake; institutional—electoral system, compulsory voting, registration requirements, and voting arrangements; and personal—age, education, political interest, and civic duty [1, 4, 5].

Even though traditional voting methods are widely accepted, they present some challenges and limitations. Many may argue that the lack of a more accessible and technologically advanced solution is one of the reasons for such high abstention rates [6, 7]. Blockchain technology presents the power to replace the traditional pen and paper scheme with a new election system. Blockchain works by comprising a sequence of blocks, each with a set of verified transactions [8], protecting information from alteration and/or manipulation, while securing anonymity and privacy, integrity, and accuracy [9]. Citizens can cast their votes on smartphone apps rather than having to queue up at polling stations, ruling out any constraints that might be associated [10].

Despite the increasing interest, there remains a significant research gap in the existing literature on blockchain-based e-voting, which has primarily focused on technical aspects, such as the design and implementation of the systems, as well as their features and requirements. Although researchers have shown increased interest in the potential of blockchain technology, it is difficult to know if it has become an object of interest to the public and what their reaction to this technology will be. It is then crucial to explore the perspectives of citizens on this technology to ensure that their interests, concerns, and expectations are appropriately addressed. This research focuses on the implementation of electronic voting systems and is aimed at identifying the associated level of acceptance of the citizens to this arrangement, exploring potential benefits, challenges, and contributing factors; also, it determines if blockchain stands out as a reliable and secure technology for the development and deployment of such electoral innovation.

This study addresses this gap by focusing on citizen acceptance of blockchain-based e-voting systems. Specifically, two research questions guide our investigation: Firstly, what factors influence the adoption of e-voting technology among citizens? Secondly, how does the integration of blockchain technology affect these factors and subsequently contribute to broader adoption of electronic voting systems?

In order to answer these questions, we make use of the social theory of political participation [11] and the unified theory of acceptance and use of technology [12] as theoretical frameworks to structure the research. The study then employs the approach of [13] which allows us to examine explicitly the contribution of blockchain technology within the theoretical frameworks by introducing an experimental condition. To do so, we randomly assign participants to cloud- or blockchain-based e-voting conditions and subsequently measure their responses through a structured survey. Data is collected in a convenience sample and analyzed using partial least squares structural equation modeling (PLS-SEM) to identify differences across conditions and explore factors influencing the acceptance of blockchain technology for e-voting.

2. Literature Review: Blockchain E-Voting

Blockchain can be defined as a chain of blocks, which are time stamped and linked by cryptographic hashes [14]. Essentially, it is a distributed ledger of transactions implemented on a peer-to-peer (P2P) network [15]. For a block of transactions to be appended, first, it must be approved by a node (in this context, also called a miner). A consensus among the majority of nodes regarding the validity of the transaction is mandatory to complete the process [16]. Blockchain networks use asymmetric cryptography, which involves the use of a pair of keys to encrypt/decrypt communication. Hashing is commonly used and consists of transforming input data into a fixed-size string of characters [17]. The hash functions are unique and deterministic. Each block of information contains a reference to the previous one and, so, for a piece of data to suffer alterations, all the other connected blocks need to be recalculated as well [18]. No entity can modify information stored on the ledger without the approval of the remaining. In summary, the records in blockchain are immutable, irreversible, and tamper evident.

Initially recognized as the foundation for cryptocurrencies like Bitcoin, blockchain has emerged as a transformative force in various sectors [19]. Blockchain e-voting appears as a solution with a set of opportunities and benefits to revolutionize the electoral process and strengthen the foundations of democracy. Physical limitations and geographical constraints no longer present a barrier, as blockchain e-voting allows citizens to cast their votes on election day digitally, only requiring a device with an internet connection to complete the process.

Educational campaigns will need to take place to promote awareness of blockchain technology, its benefits, and how it improves security, transparency, and accessibility, given that the complexity inherent in blockchain technology might interfere with mainstream public acceptance [6]. Having in mind the possibility of restricted or nonexistent access to electronic devices or internet connectivity, it is of extreme importance to preserve voting stations, as they provide an alternative for those who do not have the conditions or knowledge to pick the first option [9].

Even so, having all conditions met, blockchain e-voting might not be accepted by communities that do not share the culture and values compatible with it being a transparent, decentralized, and bottom-up process. Electoral authorities, government agencies, and political leaders and others who benefit from the status quo may contribute to the citizens' resistance, as blockchain technology should shift power away [20, 21]. Measures to address these concerns need to be implemented: educating citizens about the technology characteristics may help build trust and acceptance among them and ultimately improve the citizens' overall experience, as well as enhance government-to-citizen (G2C) interaction [22].

Regarding back-end operations and logistics, blockchain enabled voting reflects accuracy and speed, given that it automatically tallies the votes casted, decreasing the overall time and consequently the human error [9]. Financial investments associated with system' implementation and maintenance [23] and its limited scalability [14] may be viewed as a concern. As such, it is advised to have a thorough and comprehensive evaluation before considering their widespread adoption in electoral processes, to ensure efficiency and accuracy.

The transparent and immutable nature of the technology ensures that no transaction (i.e., casted vote) can be modified or deleted. Advanced cryptographic techniques are adopted to safeguard the citizens' identity, protect against potential cyberattacks, and restrain fraudulent activities [14, 15]. However, device exploitation can still be classified as a concern. This potential risk and its consequences are hardly predictable in advanced and may be difficult to detect afterwards. Attackers may gain control over the voters' authentication credentials, which can degrade the experience to the users, prevent them from voting, deceive them about the process, or publicly expose their choices [24]. It is crucial to adopt the best practices and conduct regular security audits to minimize the potential risk associated with it.

In order to minimize these limitations, a blockchain-based e-voting system should follow a common framework of principles such as the ones mentioned below in its design in operation (consult Table 1).

The implementation of these characteristics has the potential to enhance trust and confidence among citizens in the technology, ensure privacy, and mitigate the risk of manipulation, misconduct, and malpractice.

As a result of the interest in the potential of blockchain for improving e-voting, a number of applications have been trialed from which we can look to draw insights on public response. The first example appears to have been implemented in Sierra Leone as a proof of concept [26], where ballots were digitized and blockchain secured, in parallel to paper ballots. Although reliable sources on the pilot and critical analysis of the outcome do not appear to exist in the literature, the first wide-scale real demonstration appears to have been undertaken in Thailand [27] where 120,000 members voted to elect the Democratic leader without reported fraud or serious issues.

Russia has trialed the technology at the city level in 2019 and national level in 2020 and 2021. In a qualitative study [28] based on interviews with experts on these applications, a number of the theoretical benefits are found to be plausible, although it is reiterated that trust remained a key factor for future success and opposition parties have questioned the role of the blockchain system [29].

State [30], city, and county [31] elections have all been piloted in the United States, although again impartial sources or critical review seem difficult to locate. In these cases, the technology was implemented to improve the voting experience for overseas-based military personnel with the aim of improving turnout. It is essential to highlight that there was an attempted hack on the Voatz application [32]. Even though Voatz asserted that it was not close to being successful, however, several vulnerabilities were later identified by reverse-engineering the app. It was found that remote adversaries could tamper with a user's vote if they had access to the device, and that, in some election configurations, even a passive network adversary could discern a user's vote and disrupt the connection. It should be noted that the security vulnerability was found in the application, before contact with the blockchain, and it should be considered that this type of vulnerability applies to e-voting more generally.

It can be seen then that the application of blockchain for voting remains in its infancy in practice. It then becomes essential, given the costs to conduct real world trials, to understand its potential for adoption and improving e-voting as we propose here.

3. Material and Methods

3.1. Theoretical Approaches. As a result of incomplete understanding of the causes of turnout, policies designed to increase participation have often failed to achieve their aims—as previously explained in the case of postal code or e-voting. For achieving success in the implementation of a blockchain-based e-voting system, it is mandatory to not only explore the social and political context that drives political participation but also identify and study the factors that influence technology acceptance and adoption.

Different frameworks have been developed to illustrate the users' adoption by taking into account a range of factors in the models. The most common models are discussed in the following sections.

3.1.1. Political Participation Framework. "Other Turnout: A Social Theory of Political Participation" [11] explores how social norms, social capital, and social pressure impact individuals' engagement in the political process. According to this theory, immigrants, minorities, young people, the uneducated, the poor, and the politically disinterested are systematically less likely to vote, than those with higher social economic status, that is, wealthy, White, and highly educated citizens. Notwithstanding, citizens are influenced and responsive to the decisions of those around them, meaning they are more likely to cast their vote if their family, friends, coworkers, neighbors, or others in their network do it. Besides motivation, ambition and desire are too described as the leading factors. Data also suggests that the turnout rate is higher in countries where voters are automatically registered, voting is compulsory, or election day is a weekend or holiday.

3.1.2. Unified Theory of Acceptance and Use of Technology. The unified theory of acceptance and use of technology model is often regarded as the most comprehensive theory for analyzing technology adoption by individuals [33] [34] as it incorporates an exhaustive review of eight dominant technology adoption models, namely, theory of reasoned action, theory of planned behavior, technology acceptance model, motivational model, combined TAM-TPB, model of personal computer utilization, innovation diffusion theory, and social cognitive theory [35].

This framework focuses on identifying the key contributors to the individual's intentions to adopt a technology and their subsequent usage behavior—performance expectancy, effort expectancy, social influence, and facilitating conditions [36]. In 2012, an extended version of this approach

TABLE 1: Electoral principles.

Principles	Description	Reference
Accessibility	The polling station must be open and accessible for the voter who wishes to cast their vote manually and physically.	[9, 25]
Accuracy	Casted votes are counted correctly, and the declared results match the election outcomes.	[9, 24, 25]
Anonymity	The identity of voters and whom they vote for should not be revealed.	[9, 24, 25]
Auditability	Possibility of recording and validating transactions and the accuracy and fairness of the overall process.	[9, 24, 25]
Availability	Voting systems should be available as long as the voting period is open.	[25]
Completeness	All information compiled on the ballot should be handled correctly; and the system must allow for voter abstinence.	[24, 25]
Eligibility	Only registered voters should be allowed to vote.	[9, 25]
Immutability/integrity	Property that ensures that each vote is recorded as intended and cannot be tampered with in any manner.	[9, 24, 25]
Fairness	No one can find out the details before the count is released.	[25]
Privacy	Protection of personal information and the ability to control its access and use.	[9, 24, 25]
Reliability/robustness	Election systems must operate safely without loss of votes; all active nodes keep full copies of the blockchain ledger. Additionally, software and methods should be developed in such a way without any malicious code or errors.	[9, 24, 25]
Soundness	Invalid ballots should be detected and not taken into account during tallying.	[25]
Uniqueness	Citizens' votes must not be counted more than once.	[25]
Verifiability	Voters should be able to confirm that their ballots are counted correctly.	[9, 24]

was developed to introduce a social context—hedonic motivation, price value, and habit [12, 37].

3.1.3. Drivers and Barriers to the Implementation of Internet Voting. The drivers and barriers to the implementation of internet voting theory [38] provides a comprehensive holistic perspective on the factors influencing the adoption of internet voting (i-voting). It outlines 15 general drivers and/or barriers for i-voting adoption, framed within two main contexts: (1) the socioeconomic situation—encompassing social, economic, cultural/historical, political, organizational, legal, and procedural elements—and (2) the technological context.

Among these, four factors on citizens adoption stand out. The first relates to blockchain literacy, stating that the technology is perceived as too complex for the average person to understand fully, leading to uncertainty about whether introducing new technology is truly necessary, especially when it risks disrupting an already functioning electoral system, and mistrust. Facilitating conditions are also taken into consideration by pointing out that areas with limited internet access highlight the disparities (digital divide) and stump electoral inclusivity. The third aspect is habit, and it is said that individuals tend not to maintain interest in the technology if they experience no further usage of it than voting online from time to time. Lastly, hedonic motivation, elections are viewed as a community-based exercise where voters physically gather to cast their votes, and so, many may resist the idea of replacing it with technology.

The study also states that the composition of civil society influences the discussions around i-voting technology, as its members—government, civil society organizations, experts, academia, and others—may drive or impede ("middleman paradox") diffusion depending on their stance, particularly in environments lacking expert communities and with less regulated procurement. On the other hand, the presence of solid lobby groups within society fighting for the rights of visually impaired persons and expatriate voters is identified as a strong driver for i-voting adoption on the political level.

3.1.4. Enablers and Value Drivers of Blockchain. Exploring and understanding the drivers behind blockchain adoption is essential for evaluating the strategic grounds and potential benefits of integrating such technology into existing frameworks.

The adoption of blockchain is driven by a group of factors that include technological advancements, market dynamics, and evolving industry needs. From the Jardim et al. [39] empirical analysis, key statements regarding blockchain adoption were highlighted. These statements reflect consensus on critical issues such as traceability, the maturity level of blockchain, and the pivotal role of smart contracts in enhancing transparency, data integrity, and operational efficiency. Additionally, benefits such as consolidating diverse data sources into a single information hub and addressing challenges of acceptance among stakeholders were emphasized. Moreover, the potential for blockchain to automate processes across multiple partners, facilitate regulatory compliance in transactions, and streamline operations through automation accentuated its potential.

The study categorized the beforementioned adoption factors into two distinct categories: adoption incentives and adoption challenges, providing a framework that considers the drivers of adoption from two sides—drivers and challenges. Adoption challenges primarily address external factors that could influence the adoption process, such as the reliance on acceptance and adoption by other stakeholders, the level of support provided by technology providers, and the trustworthiness of the technology itself. In contrast, the adoption incentives category focuses on the inherent benefits and characteristics of blockchain technology. These encompass its capacity for automation and reduction of inefficiencies, its ability to enhance traceability and information tracking across chains, and the transparency facilitated by smart contracts.

3.2. Hypothesis Mapping and Research Model Design. Based upon the theoretical foundation laid out in the previous sections, the following segment sets out the hypothesis mapping. This alignment allows the development of a structured framework that clarifies the foundations of the research. These hypotheses, built on the constructs featured in the unified theory of acceptance and use of technology, encompass a range of user perspectives and outlooks, providing insights into the factors driving users' intentions in adopting e-voting. As to assess if blockchain stands out as a reliable and secure technology, a comparative study will take in cloud-based e-voting systems as a baseline technology group.

3.2.1. Performance Expectancy. Performance expectancy refers to the user's subjective belief that using a particular technology will enhance their productivity, efficiency, and assist in accomplishing their goals [36]. In this scenario, performance expectancy relates to the user's confidence that adopting blockchain-based e-voting systems will enable them to cast their votes securely and conveniently, as well as potentially gain other benefits.

Performance expectancy is likely to be influenced by several factors, including the awareness and comprehension of citizens regarding the potential impact of blockchain-based e-voting systems on the democratic process; the perceived ease of use of the blockchain-based e-voting system; and the user's belief in the system's ability to safeguard the integrity and privacy of their vote; and the user's prior encounters with such technology [40].

In the scope of existing blockchain literature, it has been established that performance expectancy has a significant positive impact on the behavioral intention to use blockchain technology, as evidenced by the work of Abu Afifa et al. [41] and [36].

We hypothesize the following:

H1: Performance expectancy positively influences behavioral intention to use e-voting systems.

On the other hand, studies have shown that cloud-based e-voting faces challenges in data integrity, transparency, and secrecy of the ballot, among others [42, 43]. These challenges contribute to a perceived inferior performance, influencing users' expectations and belief in the system's ability to safeguard the integrity and privacy of their vote, and consequently their adoption intentions. As such, and in comparison, those exposed to the blockchain technology are more likely to positively perceive performance expectancy.

We hypothesize the following:

H2: Blockchain technology group positively influences performance expectancy.

3.2.2. Effort Expectancy. Effort expectancy hinges on users' perceptions of a technology's user-friendliness. This subjective assessment significantly shapes an individual's motivation and intent [36].

When users expect a technology to be approachable and demand minimal effort in terms of interaction and navigation, they are more inclined to adopt it (C. [44]). In the context of blockchain-based e-voting adoption, users may express concerns about the learning curve associated with newer blockchain technology, potentially leading to an expectation of a higher level of effort in their engagement. As such, it is imperative to prioritize the education regarding both the technology and electoral processes [45].

Abu Afifa et al. [41] and Chang et al. [46] establish a connection between effort expectancy and the overall intention to implement the technology, emphasizing the nature of these factors in the context of blockchain-based e-voting, revealing a positive impact on users' intention to adopt technology.

Although similar, cloud-based systems are of widespread familiarity as most citizens use smartphones and everyday applications that rely on cloud technology, such as social media platforms, file storage, and sharing services, among others [47]. Such comfort and familiarity suggest that the learning curve associated with cloud-based technologies may be comparatively lower and that it may outweigh the concerns about its usability, overshadowing any potential issues. Consequently, individuals may exhibit a lower intention to embrace and adopt blockchain-based technology [48].

We hypothesize the following:

H3: Effort expectancy positively influences behavioral intention to use e-voting systems.

H4: Blockchain technology group negatively influences effort expectancy.

3.2.3. Social Influence. In this context, social influence refers to the impact of others' opinions, recommendations, and social interactions on a user's decision to adopt a technology [12].

Numerous studies within the field of political participation have recognized social influence as a key driver to civic engagement, claiming citizens are influenced and responsive to the decisions of those around them, meaning they are more likely to cast their vote if their family, friends, coworkers, neighbors, or others in their network do it [11].

Research on blockchain consistently highlights the impact of social connections and peer attitudes, behaviors, and recommendations in encouraging the adoption of a blockchain-based product/service, such as electronic voting systems [36].

Cloud-based systems have achieved global integration, becoming an integral part of individuals' daily lives. The widespread adoption of cloud technologies is evident, thanks to their familiarity and seamless incorporation into various applications [47]. However, blockchain-based systems, particularly in the context of e-voting, are in their early stages of development and introduction to the citizens, and, as such, the social influence factor becomes crucial [49]. That said, it is estimated that social influence will have a significant impact on the intention to adopt such systems, when compared to a cloud-based solution.

H5: Social influence positively influences behavioral intention to use e-voting systems.

H6: Blockchain technology group positively influences social influence.

3.2.4. Facilitating Conditions. Facilitating conditions encompass the user's perception of the support, resources, and infrastructure available to help them use the technology effectively [36].

In order to grasp their impact, it is essential to take into account the various elements vital to the adoption of this system. These elements include factors such as the presence of the required hardware and software, the availability of secure internet connections, and the delivery of comprehensive training and assistance.

Studies have demonstrated that facilitating conditions play a crucial role, as individuals with access to them are more likely to develop the intention and adopt a particular technology [44, 50, 51].

Since both blockchain- and cloud-based solutions require hardware (computers, smartphones, or equivalent) and access to an internet connection, the solutions are perceived as alike, leading to the anticipation of similar behaviors.

We hypothesize the following:

H7: Facilitating conditions positively influence behavioral intention to use e-voting systems.

H8: Blockchain technology group does not influence facilitating conditions.

3.2.5. Hedonic Motivation. Hedonic motivation is described as the pleasure and enjoyment a user derives from using a technology [12]. In this scenario, the citizens' motivation towards the adoption of blockchain-based e-voting systems is influenced by factors related to the amusement, excitement, and empowerment of engaging with the given technology, as well as the desire to be part of a tech-savvy minority.

The emotional experiences that encompass users' hedonic motivation significantly contribute to individuals embracing a technology [52]. Studies have confirmed that individuals are more inclined to use technology more effectively when it offers elements of fun, enjoyment, and amusement [53].

Being blockchain-based e-voting systems perceived as innovative and exciting, it is expected to present a stronger behavioral intention when compared to cloud technology.

We hypothesize the following:

H9: Hedonic motivation positively influences behavioral intention to use e-voting systems.

H10: Blockchain technology group positively influences hedonic motivation.

3.2.6. Excluded Factors. In line with the guidance provided by Venkatesh et al. [12], two components of the UTAUT2 model were purposely left out in the evaluation of the selected technology. The constructs price value and habit were intentionally omitted.

The price value reflects the user's perception of the worth of the technology in relation to its cost [12]. The pricing structure for blockchain-based e-voting systems can be highly variable based on a multitude of factors, making it difficult to create a standardized scale to effectively explain the concept, evaluate its impact on user adoption, and conduct meaningful comparative analyses [40]. Additionally, as the adoption of e-voting systems is typically driven by governments and institutions rather than by individual consumers, the direct cost incurred by individual users is often minimal or nonexistent. That said, no conclusions will be drawn about the correlation between these factors, as they are unlikely to accurately represent the impact of price value.

Habit refers to the extent to which a user's behavior regarding technology usage becomes automatic and routine [12]. This factor was eliminated from the proposed research on the assumption that blockchain-based e-voting systems are still in the early stages of their product life cycle and developmental stages; thus, there are few people who were exposed to and experienced this technology [54]. No statement can be made about the relationship between these, as it is unlikely to accurately reflect the influence of digital familiarity.

3.2.7. Trust. In order to comprehensively explore users' acceptance of e-government services such as blockchain-based e-voting, the construct of trust emerges as a crucial dimension [50]. Trust, in this context, pertains to users' confidence in the functionality, helpfulness, and reliability of the technology [55].

Prior research has found trust to be a critical indicator of behavioral intention towards adopting technology [56]. In fact, studies have established that initial trust is one of the most dominant parameters to improve the acceptance of a technology users have little to no prior experience in [57]. Henceforth, the link between how much citizens trust the technology and how willing they are to use it is clear: When citizens have a high level of trust, not only do they feel positive about the cyber transaction [58] and so adopt the e-government service [59], but also they are also more likely to stay engaged with it over time [41].

Considering historical challenges encountered by cloud-based e-voting systems concerning privacy and security issues, it is understandable that citizens present a lower level of trust in such technology when compared to blockchain solutions, renowned for their robust safety nature [24].

We hypothesize the following:

H11: Trust positively influences behavioral intention to use e-voting systems.

H12: Blockchain technology group positively influences trust.

3.2.8. Risk Perception. Risk perception plays a pivotal role in shaping the path to information disclosure and technology adoption [60, 61]. The way individuals and organizations perceive the potential risks associated with blockchain-based e-voting significantly influences their willingness to embrace and integrate it into their electoral routine.

Featherman and Pavlou [62] defined perceived risk as the "potential for loss in the pursuit of a desired outcome of using an e-service." In the present context, risk is defined as the citizens' likelihood of loss in relation to blockchain-based e-voting systems. Risk may be influenced by a range of factors and comes shaped in different ways, such as data privacy and/or security vulnerabilities and operational concerns, among others. As such, it is crucial to acknowledge historical instances where privacy risks have arisen and implement robust risk management strategies, educational initiatives, and an effective channel of communication [51, 60].

When citizens perceive the risks as low impact and/or manageable, there is a heightened disposition towards technology adoption. Contrarily, if deemed as high-level impact, perceived risks can provoke hesitation, reluctance, and resistance [63, 64].

While cloud-based applications have seamlessly integrated into people's daily routines, fostering familiarity and routine use, blockchain, being in its early developmental phases, is seen as complex and unfamiliar, contributing to a heightened sense of perceived risk among individuals, and resulting in a more cautious approach [47, 65].

Additionally, blockchain technology has been predominantly associated with Bitcoin, which, in the past, has been portrayed by the media as a facilitator of illegitimate activities, such as money laundering, terrorist financing, and tax evasion [66]. The lack of regulatory clarity surrounding blockchain contributes to an increased perception of risks as well. This approach may influence citizens to be more attentive and sensitive to apparent threats associated with blockchain-based systems, such as e-voting.

We hypothesize the following:

H13: Risk perception negatively influences behavioral intention to use e-voting systems.

H14: Blockchain technology group negatively influences risk perception.

3.2.9. Blockchain Technology Group. Exposure to a technology encompasses the individuals' familiarity, understanding, and direct engagement with it [67]. Research suggests that previous exposure to a technology positively influences the behavioral intention to use it [68]. In the present study, the blockchain technology group is exposed to participants as a binary experimental condition:

Blockchain condition—respondents evaluate an e-voting system explicitly described as blockchain-based, highlighting the properties and implications of this technology including decentralization, immutability, and transparency.

Baseline condition—respondents evaluate an otherwise identical e-voting system with no mention of blockchain with a similar explanation of the technologies' properties.

This manipulation allows us to compare two groups of e-vote users (those exposed to a blockchain design vs. those who are not) without requiring a large sample of real-world blockchain-voting users—currently scarce as such systems have seen only limited pilots.

As outlined in our discussion of blockchain technology, the specific properties of this technology are designed to bring benefits that are hypothesized to increase adoption. Moreover, as blockchain technology continues to gain acceptance and adoption across various industries, individuals are likely to perceive this technology as credible and reliable [69]. However, we hypothesize that this change is made through the existing identified drivers of technology adoption that are part of the conceptual model presented here. Once the mediating constructs of our theoretical model are accounted for, no residual direct effect of blockchain technology should remain.

We hypothesize the following:

H15: The effect of blockchain technology group is fully mediated by the constructs defined within the concept model, thereby expecting no additional direct effect on the behavioral intention to use e-voting systems.

3.2.10. The Moderator Role of Blockchain Literacy. Integrating blockchain literacy as an additional dimension is imperative for a more nuanced examination of users' acceptance of blockchain-based technologies. Blockchain literacy encompasses users' knowledge and understanding of the details surrounding blockchain technology.

Given that blockchain is a rising technology, many people are not familiarized with it [65], making assessing users' proficiency in comprehending the unique attributes of this technology instrumental in predicting their acceptance.

As individuals become more proficient in understanding the fundamentals of blockchain, not only does their comfort level with the technology and its underlying principles grow, consequently increasing their perceived effort expectation, but also, their level of understanding of functionalities and security features—transparency, security, and immutability, thereby elevating their performance expectancy [70].

We hypothesize the following:

H2a: Blockchain literacy moderates the effect of blockchain technology group on performance expectancy.

H4a: Blockchain literacy moderates the effect of blockchain technology group on effort expectancy.

Moreover, individuals develop a heightened sense of trust, recognizing the decentralized and immutable nature of blockchain as a safety measure against tampering and fraud. This helps mitigate risk perceptions, fostering greater confidence and acceptance of e-voting systems among citizens.

We hypothesize the following:

H12a: Blockchain literacy moderates the effect of blockchain technology group on trust.

H14a: Blockchain literacy moderates the effect of blockchain technology group on risk perception.

Finally, studies suggest that the relationship between exposure to blockchain technology and behavioral intention to use e-voting systems is influenced by blockchain literacy

[68]. Those with higher levels of blockchain literacy are likely to have a deeper understanding of its principles, mechanisms, and applications [70]. This understanding can influence how they interpret and engage with blockchain-based e-voting systems and ultimately their willingness to adopt them [68].

We hypothesize the following:

H15a: Blockchain literacy moderates the effect of blockchain technology group on behavioral intention.

3.2.11. The Moderator Role of Technology Savviness. Technology savviness is commonly described as an individual's proficiency and familiarity with using and adapting to new technologies. As such, and corroborated by numerous researchers, tech-savvy people are more likely to invest time and put effort in learning new technologies such as blockchain [71].

As individuals exhibit higher levels of tech savviness, they possess a deeper understanding of the technological intricacies underlying e-voting systems. This understanding not only elevates their performance expectancy by enhancing their confidence in the system's reliability and effectiveness but also reduces their perceived effort, as they are better equipped to navigate through the technological requirements seamlessly [63, 72].

We hypothesize the following:

H2b: Tech savviness moderates the effect of blockchain technology group on performance expectancy.

H4b: Tech savviness moderates the effect of blockchain technology group on effort expectancy.

Furthermore, users' familiarity with technology prompts a sense of hedonic motivation, where the enjoyment derived from interacting with innovative systems drives their engagement and participation in e-voting [73].

We hypothesize the following:

H10b: Tech savviness moderates the effect of blockchain technology group on hedonic motivation.

Research states that the impact of exposure to blockchain technology on behavioral intention may vary depending on individuals' level of tech savviness. When exposed to a (new) technology, tech-savvy individuals may find it easier to understand and adapt to blockchain and so enhance their acceptance and willingness to use blockchain-based e-voting systems [74].

We hypothesize the following:

H15b: Tech savviness moderates the effect of blockchain technology group on behavioral intention.

3.2.12. Control Variables. Several studies highlight the crucial role control variables play in research, as they ensure the analysis accurately credits observed effects to the blockchain-based technology acceptance and provide a clearer understanding of the relationships among all variables within the model.

In similar contexts, demographic factors such as age, gender, political preference, and technology literacy have proven to be instrumental in shaping individuals' perspectives and behaviors [75–78].

Below, Figure 1 illustrates the proposed conceptual model, which follows the structure and principles discussed in the previous sections.

4. Methodology

The primary objective of this research is to study the potential of blockchain-based e-voting systems in empowering democracy. To do so, the method of combining experimental conditions with PLS-SEM of [13] is applied. The participants will be divided into separate groups, exposed to either the cloud- or blockchain-based e-voting solutions, then asked survey questions. This analysis enables the identification of potential distinctions across groups, offering a comprehensive understanding of how specific subgroups within the sample might exhibit divergent responses to both approaches [70].

For data collection a structured online survey was administered via Qualtrics XM. The survey measured the construct for the conceptual model described in the section above. The survey began with an introductory segment wherein participants were informed about the research's topic and their rights as volunteers. Following this, participants were directed to a series of questions designed to assess their general technological proficiency, as well as their familiarity with blockchain technology, which served as the moderators for the study (consult Tables A3 and A2). From this point onwards, the participants were randomly assigned to one of the two technologies under study: cloud or blockchain. Before proceeding, each respondent was presented with an educational video tailored to the respective technology (consult Appendices A and B), ensuring a foundational understanding of the e-voting system being explored, and so facilitating their engagement with the following survey items. Afterwards, the survey was structured into sections dedicated to exploring each of the study's primary constructs—performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, trust, risk perception, behavioral intention to use (consult Table A1). To measure the attitudes or opinions of respondents towards the statements, the Likert 7-point agreement scale was employed—1 representing "*strongly disagree*" and 7 representing "*strongly agree*" [84]. Upon completion, participants were requested to provide demographic information—age, gender, qualifications, occupation, and residency, as well as electoral habits data—frequency and political ideology. In total, the questionnaire consisted of a set of 56 questions, with respondents investing an estimate of 7–10 min to complete it in its entirety.

The sample selection process contains five distinct stages [85]: define the target population, select the sampling frame, choose the sampling technique, determine sample size, and collect data. The target population for this study consists of individuals aged 18 years and above, as this represents the minimum age required to vote in most countries. Convenience sampling was employed for participant selection. Participants were recruited directly by researchers through

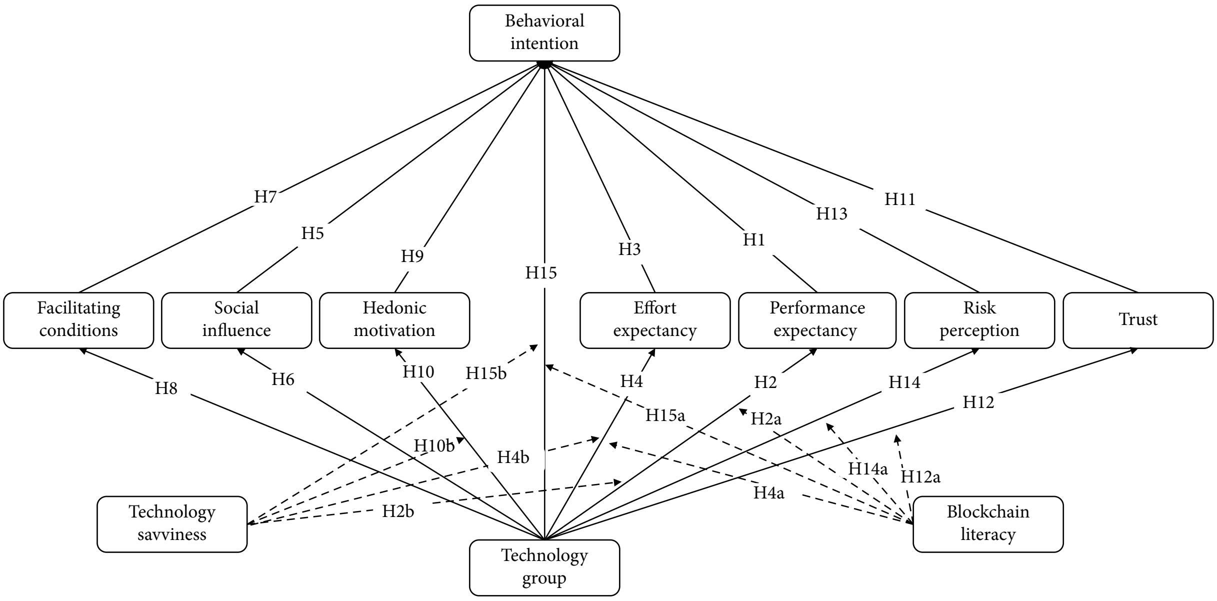

Figure 1: Proposed conceptual model.

various online channels, including social media platforms and online communities.[1] This method was chosen due to its practicality in reaching a diverse range of individuals within the target population. It is important to note that convenience sampling can introduce potential biases, as it may inadvertently favor individuals who have greater familiarity with or interest in this specific technology or technology in general. Table 2 shows that the sample does reflect this collection approach and does not result in a population representative sample, as is often the case in social sciences, with a higher proportion of younger participants and a majority of participants from either the United Kingdom or Portugal. To mitigate this effect, we include both technological savviness and blockchain literacy as variables in the model; however, this selection bias should be considered when generalizing findings to the broader population.

The sample size was determined using the inversed square root method of minimal sample size calculation [86], considering a 5% significance level and an expected minimum path coefficient in a range of 0.11–0.2, which suggested a minimum of 155 participants per survey (thus, a total of 310 respondents). As previously mentioned, the data collection was conducted via an online questionnaire administered by Qualtrics XM. Participant demographics are reported in Table 1.

Before launching the questionnaire and initiating the data collection phase, a pilot test was conducted to evaluate the effectiveness of the survey. The pilot test involved a small sample of individuals (10 participants, selected by convenience sampling method), who were asked to complete the questionnaire and provide feedback on the clarity, relevance, and comprehensiveness of the educational video and questions, as well as the usability of the online platform. Based on the inputs received, the necessary adjustments were made to the survey, including modifications to wording, formatting, and question sequence.

Ethical approval was obtained from the Ethics Committee of NOVA IMS and MagIC Research Center on February 29, 2024, ensuring compliance with ethical standards and respondents' rights and welfare. The online questionnaire was accessible to participants from March 9 to March 23, 2024. At the survey's conclusion, a total of 416 valid responses were gathered (from the 601 collected).

4.1. Data Analysis. Given the exploratory nature of this research and its complexity, PLS-SEM will be employed to study the citizens' perspective on electronic voting, as well as the variables that may influence their outlook, and detect underlying patterns.

Before withdrawing conclusions from the PLS-SEM results, the measurement models must be assessed to evaluate if the required criteria are met. Similar to other statistical methods, PLS-SEM has guidelines that suggest how to interpret the results and evaluate model results [87–89].

The first step in reflective measurement model assessment is to examine if the indicator loadings are, as recommended, above 0.708. This threshold separates the constructs that explain more than 50% of the indicator's variance from the remaining, and so consequently those who grant acceptable statement reliability. An analysis of the data (consult Table A4) revealed that two statements fell short of the desired criteria level—TS4* (0.494) and TS6* (0.507). After evaluating other measures and careful consideration, the items were removed from the model.

The second step is reviewing internal consistency reliability (consult Table A5), most often by interpreting composite reliability value or Cronbach's alpha [90]. The data shows that the internal consistency reliability values for the

TABLE 2: Survey participant demographics.

Demographic characteristics		Sample ($N = 416$)	Percentage (%)
Age	18–25	227	54.57%
	26–33	73	17.55%
	34–41	42	10.10%
	42–49	24	5.77%
	50+	50	12.02%
Gender	Female	266	63.94%
	Male	145	34.86%
	Prefer not to say	5	1.20%
Highest education level	High school	81	19.47%
	Vocational training	22	5.29%
	Bachelor's degree	218	52.40%
	Master's degree	91	21.88%
	Doctorate's degree	4	0.96%
Occupation	Student	119	28.61%
	Working student	100	24.04%
	Employed	156	37.50%
	Self-employed	24	5.77%
	Unemployed	6	1.44%
	Retired	11	2.64%
Region	Portugal	231	55.53%
	United Kingdom	69	16.59%
	United States	24	5.77%
	Brazil	11	2.64%
	Others	81	19.47%
Election participation	Never voted	35	8.41%
	Rarely	29	6.97%
	Occasionally	35	8.41%
	Often	85	20.43%
	Always	232	55.77%
Political ideology	Strongly conservative	6	1.44%
	Conservative	30	7.21%
	Moderate/independent	200	48.08%
	Liberal	151	36.30%
	Strongly liberal	29	6.97%

constructs are satisfactory to good (above 0.700), apart from the facilitating conditions construct showing a slightly lower value (0.610).

The third step is to assess the convergent validity of each construct measure. The metric used for such analysis is the average variance extracted (AVE). The minimum acceptable AVE is 0.500, as it indicates that the construct explains at least 50% of the variance of the items that make up the construct. This criterion is met (consult Table A5), which means that constructs are converging well and are reliable measures of the intended latent construct.

The fourth, and last, step is to assess the discriminant validity. Fornell and Larcker [91] proposed that the shared variance for all model constructs should not be larger than their AVEs. Recent research shows that the Fornell–Larcker criterion may not perform well in certain situations. As such, [92] proposed the heterotrait–monotrait ratio (HTMT) of the correlations, suggesting a threshold ceiling value ranging between 0.850 and 0.900. The calculated values meet the established criteria, presenting a maximum ratio value of 0.823 (consult Table A6), indicating acceptable levels of measurement reliability and validity.

TABLE 3: Support of hypothesis.

Hypothesis	Path coefficient	p value	Supported?
H1: Performance expectancy positively influences behavioral intention to use e-voting systems.	0.289	≤ 0.001	✓
H3: Effort expectancy positively influences behavioral intention to use e-voting systems.		0.687	×
H5: Social influence positively influences behavioral intention to use e-voting systems.	0.146	≤ 0.001	✓
H7: Facilitating conditions positively influences behavioral intention to use e-voting systems.		0.227	×
H9: Hedonic motivation positively influences behavioral intention to use e-voting systems.	0.290	≤ 0.001	✓
H11: Trust positively influences behavioral intention to use e-voting systems.	0.171	0.003	✓
H13: Risk perception negatively influences behavioral intention to use e-voting systems.	− 0.116	0.001	✓
H15: The effect of blockchain technology group is fully mediated by the constructs defined within the concept model, thereby expecting no additional direct effect on the behavioral intention to use e-voting systems.		0.219	×

When measurement model assessment is satisfactory, the next step is evaluating the structural model. The most frequent criteria are the inner variance inflation factor (INNER VIF), coefficient of determination (R^2), the cross-validated redundancy measure (Q^2), and the statistical significance and relevance of the path coefficients [93].

Before assessing the structural relationships, collinearity must be examined, as to ensure it does not bias the regression results. VIF values above 5 are indicative of probable collinearity issues among the predictor constructs [94]. The calculated VIF values for the data collected sit between 1.000 and 3.320 (consult Appendix Table A7), suggesting low level of correlation among predictors, providing a good level of assurance for the coefficient's estimates.

The R^2 measures the variance explained by each of the constructs. Based on Chin [87] and models are deemed weak if their R^2 values are under 0.50, moderate between 0.50 and less than 0.67, moderately strong if ranging from 0.67 to 0.75, and strong if equal to or greater than 0.75. Having registered a R^2 of 0.691 and an Adjusted R^2 of 0.679, the model is considered as moderately strong (consult Table A8).

The Q^2 method combines aspects of out-of-sample prediction and in-sample explanatory power, as it removes single points in the data and imputes them with the mean and estimates the model parameters [88, 92]. A greater Q^2 value suggests greater predictive accuracy, with small differences between predicted and original values. As a rule of thumb, Q^2 values above 0, 0.25, and 0.5 indicate small, medium, and large predictive relevance, respectively, of the PLS-path model. The obtained Q^2 value of 0.021 suggests a small predictive relevance and indicates a conversion to a mean-centered model (consult Appendix Table A9).

The final step is to assess the statistical significance and relevance of the path coefficients (consult Table A10). To determine the path coefficients significance and evaluate their values, a bootstrapping analysis (5000 iterations) was conducted. The values range between − 1 and 1 and allow inference about the direction (negative or positive) and strength (weak or strong) of the relationship between variables. The output of the analysis and interpretation can be found in the following sections.

5. Results

The results (consult Table 3) suggest that performance expectancy (H1), social influence (H5), and hedonic motivation (H9) present a statistically significant relationship ($p \leq 0.001$). The same can be said for trust (H11), revealing a positive influence on behavioral intention to adopt e-voting systems. The data also confirm that risk perception (H13) negatively influences behavioral intention to use e-voting systems. On the other hand, the effort expectancy (H3) and facilitating conditions hypotheses were rejected, presenting a p values of 0.687 and 0.227, respectively. Lastly, the influence of being in the blockchain technology group (H15) on behavioral intention to adopt e-voting systems was considered not statistically significant, supported by a p value of 0.219. Figure 2 provides the complete results of the PLS-SEM analysis for the conceptual model.

Additionally (consult Table 4), blockchain technology group displays a statistically significant relationship with effort expectancy (H4) and social influence (H6), registering a p values of 0.018 and 0.049, respectively. The hypothesis reflecting its influence on the remaining constructs—performance expectancy, facilitating conditions, hedonic motivation, trust, and risk perception—was not deemed statistically significant and was therefore rejected.

The numbers (consult Table 5) also uncover that blockchain literacy does not moderate the effect of the blockchain technology group on any of the examined constructs. All the proposed hypotheses (H2a, H4a, H12a, H14a, and H15a) were rejected, as none showed significant effects. Specifically, the p values were as follows: performance expectancy (0.514), effort expectancy (0.631), trust (0.841), risk perception (0.113), and behavioral intention (0.464). This indicates that blockchain literacy does not influence the relationship between the blockchain technology group and these constructs.

Regarding the moderating effect of tech savviness on the relationship between blockchain technology group and the constructs (consult Table 6), the tested hypotheses

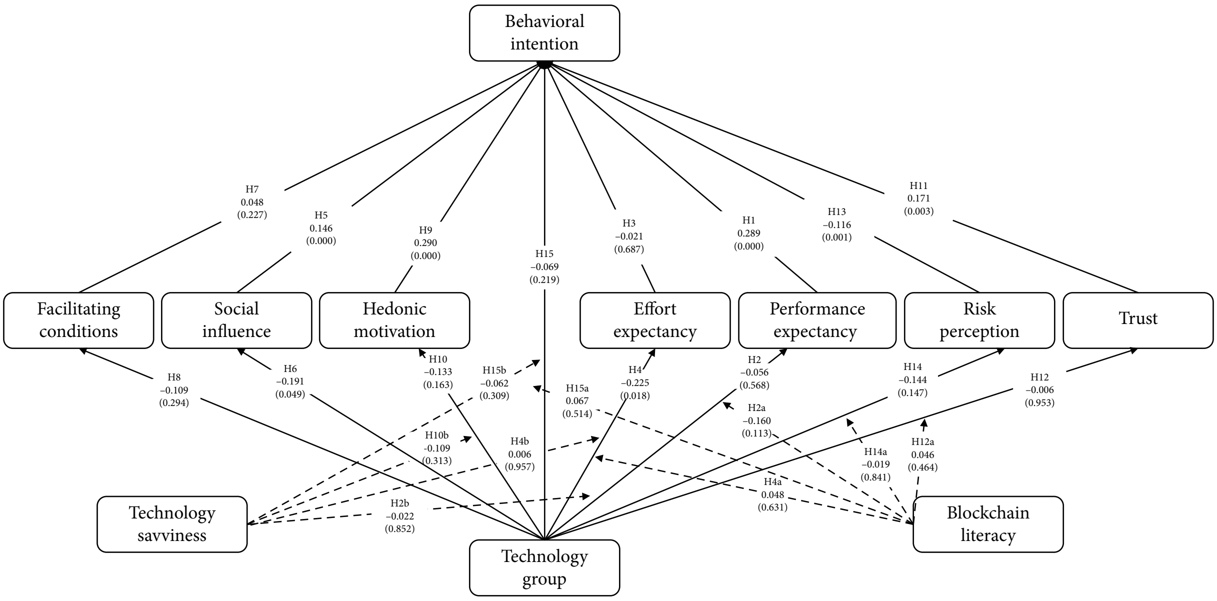

Figure 2: Structural model estimates.

TABLE 4: Support of blockchain technology group hypothesis.

Hypothesis	Path coefficient	p value	Supported?
H2: Blockchain technology group positively influences performance expectancy.		0.568	×
H4: Blockchain technology group negatively influences effort expectancy.	− 0.225	0.018	✓
H6: Blockchain technology group positively influences social influence.	− 0.191	0.049	✓
H8: Blockchain technology group does not influences facilitating conditions.		0.294	×
H10: Blockchain technology group positively influences hedonic motivation.		0.163	×
H12: Blockchain technology group positively influences trust.		0.953	×
H14: Blockchain technology group negatively influences risk perception.		0.147	×

were rejected. This suggests that tech savviness does not significantly alter the impact of blockchain technology group on performance expectancy ($p = 0.852$), effort expectancy ($p = 0.957$), hedonic motivation ($p = 0.313$), or behavioral intention ($p = 0.309$) in the context of e-voting systems.

6. Discussion

This research is aimed at understanding citizen's acceptance and adoption of blockchain e-voting systems. To do so, a technology adoption model based on the constructs from the UTAUT2 model was combined with trust and perceived risk. Additionally, an experimental condition was included to specifically evaluate blockchain technology's unique contribution.

Overall, the results revealed that performance expectancy, social influence, hedonic motivation, trust, and perception of risk associated with e-voting systems all influence behavioral intention to use e-voting systems as is common in the literature [12].

The importance of social influence, as found here, is strongly supported by the e-voting literature. Citizens are more likely to engage with e-voting if their peers—such as family, friends, or colleagues—also participate, making peer endorsement and social norms critical in promoting acceptance, especially for emerging technologies like blockchain-based e-voting systems. It should be noted that this is not always the case for the use of blockchain technology and may be domain specific, as this was not found to be the case for blockchain-based supply chains [95] or blockchain gaming [96], but was for digital asset applications as found by Restuputri et al. [97].

Performance expectancy emerged as one of the strongest predictors of behavioral intention, highlighting users' prioritization of perceived benefits and effectiveness when adopting new technologies. The prominent role of performance expectancy aligns closely with existing UTAUT2 studies, consistently identifying it as a robust and influential determinant across diverse technological contexts [34]. The importance of hedonic motivation, while consistent with the technology adoption literature, is interesting in the context

TABLE 5: Support of blockchain literacy moderator effect hypothesis.

Hypothesis	Path coefficient	p value	Supported?
H2a: Blockchain literacy moderates the effect of blockchain technology group on performance expectancy.		0.514	×
H4a: Blockchain literacy moderates the effect of blockchain technology group on effort expectancy.		0.631	×
H12a: Blockchain literacy moderates the effect of blockchain technology group on trust.		0.841	×
H14a: Blockchain literacy moderates the effect of blockchain technology group on risk perception.		0.113	×
H15a: Blockchain literacy moderates the effect of blockchain technology group on behavioral intention.		0.464	×

TABLE 6: Support of technology savviness moderator effect hypothesis.

Hypothesis	Path coefficient	p value	Supported?
H2b: Tech savviness moderates the effect of blockchain technology group on performance expectancy.		0.852	×
H4b: Tech savviness moderates the effect of blockchain technology group on effort expectancy.		0.957	×
H10b: Tech savviness moderates the effect of blockchain technology group on hedonic motivation.		0.313	×
H15b: Tech savviness moderates the effect of blockchain technology group on behavioral intention.		0.309	×

of blockchain and e-voting as the "enjoyment" or hedonic contribution is not typically proposed as either a benefit of blockchain or e-voting. This then may be an important area to explore further in the drive to increase the use of voting systems and improve democratic participation.

Notably, risk perception emerged as the strongest negative influence on adoption, in line with typical expansions of the UTAUT2 model [34], yet implementing blockchain does not appear to affect the level of perceived risk. This is important, due to its status as a relatively emerging technology, sometimes associated with fraud [98]. Increasing the perception of risk could be a major drawback of introducing blockchain to e-voting systems, and it is then significant that we do not find evidence for this effect here. This finding should also inform awareness campaigns, as linking blockchain too strongly to security threats may produce a boomerang effect and increase the association between blockchain and risk, consequently reducing the overall likelihood of adoption.

The same cannot be said for effort expectancy and facilitating conditions, whose hypotheses were not supported. While we test these based on their importance in the foundational UTAUT2 model [12], our results for effort expectancy are in line with the broader literature on UTAUT2, which finds effort expectancy to be the least reliable of the UTAUT2 constructs [34]. In the case of blockchain e-voting, this is particularly important, as we do find that the use of blockchain reduces participants view of effort expectancy, a potential benefit of applying blockchain technology. However, this benefit is then undermined by our finding that the relationship between effort expectancy and behavioral intention does not hold.

Interestingly, the results suggest that neither the users' perceptions of the ease of using e-voting systems, nor the presence of supportive resources and infrastructure yield a significant impact on their intention to adopt e-voting systems. Literature on technology adoption often emphasizes the pivotal role of perceived usefulness and ease of use in shaping user intentions. However, since it is a relatively new technology, only a few have firsthand experience, making it challenging for them to be able to assess the level of difficulty and its influence. These conclusions align with the ones drawn out of similar studies such as Sheel &Nath [99]. Moreover, since 75% of the participants report having a higher education diploma, it seems plausible to assume that they would possess the necessary equipment, have no trouble in finding the necessary information about the matter, and predict few difficulties in adopting this new technology. Furthermore, theories on political participation and voting intention [11] mark ambition, desire, motivation and network influence as the leading factors, making effort expectancy and facilitating conditions less decisive and influential factors on whether citizens would participate in the electoral act or not.

The study was undertaken with an experimental condition to try to determine whether there are significant differences between blockchain and cloud technologies in e-voting. The data collected suggests that citizens perceive blockchain-based e-voting systems to require more effort, indicating potential usability challenges and so, the need for further research and development, as supported by similar research [45]. Interestingly, though, we found the effort expectancy variable to not significantly drive adoption, indicating that even if improvements cannot be made to the user experience of the technology, this should not be considered a reason not to implement blockchain for e-voting.

Besides these conclusions, it appears that the use and knowledge of blockchain technology in e-voting systems does not consistently influence users' perceptions and attitudes compared to the cloud-based e-voting systems in all the other dimensions—performance expectancy, facilitating conditions, hedonic motivation, trust, and risk perception. It suggests a convergence on how citizens perceive and evaluate the two technologies. From the citizens' perspective, the differences between blockchain and cloud technologies may not be clear, leading to a perception that they serve similar purposes and offer comparable benefits. Consequently, it seems reasonable to expect that individuals would evaluate them similarly. These results state a broader trend in technological adoption, where the practical outcomes and perceived benefits take precedence over technical distinctions.

The role of trust is particularly important for blockchain e-voting technology. Trust is an important driver in the e-voting literature; it is the most commonly found significant extension to the UTAUT2 framework [34] and has been specifically shown as important when examining adoption for e-government services more generally [100]. It is not surprising then that we replicate this result and find trust to be an important driver of e-voting adoption. Given trust is so important, there should then be a key role for blockchain, which lists trust as a fundamental proposition of the transparency and security properties of blockchain, so then trust should be a key mediator through which blockchain can drive adoption of e-voting. Our findings suggest that simply introducing blockchain does not, on its own, translate into higher or lower trust in e-voting, and blockchain technology is then not delivering one of its most important claimed benefits. This was additionally not moderated by either technology savviness or blockchain literacy, indicating that the level of ability to understand or the available knowledge does not affect this result, meaning that understanding the technology may not be the issue and simple awareness campaigns to improve knowledge or ability may not unlock the trust potential of blockchain. It should be noted that the difference between general trust (e.g., trust in technology or institutions in a broad sense) and political trust (i.e., trust in the government or electoral authorities) may play a role here. In this study, only general trust was measured, meaning that any distinct effects arising from variations in political trust remain unexplored. Political trust can shape how people specifically perceive an e-voting system's legitimacy; if citizens harbor doubts about government integrity, they may remain wary of any technology introduced under that government's oversight. Conversely, in contexts of high political trust, even relatively new or complex voting systems might be more easily accepted, as individuals assume government authorities have thoroughly vetted them. As a result, the role of political trust could remain a potential area for further study.

Moreover, our findings demonstrate that neither the individuals' level of blockchain literacy, nor their level of technology savviness, play a significant role on the acceptance and adoption of such systems. This suggests that concerns about digital literacy, often found in the literature, may be less critical than often assumed in this case, as these factors do not appreciably shape users' attitudes and intentions of the characteristics of the technology. The study confirms that the benefits or challenges of blockchain and, consequently, its stand on the adoption in e-voting are not due to users' current levels of technical knowledge or blockchain familiarity. The lack of correlation between blockchain literacy, tech savviness, and the perceived impact of blockchain technology on e-voting adoption can be attributed to several factors. First, blockchain e-voting systems represent a relatively new technological innovation, and as such, there may be a lack of consensus regarding the level of technological proficiency and resources needed for their use [101]. Secondly, given that blockchain e-voting systems offer compelling benefits such as enhanced security, transparency, and accessibility in the voting process, it could happen that these advantages may serve as strong motivators for citizens to overcome any perceived technological barriers, learn and adopt the technology [102].

Studying blockchain technology at such an early stage of potential mass adoption is essential to help understand consumers response without expensive large-scale pilot programs but may result in limitations. For instance, as users become more accustomed to its functionalities, so their attitudes and behaviors towards blockchain-based e-voting systems may evolve. Secondly, while the evaluation of blockchain e-voting technology in this study is primarily focused on users' intentions to use the system, it must be recognized that intention does not always translate into actual usage.

Having performance expectancy, social influence, hedonic motivation, trust, and risk perception emerged as the main drivers, it is suggested that while designing and developing such systems, the user perceptions and motivations should be considered. Based on the literature review, and on the results, leveraging social influence through strategic communication and/or endorsements from trusted figures could further boost adoption rates. Communication should take into account the potential for associating either blockchain or e-voting with risk or security vulnerability. Educational initiatives aimed at increasing public awareness and understanding of e-voting technologies could alleviate concerns and enhance acceptance. However, these must come within a broader policy of the creation of regulatory frameworks that offer clear accountability, oversight mechanisms, and user protections. Cybersecurity should both be covered within the regulatory framework and communicate in such a way as to emphasize system resilience and independent verification rather than technical complexity, to avoid reinforcing risk perceptions. These frameworks could reinforce citizens' trust in electoral processes, especially when implemented transparently and in collaboration with independent bodies as is possible on blockchain.

Finally, since the introduction of blockchain technology was found to not drive adoption on its own in this context, its integration must not only explore effective integration strategies that leverage its unique features, such as transparency and immutability, but more importantly, be part of a broader strategy that emphasizes user-centric design principles. Transparent processes, robust security measures, policy frameworks and regulatory approaches, intuitive user interfaces, enjoyable user experiences, and effective communication strategies are key factors to develop an e-voting system and cultivate trust among the citizens.

7. Conclusion

This research provides a complete framework for assessing the citizens' perspective on blockchain-based e-voting system adoption. A model designed upon the UTAUT2 methodology, combined with an experimental approach, made testing the cause–effect relationship between the factors and behavior intention possible.

The results state that users are more likely to adopt e-voting systems when they perceive them to be effective, socially endorsed, enjoyable, trustworthy, and low in perceived risk.

However, and since e-voting is a relatively new concept, only a few people have firsthand experience with it, making it challenging to assess the level of difficulty and its influence. Even so, the data collected suggests that citizens perceive blockchain-based e-voting systems to require more effort when compared to cloud technology, indicating potential usability challenges, and emphasizing the need for tailored educational initiatives to bridge knowledge gaps and empower citizens with the necessary skill set and understanding to effectively engage with blockchain e-voting systems.

Overall, the use and knowledge of blockchain technology does not consistently influence users' perceptions and attitudes when compared to the cloud. These results state a broader trend in technological adoption, where the practical outcomes and perceived benefits take precedence over technical distinctions. Other factors may have a stronger influence on the subject matter and so, further research may be needed to identify them, as well as understand their impact on user acceptance and adoption.

Overall, this research contributes to an understanding of the dynamics driving citizens' acceptance and adoption of e-voting systems, while offering valuable insights for policymakers, electoral authorities, technology developers, and other stakeholders involved in the design, implementation, and regulation of e-voting systems. The findings suggest that designers of e-voting systems should prioritize factors such as performance expectancy, social influence, hedonic motivation, trust, and risk perception, as these significantly influence adoption. While blockchain technology in theory offers benefits in transparency and security, it alone does not drive adoption; and thus, cannot be relied upon to drive turnout. Policymakers should craft regulations emphasizing user-centric design and public education to enhance acceptance and trust in e-voting systems and the integrity, inclusivity, and efficiency in democratic processes.

Blockchain-Based E-Voting System's Video Script

Voting and expressing ourselves has never been more crucial, and blockchain technology is here to revolutionize the way we do it.

We are used to the traditional way of voting with pen and paper. While it is familiar, it does have its challenges—it can take a lot of time, it is manual and prone to errors, and it relies heavily on the integrity of the officials, among other things.

Let us explore how technology, specifically blockchain, is reshaping this process.

Blockchain works like a digital ledger supervised by a decentralized network of participants who collectively manage and store the votes.

This decentralized control removes potential vulnerabilities, as the entire system's integrity relies on the security measures maintained by the combined efforts of many participants. Furthermore, since all votes are stored in a network of computers, there is a significantly lower risk of data breaches or manipulation.

You can vote by downloading a mobile app. After, you verify your identity—often via document scanning or live face screening—and you are ready to vote. It is fast, easy, and accessible.

In summary, blockchain-based e-voting emerges as a transformative stride in our democratic participation, offering accessibility, efficiency, and real-time data. At the same time, it is crucial to strike a balance, mitigating the associated risks.

Join us in this exploration of a potential future of our electoral processes using blockchain-based systems.

Cloud-Based E-Voting System's Video Script

Voting and expressing ourselves has never been more crucial, and cloud technology is here to revolutionize the way we do it.

We are used to the traditional way of voting with pen and paper. While it is familiar, it does have its challenges—it can take a lot of time, it is manual and prone to errors, and it relies heavily on the integrity of the officials, among other things.

Let us explore how technology, specifically the cloud, is reshaping this process.

The cloud works like an online folder supervised by a central authority that manages and stores the votes.

This centralized control introduces potential vulnerabilities, as the entire system's integrity relies on the security measures implemented by the central authority. Furthermore, since all votes are stored in a single location, there is a risk of data breaches or manipulation.

You can vote by downloading a mobile app. After, you verify your identity—often via document scanning or live face screening—and you are ready to vote. It is fast, easy, and accessible.

In summary, cloud-based e-voting emerges as a transformative stride in our democratic participation, offering accessibility, efficiency, and real-time data. At the same time, it is crucial to strike a balance, mitigating the associated risks.

Join us in this exploration of a potential future of our electoral processes using cloud-based systems.

TABLE A1: Question forms.

Variable	Questions	Adopted from
Performance expectancy (PE)	A blockchain-based internet voting system would enable a more efficient and accurate electoral process.	[12, 36]
	A blockchain-based internet voting system would increase the transparency and credibility of the electoral process.	
	A blockchain-based internet voting system would provide me with a secure and private channel to cast my vote.	
	I would be able to vote more conveniently and quickly if I use the blockchain-based internet voting system.	
Effort expectancy (EE)	I believe the blockchain-based internet voting system would be easy to use.	
	I believe there would be a tutorial/help guidance for using the blockchain-based internet voting system.	
	I believe that the blockchain-based internet voting system ballot design would be easy to understand.	
Social influence (SI)	People who influence my behavior would think that I should use a blockchain-based internet voting system.	
	People who are important to me would think that I should use a blockchain-based internet voting system.	
	In general, my country would support the adoption of a blockchain-based internet voting system.	
Facilitating conditions (FC)	I would have the necessary resources to use a blockchain-based internet voting system.	
	My country would have the necessary resources for implementing a blockchain-based internet voting system.	
	Assistance would be available in case of system difficulties.	
Hedonic motivation (HM)	Using a blockchain-based internet voting system would be fun.	
	Using a blockchain-based internet voting system would be enjoyable.	
	Using a blockchain-based internet voting system would be very entertaining.	
Behavioral intention to use (BI)	I would use a blockchain-based internet voting system in the near future.	[76, 79]
	I would prefer a blockchain-based internet voting system over traditional paper and pencil voting.	
	I would be committed to use a blockchain-based internet voting system in the upcoming elections.	
Trust in technology (TT)	I believe a blockchain-based internet voting system can keep the voting data secure and less prone to fraud.	[80, 81]
	A blockchain-based internet voting system has enough safeguards to make me feel comfortable using it in the election process.	
	In general, the blockchain-based internet voting system is a robust and safe environment to vote.	[82]
Risk perception (RP)	Using a blockchain-based internet voting system would be risky.	[62]
	Using a blockchain-based internet voting system would subject my voting account to potential fraud.	
	Using a blockchain-based internet voting system would put my privacy at risk.	
Technology savviness (TS)	I can usually figure out how new high-tech products and services work without help from others.	[83]
	I keep up with the latest technological developments in my areas of interest.	
	I am always open to learning about new and different technologies.	
	There is no sense trying out new high-tech products when what I have already is working fine.	
	I enjoy the challenge of figuring out high-tech gadgets.	
	I have avoided trying new high-tech gadgets because of the time it takes to learn them.	
Blockchain literacy (BL)	I have heard of blockchain technology.	[70].
	I am aware of the basic principles and functionalities of blockchain technology.	
	I am aware of and know how to use a blockchain-based internet voting system.	

TABLE A2: Blockchain literacy profile of participants.

Blockchain literacy		Sample ($N = 416$)	Percentage (%)
I have heard of blockchain technology.	Strongly agree	83	19.95%
	Agree	118	28.37%
	Partially agree	51	12.26%
	Neutral	29	6.97%
	Partially disagree	14	3.37%
	Disagree	47	11.30%
	Strongly disagree	74	17.79%
I am aware of the basic principles and functionalities of blockchain technology.	Strongly agree	36	8.65%
	Agree	67	16.11%
	Partially agree	71	17.07%
	Neutral	47	11.30%
	Partially disagree	36	8.65%
	Disagree	71	17.07%
	Strongly disagree	88	21.15%
I am aware of and know how to use a blockchain-based internet voting system.	Strongly agree	17	4.09%
	Agree	26	6.25%
	Partially agree	53	12.74%
	Neutral	52	12.50%
	Partially disagree	39	9.38%
	Disagree	113	27.16%
	Strongly disagree	116	27.88%

TABLE A3: Technology savviness profile of participants.

Technology savviness		Sample ($N = 416$)	Percentage (%)
I can usually figure out how new high-tech products and services work without help from others.	Strongly agree	115	27.64%
	Agree	151	36.30%
	Partially agree	91	21.88%
	Neutral	18	4.33%
	Partially disagree	24	5.77%
	Disagree	15	3.61%
	Strongly disagree	2	0.48%
I keep up with the latest technological developments in my areas of interest.	Strongly agree	81	19.47%
	Agree	153	36.78%
	Partially agree	107	25.72%
	Neutral	34	8.17%
	Partially disagree	22	5.29%
	Disagree	18	4.33%
	Strongly disagree	1	0.24%
I am always open to learning about new and different technologies.	Strongly agree	140	33.65%
	Agree	171	41.11%
	Partially agree	70	16.83%
	Neutral	18	4.33%
	Partially disagree	11	2.64%
	Disagree	4	0.96%
	Strongly disagree	2	0.48%
There is no sense trying out new high-tech products when what I have already is working fine.	Strongly agree	19	4.57%
	Agree	21	5.05%
	Partially agree	58	13.94%
	Neutral	29	6.97%
	Partially disagree	93	22.36%
	Disagree	123	29.57%
	Strongly disagree	73	17.55%
I enjoy the challenge of figuring out high-tech gadgets.	Strongly agree	76	18.27%
	Agree	125	30.05%
	Partially agree	102	24.52%
	Neutral	66	15.87%
	Partially disagree	24	5.77%
	Disagree	19	4.57%
	Strongly disagree	4	0.96%
I have avoided trying new high-tech gadgets because of the time it takes to learn them.	Strongly agree	8	1.92%
	Agree	22	5.29%
	Partially agree	60	14.42%
	Neutral	45	10.82%
	Partially disagree	57	13.70%
	Disagree	139	33.41%
	Strongly disagree	85	20.43%

TABLE A4: Outer loadings (prior).

Item/statement < -construct	Outer loadings
TS4* < -TS	0.494
TS6* < -TS	0.507
FC2 < -FC	0.719
FC1 < -FC	0.728
SI3 < -SI	0.730
TS1 < -TS	0.737
FC3 < -FC	0.793
TS2 < -TS	0.795
PE4 < -PE	0.796
TS5 < -TS	0.823
TS3 < -TS	0.826
BL3 < -BL	0.827
PE3 < -PE	0.836
EE2 < -EE	0.861
SI1 < -SI	0.865
RP3 < -RP	0.871
BL1 < -BL	0.873
PE2 < -PE	0.874
EE1 < -EE	0.894
HM3 < -HM	0.898
BI2 < -BI	0.914
SI2 < -SI	0.914
HM1 < -HM	0.915
PE1 < -PE	0.915
EE3 < -EE	0.918
RP1 < -RP	0.919
BI1 < -BI	0.926
BL2 < -BL	0.927
HM2 < -HM	0.932
TT1 < -TT	0.933
RP2 < -RP	0.941
TT2 < -TT	0.948
BI3 < -BI	0.950
TT3 < -TT	0.952
Age < -age	1.000
Gender <- gender	1.000
Ideology <- ideology	1.000
Technology group <- technology group	1.000
BL x technology group - > BL x technology group	1.000
TS x technology group - > TS x technology group	1.000

TABLE A5: Measurement model assessment measure overview.

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
BI	0.922	0.924	0.951	0.865
BL	0.849	0.854	0.909	0.769
EE	0.871	0.879	0.921	0.794
FC	0.610	0.609	0.791	0.558
HM	0.903	0.910	0.939	0.837
PE	0.878	0.882	0.917	0.734
RP	0.898	0.909	0.936	0.830
SI	0.788	0.814	0.877	0.706
TS	0.839	0.852	0.891	0.672
TT	0.939	0.941	0.961	0.892

TABLE A6: Heterotrait–monotrait ratio (HTMT).

Constructs	HTMT
PE < -> BI	0.823
TT < -> PE	0.797
FC < -> EE	0.771
TT < -> BI	0.758
HM < -> BI	0.747
PE < -> EE	0.705
PE < -> HM	0.699
TT < -> RP	0.680
SI < -> BI	0.643
TT < -> HM	0.622
SI < -> PE	0.615
TT < -> SI	0.598
RP < -> PE	0.572
RP < -> BI	0.548
PE < -> FC	0.538
EE < -> BI	0.520
SI < -> HM	0.515
HM < -> EE	0.506
TS < -> BL	0.502
FC < -> BI	0.501
SI < -> FC	0.484
TT < -> FC	0.484
HM < -> FC	0.458
TT < -> EE	0.429
SI < -> EE	0.379
TS < -> FC	0.377
TS < -> EE	0.364
RP < -> HM	0.357
Gender <- > BL	0.313
RP < -> EE	0.282
SI < -> RP	0.281
TS < -> HM	0.272
TS < -> Gender	0.252
RP < -> FC	0.232
TS < -> PE	0.232
TS < -> BI	0.204
HM < -> BL	0.194
FC < -> BL	0.189
TS < -> age	0.183
TS < -> SI	0.182
EE < -> BL	0.171
TT < -> BL	0.171
Gender <- > FC	0.156
Ideology <- > EE	0.147
FC < -> age	0.146
Ideology <- > age	0.145
SI < -> BL	0.145
PE < -> ideology	0.138
SI < -> gender	0.137
TT < -> TS	0.134
Technology group <- > EE	0.131
PE < -> BL	0.130
EE < -> age	0.125
BL < -> BI	0.123
RP < -> age	0.116
Ideology <- > FC	0.113
Technology group <- > SI	0.108
Ideology <- > BI	0.104
SI < -> age	0.097
Technology group <- > FC	0.095
TS < -> RP	0.087
BL < -> age	0.081
Technology group <- > HM	0.078
Technology group <- > BI	0.076
Gender <- > age	0.075
Ideology <- > gender	0.075
Technology Group <- > RP	0.075
TT < -> ideology	0.074
TS < -> ideology	0.066
PE < -> age	0.059
Gender <- > EE	0.055
HM < -> age	0.054
Ideology <- > BL	0.050
PE < -> gender	0.050
SI < -> ideology	0.049
Ideology <- > HM	0.047
HM < -> gender	0.043
RP < -> gender	0.043
Technology group <- > ideology	0.042
BI <- > age	0.040
Technology group <- > TS	0.038
Technology group <- > PE	0.036
Gender <- > BI	0.034
Technology group <- > BL	0.032
TT < -> age	0.027
Technology group <- > gender	0.026
RP < -> BL	0.023
Technology group <- > TT	0.022
RP < -> ideology	0.019
TT < -> gender	0.012
Technology group <- > age	0.004

TABLE A7: Inner variance inflation factor.

Constructs	BI
PE - > BI	3.320
TT - > BI	3.181
BL - > BI	2.686
TS - > BI	2.653
BL - > EE	2.557
BL - > PE	2.557
BL x technology group - > BI	2.527
BL x technology group - > EE	2.482
BL x technology group - > PE	2.482
TS - > EE	2.435
TS - > PE	2.435
TS x technology group - > BI	2.404
TS x technology group - > EE	2.359
TS x technology group - > PE	2.359
EE - > BI	2.247
BL - > RP	2.022
BL - > TT	2.022
BL x technology group - > RP	2.021
BL x technology group - > TT	2.021
TS - > HM	1.925
TS x technology group - > HM	1.924
HM - > BI	1.870
RP - > BI	1.846
FC - > BI	1.697
SI - > BI	1.573
Gender - > BI	1.181
Age - > BI	1.095
Ideology - > BI	1.073
Technology group - > BI	1.045
Technology group - > EE	1.003
Technology group - > PE	1.003
Technology group - > HM	1.001
Technology group - > RP	1.001
Technology group - > TT	1.001
Technology group - > FC	1.000
Technology group - > SI	1.000

TABLE A8: *R*-squared.

	***R*-squared**	**Adjusted *R*-squared**
BI	0.691	0.679

TABLE A9: *Q*-squared.

	Q^2 predict	**RMSE**	**MAE**
BI	0.021	0.995	0.799

TABLE A10: Path coefficient.

Path	Hypothesis	Original sample	Sample mean	Standard deviation	T-statistics	p values
PE - > BI	H1	0.289	0.292	0.070	4.146	≤ 0.001
EE - > BI	H3	− 0.021	− 0.018	0.052	0.403	0.687
SI - > BI	H5	0.146	0.145	0.035	4.159	≤ 0.001
FC - > BI	H7	0.048	0.050	0.040	1.209	0.227
HM - > BI	H9	0.290	0.287	0.048	6.044	≤ 0.001
TT - > BI	H11	0.171	0.169	0.059	2.925	0.003
RP - > BI	H13	− 0.116	− 0.118	0.033	3.466	0.001
TG - > BI	H15	− 0.069	− 0.069	0.056	1.228	0.219
TG - > PE	H2	− 0.056	− 0.054	0.098	0.570	0.568
TG - > EE	H4	− 0.225	− 0.225	0.095	2.377	0.018
TG - > SI	H6	− 0.191	− 0.191	0.097	1.971	0.049
TG - > FC	H8	− 0.109	− 0.111	0.104	1.050	0.294
TG - > HM	H10	− 0.133	− 0.133	0.095	1.396	0.163
TG - > TT	H12	− 0.006	− 0.007	0.099	0.059	0.953
TG - > RP	H14	− 0.144	− 0.143	0.099	1.452	0.147
BL x TG - > PE	H2a	0.067	0.069	0.103	0.652	0.514
BL x TG - > EE	H4a	0.048	0.048	0.101	0.480	0.631
BL x TG - > TT	H12a	− 0.019	− 0.015	0.097	0.201	0.841
BL x TG - > RP	H14a	− 0.160	− 0.161	0.101	1.585	0.113
BL x TG - > BI	H15a	0.046	0.048	0.063	0.732	0.464
TS x TG - > PE	H2b	− 0.022	− 0.020	0.120	0.186	0.852
TS x TG - > EE	H4b	0.006	0.006	0.111	0.054	0.957
TS x TG - > HM	H10b	− 0.109	− 0.107	0.108	1.008	0.313
TS x TG - > BI	H15b	− 0.062	− 0.063	0.061	1.017	0.309

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics Statement

This study collected data from participants in an online questionnaire. Ethics approval was granted by the NOVA Information Management School Ethics Committee prior to the collection of data.

Disclosure

The authors declare that they are in agreement with this submission and for the paper to be published if accepted.

Conflicts of Interest

The authors declare no conflicts of interest.

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Endnotes

[1] Recruitment was conducted via Facebook groups, relevant subreddits, Instagram posts, and Linked In. These platforms hosted communities with interests in blockchain, digital governance, civic tech, technology policy, expat life.

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