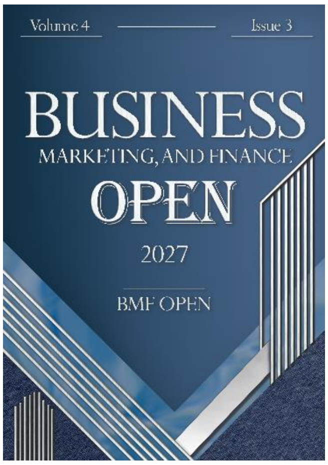
Validation and Prioritization of Drivers Affecting the Implementation of a Blockchain-Based Tax Policy Model: An Integrated Approach Using Structural Equation Modeling and Multi-Criteria Decision-Making Techniques



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Ali Khoshdel [1], Negar Khosravipour [2,*] and Amirreza Keyghobadi [3]

[1] Department of Accounting, CT.C., Islamic Azad University, Tehran, Iran;
[2] Department of Accounting, CT.C., Islamic Azad University, Tehran, Iran;
[3] Department of Industrial Management, CT.C., Islamic Azad University, Tehran, Iran;

* Correspondence: neg.khosravipour@iauctb.ac.ir

Abstract: The present study aimed to develop and propose a comprehensive tax policy model based on the integration of blockchain technology into the tax system. Given the challenges faced by traditional tax systems in terms of transparency, efficiency, and tax evasion, this study sought to explain how tax policymaking can be transformed through distributed ledger technology. In terms of purpose, this research was applied, and in terms of nature, it employed a mixed-methods approach comprising qualitative and quantitative components. In the qualitative phase, the components and dimensions of the model were identified through a meta-synthesis method and semi-structured interviews with experts, including university professors and senior tax administrators, and were extracted through content analysis. In the quantitative phase, a questionnaire was distributed among specialists to validate the model, and the data were analyzed using structural equation modeling (SEM) and SmartPLS software. The findings led to the identification of four principal dimensions: "technical and technological infrastructure," "legal and institutional requirements," "behavioral and social factors," and "operational and policy processes." The quantitative findings confirmed all causal relationships incorporated into the model and demonstrated that blockchain integration had a direct and significant effect on enhancing transparency, reducing tax collection costs, and improving tax compliance. The prioritization results also indicated that "data security" and "legal integration" were the most important factors in implementing the model. The proposed model provides a coherent framework for transitioning from a traditional tax system to a smart tax system. Implementing this model not only reduces corruption and tax evasion but also rebuilds trust between the government and taxpayers by establishing an immutable platform for recording transactions, thereby ensuring the overall effectiveness of tax policies in the digital economy.

Keywords: blockchain, tax policymaking, smart tax system, information transparency, digital transformation, structural equation modeling, data-driven governance.

1. Introduction

Digital transformation has fundamentally altered the institutional, technological, and managerial foundations of contemporary taxation. The expansion of electronic commerce, digital platforms, crypto-assets, cross-border transactions, and data-intensive business models has created economic activities that are increasingly difficult to identify, evaluate, and tax through conventional administrative mechanisms. Traditional tax systems generally rely on centralized databases, fragmented organizational processes, retrospective audits, and taxpayer self-reporting, all of which may generate delays, information asymmetry, administrative costs, and opportunities for tax evasion or avoidance. These limitations have intensified the need for tax administrations to adopt technologies capable of providing real-time information, automated verification, secure data exchange, and integrated transaction monitoring. In this context, blockchain has emerged as a potentially transformative infrastructure for redesigning tax administration and policymaking because it enables distributed recordkeeping, transaction traceability, tamper resistance, and programmable execution through smart contracts. The adoption of blockchain in financial and governmental systems may therefore represent not merely a technological upgrade but an institutional transition toward transparent, data-driven, and intelligent governance [1-3].

Blockchain is a distributed ledger architecture through which validated transactions are recorded across a network of authorized or decentralized participants. Once data are verified and incorporated into the ledger, their alteration becomes technically difficult without network consensus, thereby strengthening the integrity and auditability of financial information. From a managerial perspective, these characteristics may reduce dependence on intermediaries, facilitate interorganizational coordination, and improve the quality and timeliness of information available to decision-makers. Blockchain adoption has also been associated with improvements in corporate financial reporting quality because immutable records and transparent transaction histories can constrain opportunistic reporting and strengthen monitoring mechanisms [4]. Similarly, blockchain-based systems may improve the accuracy, efficiency, and trustworthiness of financial reporting when combined with advanced analytical technologies such as generative artificial intelligence [5]. The capacity of blockchain to enhance transparency, security, and environmental, social, and governance reporting further demonstrates its potential to improve accountability across organizational and institutional environments [6, 7].

The relevance of blockchain to taxation derives from the central importance of reliable information in tax assessment, collection, monitoring, and enforcement. Tax authorities require comprehensive and verifiable information concerning taxable transactions, taxpayer identities, income flows, deductions, invoices, assets, and liabilities. However, such information is often dispersed across taxpayers, financial institutions, customs organizations, employers, vendors, and other governmental agencies. Fragmented information architectures may prevent tax administrations from obtaining an integrated understanding of economic activities and may increase the costs associated with verification and auditing. A blockchain-based tax system can provide a shared and synchronized database through which authorized stakeholders record and access validated information under predefined rules. Such an infrastructure could facilitate automated cross-checking, reduce duplicate records, improve the quality of electronic invoices, and support data-driven tax governance. Effective data governance and data management are particularly important in digital taxation because the usefulness of electronic invoices and transaction-level information depends on data quality, interoperability, ownership, accessibility, security, and institutional accountability [8].

The application of blockchain to value-added tax is among the most frequently discussed areas of blockchain-based tax reform. Value-added tax systems typically involve extensive transaction chains, multiple businesses, input tax credits, invoices, and periodic reporting requirements. Fraud may occur through false invoices, unreported sales, artificial transactions, missing traders, or improper refund claims. Blockchain can potentially address these vulnerabilities by recording invoices and tax-related transactions in a traceable ledger and by automatically reconciling the tax paid and claimed across supply chains. Systematic evidence concerning blockchain-based value-added tax systems indicates that distributed ledgers can contribute to greater transparency, improved transaction tracking, reduced fraud, and more effective tax collection, although their implementation depends on legal, technical, organizational, and behavioral conditions [9]. Research on the critical factors affecting blockchain adoption in value-added tax systems similarly suggests that technological readiness alone is insufficient and that implementation requires supportive regulation, institutional coordination, stakeholder acceptance, implementation capacity, and appropriate governance arrangements [10].

Blockchain-based taxation is especially significant in digital economies, where conventional concepts of physical presence, jurisdiction, documentation, and taxable location have become increasingly difficult to apply. Digital businesses may supply services across national borders without maintaining substantial physical operations in the markets from which they generate revenue. Moreover, the scalability and mobility of digital assets may allow income and transactions to move across platforms and jurisdictions more rapidly than traditional tax administrations can monitor. A study of blockchain integration into Ghana's tax policy illustrates that the technology may support the taxation of digital economic activities by improving traceability, reducing information gaps, and strengthening the administrative capacity of tax authorities, while simultaneously creating regulatory, infrastructural, and human-capital challenges [11]. National tax structures and corporate income tax rules also influence how digital transactions and blockchain-based systems should be incorporated into existing fiscal arrangements [12]. Therefore, the suitability of blockchain-based tax policies must be evaluated within the economic, legal, and administrative context of each country rather than through a universally standardized approach.

The emergence of cryptocurrencies and crypto-assets has further increased the urgency of tax-system modernization. Crypto-assets can be transferred directly between users, held in digital wallets, exchanged across international platforms, and used for investment, payment, lending, staking, and decentralized financial activities. These characteristics create significant challenges for taxpayer identification, transaction valuation, jurisdictional determination, information reporting, and enforcement. Tax authorities have responded differently to cryptocurrency investment, reflecting variation in legal definitions, reporting obligations, capital gains treatment, enforcement capacity, and regulatory policy [13]. Staking income presents an additional taxation challenge because countries differ in determining when taxable income arises, how rewards should be valued, and whether staking should be classified as investment income, business income, or another category [14]. Cryptocurrency exposure may also affect corporate tax behavior, as firms with greater involvement in digital assets may encounter new opportunities, uncertainties, or incentives related to tax avoidance [15]. These developments indicate that blockchain is simultaneously an object of taxation and a technological instrument through which tax compliance may be strengthened.

The regulatory treatment of crypto-assets must therefore be integrated with broader tax-policy reforms. Value-added tax rules concerning cryptocurrency transactions and speculative activities remain legally complex, particularly when digital assets perform multiple functions as exchange instruments, investment assets, utility tokens, or financial products. Regulatory experience within the European Union demonstrates the importance of establishing coherent legal classifications and tax treatments for cryptocurrency transactions and speculation [16]. At the same time, policy frameworks for crypto-asset ecosystems should account for social, economic, ethical, and jurisprudential considerations, especially in jurisdictions where financial regulation is influenced by specific legal and religious principles [17]. The development of national digital currencies similarly raises important questions concerning monetary policy, financial stability, transaction monitoring, privacy, and the relationship between central banks and tax authorities. In Iran, the issuance of a national digital currency may affect monetary-policy mechanisms and the broader architecture of digital financial governance [18]. Consequently, blockchain-based tax policy should be coordinated with monetary, banking, accounting, and digital-asset policies.

Despite its potential benefits, blockchain cannot automatically resolve all problems of tax administration. Its implementation introduces legal and regulatory concerns relating to privacy, data protection, cybersecurity, digital identity, evidence, jurisdiction, liability, and access rights. The permanent and distributed nature of blockchain records may conflict with legal requirements governing data correction, deletion, confidentiality, or the right to be forgotten. Furthermore, smart contracts may execute predetermined rules automatically, but legal responsibility remains unclear when coding errors, inaccurate inputs, or contradictory regulations produce unintended outcomes. The legal implications of blockchain for tax compliance and financial regulation therefore require explicit rules concerning governance, accountability, interoperability, and regulatory supervision [19]. The growth of decentralized finance creates additional challenges because transactions may occur through protocols that lack conventional intermediaries or clearly identifiable responsible entities, thereby complicating legal enforcement and tax administration [20]. Accordingly, the successful adoption of blockchain in taxation requires legal reform alongside technological development.

Information security represents another major consideration in blockchain-based tax systems. Although blockchain can protect data integrity through cryptographic mechanisms and distributed validation, it does not eliminate all cybersecurity risks. Weak digital identities, compromised private keys, insecure interfaces, poor smart-contract design, unreliable external data sources, and unauthorized access to linked databases may undermine system security. Furthermore, tax data are highly sensitive because they contain personal, financial, commercial, and transactional information. A blockchain-based system must therefore establish appropriate distinctions between transparency and confidentiality. Public blockchains may provide broad visibility but may be unsuitable for confidential tax information, whereas permissioned blockchains can restrict participation and data access to authorized actors. Blockchain's contribution to financial audits illustrates how secure and traceable records may improve evidence quality, continuous auditing, and fraud detection, provided that technical and governance controls are appropriately designed [21]. Intelligent risk-management systems based on blockchain may also improve the identification and management of financial risks by integrating reliable transaction data with decision-support capabilities [22].

The implementation of blockchain also has significant organizational and managerial implications. Tax administrations often operate through hierarchical structures, established routines, legacy information systems, and legally standardized procedures. Introducing distributed ledger technology may require changes in organizational roles, interdepartmental relationships, employee competencies, performance indicators, and decision-making authority. Resistance to change may arise when employees perceive blockchain as technically complex, threatening to existing responsibilities, or inconsistent with established administrative practices. Successful implementation therefore depends on leadership commitment, organizational readiness, stakeholder education, technical training, and effective change management. Experience from other sectors indicates that blockchain adoption requires operational strategies adapted to institutional conditions and stakeholder capabilities. For example, the identification of operational strategies for applying blockchain in Iran's tourism sector emphasizes the importance of infrastructure, institutional support, awareness, coordination, and implementation planning [23]. These requirements are equally relevant to tax administrations, where technological reform must be translated into operational procedures and accepted organizational practices.

Economic and administrative efficiency constitutes a central justification for blockchain-based tax policy. Conventional tax collection may involve repeated data entry, manual reconciliation, document verification, lengthy audits, and coordination among multiple agencies. These processes increase compliance costs for taxpayers and administrative costs for governments. Blockchain may reduce such costs by automating reporting, validating transactions at the point of occurrence, and enabling continuous rather than exclusively retrospective auditing. Artificial intelligence-driven tax administration and blockchain-based models may both strengthen compliance, although blockchain is particularly valuable for establishing trusted and traceable data environments upon which automated analytical systems can operate [24]. Blockchain architecture may also reshape accounting and management practices by changing how digital-currency transactions are recorded, controlled, and reported [25]. Nevertheless, the economic value of implementation depends on whether expected savings and compliance gains exceed the costs of system development, integration, maintenance, training, and regulatory adaptation.

Tax compliance is influenced not only by enforcement capacity but also by taxpayer trust, perceived fairness, simplicity, and confidence in governmental institutions. Blockchain-based systems may strengthen trust by making tax calculations and transaction records more transparent, reducing discretionary manipulation, and creating consistent audit trails. Taxpayers may be more willing to comply when they believe that tax rules are applied fairly and that reported information cannot be selectively altered. Conversely, extensive transaction monitoring may create concerns about surveillance, privacy, and governmental control. Therefore, behavioral acceptance should be regarded as a core component of blockchain-based tax policy rather than as a secondary implementation issue. The future of tax administration will depend on balancing the opportunities of blockchain, including transparency, automation, and traceability, against risks involving privacy, exclusion, technical complexity, and excessive dependence on digital infrastructure [1]. E-government research similarly demonstrates that blockchain opportunities coexist with technical, legal, security, and governance risks that must be addressed through careful institutional design [2].

Blockchain-based tax reform is also connected to the wider challenge of tax avoidance in a globalized digital economy. Multinational enterprises can exploit differences among national tax systems, intangible assets, transfer-pricing practices, complex corporate structures, and digital business models to shift profits or reduce taxable income. Research on the drivers of tax avoidance by multinational enterprises in developing economies indicates that institutional weaknesses, regulatory gaps, information asymmetry, and the complexity of the digital economy jointly contribute to avoidance behavior [26]. Blockchain cannot independently harmonize international tax laws, but it may provide more reliable transaction records, beneficial-ownership information, and cross-border data-sharing mechanisms. Such capabilities may strengthen the evidentiary basis for tax assessment and reduce opportunities to conceal or manipulate financial flows. However, the effectiveness of these mechanisms depends on international cooperation, common data standards, interoperable systems, and agreements concerning information access and taxpayer rights.

Environmental, social, and governance considerations further demonstrate the expanding role of taxation in influencing organizational behavior. Tax policy is not limited to revenue collection but can also guide corporate conduct, investment patterns, sustainability, and stakeholder accountability. Environmental tax laws, for example, can affect the ESG performance of heavily polluting enterprises by altering the incentives and expectations of firms and stakeholders [27]. Blockchain-based tax infrastructures could improve the traceability of environmentally relevant transactions, emissions-related payments, subsidies, and tax incentives, thereby supporting more effective monitoring of sustainability-oriented fiscal policies. Moreover, blockchain-enabled reporting may integrate tax data with ESG information and improve the verifiability of corporate disclosures [6]. These applications show that a blockchain-based tax model may contribute not only to administrative efficiency but also to broader objectives of responsible governance and sustainable development.

Within Iran, the potential contribution of blockchain to tax-revenue realization is particularly important because fiscal sustainability requires reliable revenue mobilization, reduced dependence on unstable income sources, and stronger control of tax evasion. Previous research has indicated that blockchain may enhance the realization of tax revenues in Iran by improving transparency, transaction monitoring, information integration, and the reliability of taxable records [28]. Nevertheless, domestic implementation must account for existing legal structures, technological capacity, administrative fragmentation, taxpayer behavior, financial-sector conditions, and the specific characteristics of Iran's digital economy. The development of blockchain-based tax policy therefore requires an integrated model that identifies not only technological components but also legal, institutional, behavioral, social, operational, and policy-related drivers. Without such integration, isolated technological investments may fail to produce meaningful administrative change.

In particular, limited attention has been devoted to combining empirical model validation with systematic prioritization of implementation drivers. Structural equation modeling can evaluate measurement validity and test causal relationships among latent constructs, whereas multi-criteria decision-making techniques can determine the relative importance and ranking of complex and interdependent factors. The integration of these approaches can produce more actionable findings for policymakers by distinguishing statistically validated relationships from strategically prioritized implementation requirements. The assessment of blockchain adoption factors in tax systems, financial reporting, and related regulatory settings reinforces the need to move from broad technological advocacy toward empirically grounded implementation models [3, 4, 10]. Accordingly, this study aimed to validate and prioritize the drivers affecting the implementation of a blockchain-based tax policy model by integrating structural equation modeling with multi-criteria decision-making techniques.

2. Methodology

In terms of purpose, the present study was applied, and in terms of its nature and implementation method, it was a descriptive-survey study employing a mixed-methods approach consisting of qualitative and quantitative phases. In the qualitative phase, the Delphi method was used to identify, refine, and initially validate the drivers affecting the implementation of the blockchain-based tax policy model. At this stage, based on a comprehensive review of the research literature and the opinions of academic experts and specialized managers in taxation, information technology, and blockchain, a researcher-developed questionnaire was prepared. Through several Delphi rounds, the indicators were evaluated, revised, and finalized. The content validity of the questionnaire was established through review and approval by university professors and subject-matter experts. Its reliability was assessed using Cronbach's alpha coefficient, which exceeded 0.70 for all dimensions, indicating satisfactory reliability of the measurement instrument.

In the quantitative phase, the study was conducted using a descriptive-survey method, and the required data were collected through a researcher-developed questionnaire. The statistical population consisted of employees, managers, and experts of the Tehran Tax Administration. Given the size of the population and based on Cochran's formula, the sample size was determined to be 384 participants. Simple random sampling was used to ensure that all members of the population had an equal probability of selection.

To confirm the extracted structure, confirmatory factor analysis and measurement-model assessment were conducted using structural equation modeling. Convergent validity, discriminant validity, composite reliability, Cronbach's alpha coefficient, average variance extracted (AVE), and model-fit indices were evaluated. SmartPLS software was used for this purpose. In addition to validating the measurement model, the software was used to test the relationships among the constructs and determine the effects of the identified drivers on the implementation of the blockchain-based tax policy model.

In the final phase, following confirmation of the structural model and validation of the relationships among the variables, a multi-criteria decision-making technique was used to determine the relative importance and prioritize the influential drivers. Accordingly, the weight and rank of each factor were calculated, and the final research model was proposed. Thus, integrating the Delphi method, exploratory factor analysis, confirmatory factor analysis, structural equation modeling, and multi-criteria decision-making techniques enhanced the scientific rigor of the study and enabled the validation, structural explanation, and systematic prioritization of the drivers affecting the implementation of the blockchain-based tax policy model.

3. Findings and Results

To evaluate the conceptual model of the study, determine whether causal relationships existed among the research variables, and assess the consistency of the observed data with the conceptual model, the research hypotheses were tested using structural equation modeling. The results of the hypothesis tests are presented in the diagrams.

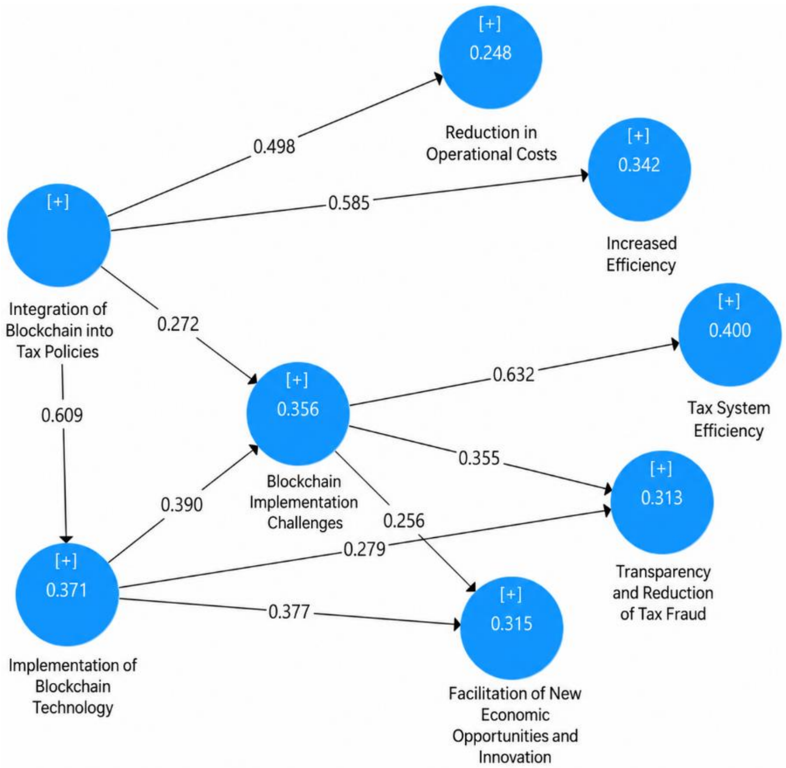

Figure 1. Measurement of the Overall Model and Hypothesis-Testing Results in the Standardized Mode

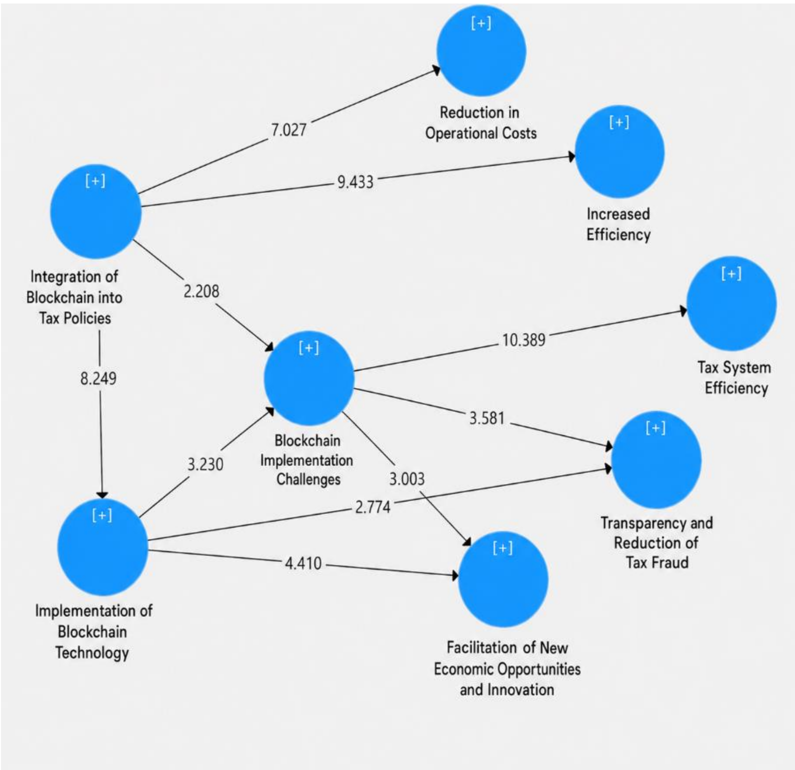

Figure 2. Measurement of the Overall Model and Hypothesis-Testing Results in the Significance Mode

The validity, reliability, and goodness of fit of the model are examined below.

Indicator reliability was assessed using two criteria:

1. Cronbach's alpha
2. Composite reliability

Cronbach's alpha is a classical criterion for reliability assessment and is regarded as an appropriate measure of internal consistency. One of the reliability criteria applied in structural equation modeling is the internal consistency of measurement models. Internal consistency indicates the degree of correlation between a construct and its associated indicators. A high proportion of variance shared between a construct and its indicators, relative to the measurement error associated with each indicator, indicates high internal consistency. A Cronbach's alpha value greater than 0.70 indicates acceptable reliability (Cronbach, 1951). Some researchers have proposed a threshold value of 0.60 for variables measured using a small number of items (Davari & Rezazadeh, 2013, p. 79).

Table 1. Cronbach's Alpha Coefficients

Construct	Cronbach's Alpha
Blockchain integration	0.719
Blockchain implementation	0.765
Blockchain challenges	0.751
Efficiency and cost	0.715
Efficiency and transparency	0.738

Because Cronbach's alpha is a traditional criterion for determining construct reliability, partial least squares structural equation modeling uses a more modern measure known as composite reliability. Composite reliability is superior to Cronbach's alpha because construct reliability is not calculated in absolute terms but is estimated by considering the correlations between the constructs and their indicators. Consequently, both criteria are used to obtain a more comprehensive assessment of reliability in the PLS method.

The composite reliability of a construct is calculated as a ratio in which the numerator represents the variance shared between the construct and its indicators, while the denominator additionally incorporates measurement error. A composite reliability value greater than 0.70 indicates adequate internal consistency of the measurement model, whereas a value below 0.60 indicates inadequate reliability (Davari & Rezazadeh, 2013, p. 79).

Table 2. Composite Reliability

Construct	Composite Reliability
Blockchain integration	0.787
Blockchain implementation	0.844
Blockchain challenges	0.918
Efficiency and cost	0.885
Efficiency and transparency	0.960

Convergent validity is the second criterion used to assess the fit of measurement models in the PLS method. Average variance extracted indicates the average amount of variance shared between each construct and its indicators. AVE represents the degree of correlation between a construct and its indicators; the greater this correlation, the better the measurement-model fit. An AVE value greater than 0.50 indicates acceptable convergent validity (Fornell & Larcker, 1981). Some researchers have considered 0.40 to be the minimum acceptable value.

Table 3. Convergent Validity

Construct	AVE
Blockchain integration	0.552
Blockchain implementation	0.644
Blockchain challenges	0.651
Efficiency and cost	0.720
Efficiency and transparency	0.649

In partial least squares analysis, which is commonly performed using SmartPLS software, the Fornell–Larcker criterion is used to assess discriminant validity. Discriminant validity concerns the extent to which the indicators of one construct exhibit lower correlations with the indicators of other constructs. According to the Fornell–Larcker criterion, the square root of the variance explained by each construct must be greater than the correlations between that construct and the other constructs (Fornell & Larcker, 1981). Therefore, the values on the principal diagonal of the matrix must be greater than all other values in the corresponding column (Azar et al., 2012). The Fornell–Larcker matrix is presented below.

Table 4. Fornell–Larcker Matrix

Construct	Blockchain Integration	Blockchain Implementation	Blockchain Challenges	Efficiency and Cost	Efficiency and Transparency
Blockchain integration	0.743				
Blockchain implementation	0.342	0.803			
Blockchain challenges	0.331	0.470	0.807		
Efficiency and cost	0.440	0.692	0.650	0.849	
Efficiency and transparency	−0.066	−0.259	−0.213	−0.386	0.806

As shown, the values on the principal diagonal of the matrix are greater than all other values in their corresponding columns, indicating that the research model has satisfactory discriminant validity.

The goodness-of-fit criterion relates to the overall assessment of structural equation models. After evaluating the measurement and structural components of the research model, researchers can use this criterion to assess the fit of the overall model. The goodness-of-fit index is the principal criterion used to evaluate overall model fit. Values of 0.01, 0.25, and 0.36 have been proposed as indicating weak, moderate, and strong goodness of fit, respectively (Wetzels et al., 2009). This criterion is calculated using the following formula:

$$\mathrm{GOF} = \sqrt{\overline{\mathrm{Communality}} \times \overline{R^2}} \qquad (3\text{-}1)$$

Table 5. GOF Criteria

Construct	Communality	R^2
Blockchain integration	0.423964	–
Blockchain implementation	0.287966	0.618485
Blockchain challenges	0.489617	0.682023
Efficiency and cost	0.349199	0.574394
Efficiency and transparency	0.470358	0.121715

Accordingly, the mean communality was calculated as follows:

$$\overline{\mathrm{Communality}} = 0.40$$

Based on the R^2 values presented in Table 5, the mean R^2 was calculated as follows:

$$\overline{R^2} = 0.50$$

Thus, the GOF value was calculated as follows:

$$\mathrm{GOF} = \sqrt{0.50 \times 0.40} = \sqrt{0.20} \approx 0.44$$

Given the threshold values of 0.01, 0.25, and 0.36 for weak, moderate, and strong model fit, respectively, the obtained value of 0.44 indicates a strong overall fit of the model.

Path analysis was used to investigate the causal relationships between the independent and dependent variables and to confirm the overall model. Path analysis was performed using SmartPLS software. The following table summarizes the path coefficients, significance values, and hypothesis-testing results.

Table 6. Hypothesis-Testing Results

Research Hypothesis	Standardized Coefficient	t-Value	Result
Implementing blockchain technology in tax systems significantly improves transparency and reduces tax fraud.	0.27	2.77	Supported
Challenges associated with blockchain implementation, such as legal and organizational constraints, may negatively affect the efficiency of the tax system.	0.63	10.39	Supported
Integrating blockchain into tax policies reduces operational costs and increases efficiency.	0.58	9.43	Supported
Using blockchain in the tax system facilitates new economic opportunities and innovation.	0.37	4.41	Supported

Research Hypothesis 1 proposed that implementing blockchain technology in tax systems would significantly improve transparency and reduce tax fraud. The statistical analysis of the relationship between the two variables indicated that, according to Table 6, the t-value of the path between the variables was greater than 1.96. Therefore, this hypothesis was supported. Moreover, because the obtained coefficient was positive, the effect was direct.

Research Hypothesis 2 proposed that challenges associated with blockchain implementation, such as legal and organizational constraints, could negatively affect the efficiency of the tax system. The statistical analysis of the relationship between the two variables indicated that, according to Table 6, the t-value of the path between the variables was greater than 1.96. Therefore, this hypothesis was supported. Moreover, because the obtained coefficient was positive, the estimated relationship was direct.

Research Hypothesis 3 proposed that integrating blockchain into tax policies would reduce operational costs and increase efficiency. The statistical analysis of the relationship between the two variables indicated that, according to Table 6, the t-value of the path between the variables was greater than 1.96. Therefore, this hypothesis was supported. Moreover, because the obtained coefficient was positive, the effect was direct.

Research Hypothesis 4 proposed that using blockchain in the tax system would facilitate new economic opportunities and innovation. The statistical analysis of the relationship between the two variables indicated that, according to Table 6, the t-value of the path between the variables was greater than 1.96. Therefore, this hypothesis was supported. Moreover, because the obtained coefficient was positive, the effect was direct.

This section is presented step by step based on the procedures described previously. The criteria were evaluated by 15 experts. The following table presents the aggregated pairwise-comparison judgments. In these matrices,

$$\tilde{x}_{ij} = (l_{ij}, m_{ij}, u_{ij})$$

represents a triangular fuzzy number, and the diagonal elements are defined as:

$$\tilde{x}_{ii} = (0,0,0), i = 1,2,3, \dots, n$$

Accordingly, the experts' opinions were collected and aggregated using the formulas described in the data-analysis method.

Table 7. Decision Matrix

	C5	C4	C3	C2	C1
C1	(2.00, 3.43, 4.00)	(2.00, 3.11, 4.00)	(3.00, 3.72, 4.00)	(3.00, 3.72, 4.00)	(0.00, 0.00, 0.00)
C2	(3.00, 3.22, 4.00)	(2.00, 2.85, 4.00)	(3.00, 3.46, 4.00)	(0.00, 0.00, 0.00)	(2.00, 2.21, 3.00)
C3	(2.00, 3.13, 4.00)	(2.00, 2.94, 4.00)	(0.00, 0.00, 0.00)	(3.00, 3.07, 4.00)	(3.00, 3.07, 4.00)
C4	(2.00, 2.06, 3.00)	(0.00, 0.00, 0.00)	(3.00, 3.14, 4.00)	(2.00, 2.06, 3.00)	(2.00, 2.06, 3.00)
C5	(0.00, 0.00, 0.00)	(2.00, 2.06, 3.00)	(3.00, 3.07, 4.00)	(3.00, 3.07, 4.00)	(3.00, 3.07, 4.00)

The following table presents the Vmatrix.

Table 8. VMatrix

Total-Relation Matrix	C5	C4	C3	C2	C1
C1	(0.30, 0.62, 4.00)	(0.28, 0.59, 4.00)	(0.40, 0.70, 4.16)	(0.37, 0.64, 4.00)	(0.22, 0.44, 3.66)
C2	(0.34, 0.56, 3.83)	(0.28, 0.53, 3.83)	(0.40, 0.63, 3.99)	(0.24, 0.43, 3.67)	(0.32, 0.49, 3.63)
C3	(0.28, 0.57, 4.00)	(0.27, 0.54, 4.00)	(0.25, 0.49, 4.00)	(0.35, 0.57, 4.00)	(0.34, 0.53, 3.83)
C4	(0.28, 0.46, 3.47)	(0.18, 0.35, 3.34)	(0.38, 0.55, 3.65)	(0.31, 0.46, 3.47)	(0.30, 0.43, 3.33)
C5	(0.22, 0.41, 3.68)	(0.29, 0.48, 3.81)	(0.42, 0.60, 4.01)	(0.39, 0.55, 3.85)	(0.37, 0.51, 3.69)

To apply the relationships obtained from fuzzy DEMATEL in the fuzzy analytic network process, the total-relation matrix must first be defuzzified. Therefore, the relation matrix was initially defuzzified and then normalized by column. The final stage of the fuzzy analytic network process is presented below.

Table 9. Final Stage of the Fuzzy Analytic Network Process

Total-Relation Matrix	C5	C4	C3	C2	C1
C1	1.1366	1.1090	1.2333	1.1582	0.9447
C2	1.0745	1.0408	1.1577	0.9397	0.9903
C3	1.0946	1.0720	1.0395	1.1070	1.0511
C4	0.9373	0.8230	1.0469	0.9442	0.8968
C5	0.9302	1.0121	1.1445	1.0766	1.0222

This stage was divided into seven sections, including information on weights and dimensions. The subsets were analyzed using the fuzzy analytic network process to identify and analyze the influential factors. Because of space limitations, only one example is presented in this section. After the questionnaire had been developed, copies were distributed to the 15 tax experts participating in the study. Subsequently, the validation and analysis criteria were examined.

At this stage, all questionnaires were compared in terms of relative importance. Accordingly, pairwise-comparison matrices were constructed, and the importance coefficients of the principal indicators, as well as the matrix of the relative importance coefficients of the indicators, were calculated.

Based on the relative importance values calculated in the previous stage, triangular fuzzy numbers were computed to integrate all expert judgments. The set of triangular fuzzy numbers was defined as follows:

$$\tilde{a}_{ij} = \left(\alpha_{ij}, \beta_{ij}, \delta_{ij}\right)$$

where $\tilde{a}_{ij}$denotes the set of triangular fuzzy numbers, $\alpha_{ij}$is the minimum value of criterion $j$for dimension i, $\beta_{ij}$is the geometric mean of criterion $j$for dimension i, and $\delta_{ij}$is the maximum value of criterion $j$for dimension i.

The following table presents the triangular fuzzy numbers calculated for the criteria. The values in parentheses represent the minimum value of criterion $j$for dimension i, the geometric mean of criterion $j$for dimension i, and the maximum value of criterion $j$for dimension i.

Table 10. Final DEMATEL Matrix

	C6	C5	C4	C3	C2
C1	(1, 1, 1)	(9, 5.614, 3)	(9, 6.3568, 1)	(8, 4.025, 0.25)	(8, 3.949, 0.333)
C2	(0.333, 0.178, 0.111)	(1, 1, 1)	(8, 5.0642, 0.5)	(5, 2.506, 0.333)	(6, 2.271, 1)
C3	(1, 0.157, 0.111)	(2, 0.197, 0.125)	(1, 1, 1)	(0.5, 0.196, 0.149)	(2, 0.235, 0.125)
C4	(4, 0.248, 0.125)	(3, 0.399, 0.2)	(8, 5.110, 2)	(1, 1, 1)	(4, 1.135, 0.333)
C5	(3, 0.253, 0.125)	(1, 0.439, 0.166)	(8, 4.264, 0.5)	(3, 0.882, 0.25)	(1, 1, 1)

At this stage, the coefficients of the pairwise-comparison matrices were calculated using the definitions of the fuzzy analytic hierarchy process:

$$\left[\sum_{i=1}^{m}\sum_{j=1}^{n} M_{ij}\right]^{-1} = (18.825,\ 64.651,\ 131.833)^{-1} = (0.0075,\ 0.0154,\ 0.0531)$$

$$S_1 = (5.916,\ 22.9838,\ 43) \times (0.0075,\ 0.0154,\ 0.0531) = (0.4437,\ 0.3539,\ 2.2833)$$

$$S_2 = (3.111,\ 11.8182,\ 24.333) \times (0.0075,\ 0.0154,\ 0.0531) = (0.02333,\ 0.1820,\ 1.2920)$$

$$S_3 = (2.845,\ 14.251,\ 42.5) \times (0.0075,\ 0.0154,\ 0.0531) = (0.0288,\ 0.2191,\ 2.3071)$$

$$S_4 = (3.801,\ 8.305,\ 27) \times (0.0075,\ 0.0154,\ 0.0531) = (0.0285,\ 0.1278,\ 1.4337)$$

$$S_5 = (2.152,\ 7.304,\ 21) \times (0.0075,\ 0.0154,\ 0.0531) = (0.01614,\ 0.1124,\ 1.1151)$$

At this stage, the degree of possibility of each S_i being greater than the other S_i values was calculated:

$$\min V(S_1 \geq S_2, S_3, S_4, S_5, S_6) = 1$$
$$\min V(S_2 \geq S_1, S_3, S_4, S_5, S_6) = 0.8315$$
$$\min V(S_3 \geq S_1, S_2, S_4, S_5, S_6) = 0.9185$$
$$\min V(S_4 \geq S_1, S_2, S_3, S_5, S_6) = 0.8140$$
$$\min V(S_5 \geq S_1, S_2, S_3, S_4, S_6) = 0.7354$$

These values represent the unnormalized weights of indicators C1 through C6. The normalized weights of the indicators are presented below:

$$W = [0.2325,\ 0.1933,\ 0.2136,\ 0.1893,\ 0.1710]$$

The interdependencies among the criteria calculated using the fuzzy DEMATEL method were then examined.

Table 11. Interdependencies Among the Criteria Calculated Using the DEMATEL Method

	C5	C4	C3	C2	C1
C1	0.18052	0.18001	0.17987	0.18213	0.15799
C2	0.17066	0.16894	0.16884	0.14777	0.16562
C3	0.17385	0.17400	0.15160	0.17408	0.17578
C4	0.14887	0.13358	0.15268	0.14848	0.14998
C5	0.14774	0.16428	0.16691	0.16930	0.17095

Considering the interdependencies among the criteria, their final weights were obtained by integrating the results using the following relationship:

$$W_{\varepsilon} = B \times W$$

Table 12. Final Indicator Weights

Indicator	C1	C2	C3	C4	C5	Initial Weight	Final Weight	Rank
Reduction in operational costs	0.1579	0.1821	0.1798	0.1800	0.1805	0.232	0.175	1
Increased efficiency	0.1656	0.1477	0.1688	0.1689	0.1706	0.193	0.165	3
Tax-system efficiency	0.1757	0.1740	0.1516	0.1740	0.1738	0.213	0.169	2
Transparency and reduction of tax fraud	0.1499	0.1484	0.1526	0.1335	0.1488	0.189	0.150	5
Facilitation of new economic opportunities and innovation	0.1709	0.1693	0.1669	0.1642	0.1477	0.171	0.164	4

The table above presents the overall weights of the indicators, calculated based on the relationships, procedures, and final weights described above.

4. Discussion and Conclusion

The present study sought to validate and prioritize the drivers affecting the implementation of a blockchain-based tax policy model by integrating structural equation modeling with fuzzy DEMATEL and the fuzzy analytic network process. The findings generally supported the proposed conceptual model and demonstrated that blockchain implementation, blockchain integration, implementation challenges, efficiency and cost, and efficiency and transparency were empirically distinguishable and sufficiently reliable constructs. Cronbach's alpha coefficients ranged from 0.715 to 0.765, composite reliability values ranged from 0.787 to 0.960, and average variance extracted values exceeded the minimum acceptable threshold for all constructs. The Fornell–Larcker results also supported discriminant validity, while the goodness-of-fit value of 0.44 indicated a strong overall fit. These findings suggest that the proposed framework provides a statistically acceptable representation of the technological, operational, and institutional factors involved in blockchain-based tax policymaking. This result is consistent with studies emphasizing that blockchain adoption in taxation should be approached as a multidimensional transformation involving technological infrastructure, governance arrangements, organizational readiness, regulatory compatibility, and stakeholder acceptance rather than as the isolated installation of a new information system [1, 10, 11].

The first hypothesis indicated that implementing blockchain technology in tax systems significantly improves transparency and reduces tax fraud. The standardized coefficient of 0.27 and a t-value of 2.77 confirmed a statistically significant direct relationship. Although the magnitude of this coefficient was lower than those of some other paths in the model, it nevertheless demonstrated that blockchain implementation can make a meaningful contribution to the integrity of tax administration. This finding can be explained by the fundamental properties of blockchain, including immutability, distributed verification, traceability, timestamped records, and restricted alteration of validated transactions. When tax-related transactions, invoices, payments, and declarations are registered in a shared ledger, opportunities for retrospectively changing records, generating fraudulent invoices, concealing transactions, or reporting inconsistent information are reduced. The finding is consistent with previous evidence that blockchain-based value-added tax systems can improve transaction visibility and reduce fraud by establishing verifiable links between purchases, sales, input tax credits, and tax liabilities [9]. It also aligns with the argument that blockchain can improve tax compliance by generating reliable audit trails and enabling tax authorities to detect anomalies more rapidly than in fragmented and manually reconciled systems [19, 24].

The positive effect of blockchain implementation on transparency is also compatible with findings from financial reporting and auditing research. Blockchain-supported accounting records improve information integrity because transactions can be verified against an immutable history rather than relying exclusively on records controlled by individual organizations. This feature can constrain opportunistic reporting and increase the reliability of data available to tax authorities, auditors, and other stakeholders. Previous research has shown that blockchain adoption is associated with higher financial reporting quality, particularly through stronger traceability and reduced opportunities for information manipulation [4]. Similarly, blockchain has been found to enhance the transparency, security, and accountability of financial accounting and ESG reporting systems [6, 7]. The present findings therefore indicate that the transparency benefits identified in corporate reporting can extend to tax administration, where reliable transaction-level information is essential for tax assessment, compliance monitoring, and fraud prevention.

Nevertheless, the relatively moderate coefficient obtained for the transparency and fraud-reduction relationship indicates that blockchain alone cannot eliminate tax fraud. Fraud may be transferred from the ledger itself to the points at which data enter the system. If taxpayers, intermediaries, or organizations provide inaccurate information before validation, blockchain may permanently preserve incorrect data rather than correct them. The effectiveness of the technology therefore depends on verified digital identities, accurate external data sources, secure interfaces, effective audit rules, and institutional capacity to interpret and act upon recorded information. This observation is consistent with research indicating that blockchain opportunities coexist with privacy, cybersecurity, interoperability, and governance risks [1, 2]. It also supports the emphasis placed on data governance in digital taxation, because the quality of blockchain-based tax records ultimately depends on data standards, ownership rules, access controls, and organizational accountability [8].

The second hypothesis concerned the effect of implementation challenges, including legal and organizational constraints, on tax-system efficiency. The path coefficient of 0.63 and a t-value of 10.39 represented the strongest relationship identified in the structural model. This finding demonstrates that the challenges surrounding blockchain implementation constitute a central determinant of whether the technology can be successfully institutionalized in tax administration. The positive reported coefficient should be interpreted in accordance with the coding and direction of the modeled outcome. Substantively, the finding indicates that legal, organizational, technical, and institutional challenges exert a substantial influence on the efficiency-related consequences of implementation. Where these challenges are severe or poorly managed, they may obstruct system integration, delay implementation, increase costs, and reduce the expected benefits of blockchain. This conclusion is consistent with studies showing that legal uncertainty, regulatory fragmentation, data-protection requirements, accountability problems, and institutional resistance are among the most important obstacles to blockchain-based tax compliance and financial regulation [19, 20].

The importance of implementation challenges may also be attributed to the incompatibility between distributed ledger systems and conventional administrative arrangements. Tax administrations commonly depend on centralized authority, hierarchical decision-making, legacy databases, and legally prescribed procedures. Blockchain, by contrast, requires decisions regarding network governance, validation authority, access permissions, data-sharing protocols, smart-contract design, and responsibility for errors. Without clear institutional arrangements, distributed systems may create uncertainty rather than efficiency. Previous research on blockchain integration into digital-economy taxation has similarly shown that limited infrastructure, inadequate expertise, regulatory ambiguity, and organizational constraints can weaken implementation outcomes even when the technology offers substantial benefits [11]. Studies of blockchain adoption in value-added tax systems likewise identify governmental support, regulatory readiness, organizational capability, interoperability, and stakeholder trust as critical conditions for successful implementation [10]. Thus, the strong path coefficient found in this study reinforces the conclusion that implementation challenges should be treated as core strategic variables rather than secondary technical problems.

The third hypothesis showed that integrating blockchain into tax policies reduces operational costs and increases efficiency. The standardized coefficient of 0.58 and a t-value of 9.43 confirmed a strong and significant direct effect. This result suggests that the value of blockchain is greatest when it is integrated into tax-policy processes rather than used as a separate recordkeeping tool. Integration can automate the exchange of information among taxpayers, tax authorities, banks, customs agencies, employers, and other governmental organizations. It can also reduce repetitive data entry, document duplication, manual reconciliation, retrospective verification, and dependence on paper-based evidence. These improvements can lower administrative expenses for tax authorities and compliance costs for taxpayers. The result aligns with comparative research demonstrating that blockchain-based tax-administration models can increase compliance efficiency through automated verification, secure information exchange, and continuous monitoring [24]. It is also consistent with research suggesting that blockchain architecture can improve accounting and management processes by increasing the speed and reliability of transaction registration and reducing reliance on intermediaries [3, 25].

The cost-reduction effect can further be explained through the transition from periodic reporting to event-based or near-real-time taxation. In conventional systems, tax authorities often receive aggregated information after transactions have occurred, requiring subsequent auditing and reconciliation. In a blockchain-supported system, relevant tax data may be recorded and verified at the time of the transaction. Smart contracts may then calculate, allocate, or transfer tax liabilities according to predefined rules. Such mechanisms can reduce processing delays and allow tax administrators to concentrate on high-risk cases instead of routinely verifying all records. Similar benefits have been observed in blockchain-supported auditing, where continuous access to validated information can reduce the time and resources required for evidence collection and transaction testing [21]. Moreover, intelligent systems that combine blockchain with advanced analytical technologies may further improve accuracy, efficiency, and trust by using immutable data as the foundation for automated reporting and risk assessment [5, 22].

The fourth hypothesis demonstrated that using blockchain in the tax system facilitates new economic opportunities and innovation. The standardized coefficient of 0.37 and a t-value of 4.41 confirmed a significant direct effect. This finding indicates that blockchain-based tax policy can contribute to objectives beyond revenue collection and compliance enforcement. A transparent and predictable tax infrastructure may support the development of digital businesses, fintech services, automated payment systems, crypto-asset markets, and innovative financial products. When the tax treatment of digital transactions is clear and transaction records can be verified efficiently, firms may face less uncertainty and lower administrative burdens. The finding is compatible with research emphasizing that blockchain integration can create opportunities for improving taxation in digital economies while simultaneously supporting financial innovation and more effective public administration [2, 11]. It also accords with studies showing that digital currencies and blockchain architecture can reshape accounting, monetary policy, and financial-management systems [18, 25].

However, the innovation-enhancing effect depends on the establishment of coherent rules for crypto-assets and blockchain-based financial activities. The absence of legal clarity concerning cryptocurrency valuation, staking rewards, decentralized finance, and cross-border transactions may discourage compliant innovation or drive activities toward informal markets. International differences in the taxation of cryptocurrency investments and staking demonstrate that uncertainty remains regarding the timing, classification, and valuation of taxable income [13, 14]. Legal debates surrounding value-added tax and cryptocurrency speculation similarly show that innovative financial activities require clear regulatory categorization [16]. Moreover, cryptocurrency exposure may create new tax-avoidance opportunities when reporting standards and enforcement mechanisms do not keep pace with technological change [15]. Therefore, blockchain-based tax innovation should be accompanied by adaptive regulation, clear reporting obligations, and effective oversight.

The prioritization results complement the structural model by showing that reducing operational costs received the highest final weight of 0.175, followed by tax-system efficiency with a weight of 0.169, increased efficiency with a weight of 0.165, facilitation of new economic opportunities and innovation with a weight of 0.164, and transparency and reduction of tax fraud with a weight of 0.150. These results indicate that experts viewed the operational and efficiency-related consequences of blockchain as more immediately important than its transparency-related outcomes. This prioritization may reflect the practical concerns of tax administrators, who face substantial workloads, fragmented procedures, delayed information exchange, and high enforcement costs. From this perspective, blockchain is particularly valuable when it simplifies processes and increases administrative capacity. The result is consistent with studies that frame blockchain as a means of reducing intermediation, improving process coordination, and increasing the efficiency of financial and administrative systems [3, 24].

The relatively lower ranking of transparency and fraud reduction does not imply that these outcomes are unimportant. Rather, transparency may function as an enabling mechanism through which operational efficiency, compliance, and cost reduction are achieved. Transparent records reduce the need for repeated verification, allow faster risk identification, and improve the reliability of automated tax procedures. In addition, the benefits of transparency may emerge gradually and depend on broad adoption across taxpayers and institutions, whereas operational cost savings may be more immediately observable. The prioritization findings therefore suggest that policymakers may gain stronger organizational support by initially emphasizing measurable efficiency and cost benefits while designing the system to produce longer-term improvements in transparency and compliance. This interpretation is supported by studies showing that blockchain improves reporting quality and auditability but that such benefits depend on complementary organizational and regulatory arrangements [4, 7, 21].

The findings also have implications for the Iranian tax system. Blockchain may help integrate fragmented tax information, improve the traceability of transactions, and strengthen the realization of sustainable tax revenues. Previous Iranian research has highlighted the potential of blockchain to increase tax-revenue realization by enhancing transparency and access to reliable financial information [28]. The present study extends this literature by empirically validating the relationships among implementation, integration, challenges, transparency, cost, and efficiency and by ranking their relative importance. The results also suggest that blockchain-based tax reform should be coordinated with developments in national digital currency, crypto-asset regulation, data governance, and financial reporting [8, 17, 18]. Such coordination is necessary because tax administration cannot be modernized independently of the broader digital financial ecosystem.

Overall, the combined SEM and fuzzy multi-criteria findings demonstrate that implementing a blockchain-based tax policy model is feasible but conditional. Blockchain implementation directly contributes to transparency and fraud reduction, policy integration improves efficiency and lowers operational costs, and the technology creates opportunities for economic innovation. At the same time, implementation challenges have a particularly strong influence on the success of the model. The findings therefore support a socio-technical understanding of blockchain adoption in which technical infrastructure must be aligned with legal frameworks, institutional responsibilities, data-governance mechanisms, employee capabilities, and taxpayer acceptance. This conclusion is consistent with the broader literature, which portrays blockchain as a transformative but context-dependent technology whose benefits emerge only when technological, regulatory, and organizational conditions are jointly addressed [1, 10, 19].

The findings of this study should be interpreted in light of several limitations. First, the quantitative data were collected from employees, managers, and experts of the tax administration in Tehran, which may limit the generalizability of the results to tax organizations in other provinces or countries. Second, the study relied primarily on self-reported questionnaire data, which may have been influenced by respondents' perceptions, expectations, or familiarity with blockchain. Third, because blockchain-based tax systems have not yet been fully implemented in the study context, some assessments were based on expert judgments and anticipated outcomes rather than observations of a mature operational system. Fourth, the cross-sectional design did not allow changes in attitudes, institutional readiness, or implementation performance to be examined over time. Finally, the prioritization results depended on the judgments of a relatively limited expert panel and may vary when different groups of policymakers, taxpayers, technology providers, or legal specialists are consulted.

Future studies should test the proposed model using larger and more geographically diverse samples and compare the findings across different tax jurisdictions. Longitudinal research could examine how organizational readiness, taxpayer acceptance, and system performance change before, during, and after blockchain implementation. Experimental or pilot studies should also evaluate actual effects on collection costs, processing time, fraud detection, tax compliance, and taxpayer satisfaction. Future researchers may incorporate additional variables such as digital literacy, perceived fairness, trust in government, cybersecurity readiness, privacy concerns, top-management support, and interorganizational collaboration. Comparative analyses of public, private, consortium, and permissioned blockchain architectures would also clarify which configuration is most suitable for different tax functions. Further studies should additionally investigate the integration of blockchain with artificial intelligence, electronic invoicing, national digital currencies, smart contracts, and real-time risk-analysis systems.

Tax policymakers should adopt a phased implementation strategy beginning with clearly defined and high-value applications such as electronic invoicing, value-added tax reconciliation, and interagency information exchange. Before large-scale deployment, tax authorities should establish comprehensive legal standards for data ownership, privacy, access rights, smart-contract liability, digital identity, and dispute resolution. A permissioned blockchain governed by authorized public institutions may provide a more appropriate balance between transparency and confidentiality than an unrestricted public network. Tax organizations should also modernize legacy systems, develop common data standards, invest in cybersecurity, and train employees in blockchain-based processes. Pilot projects should be evaluated using measurable indicators such as operational cost, processing time, error rates, fraud detection, taxpayer compliance, and user satisfaction. Finally, taxpayers, accounting professionals, financial institutions, software providers, and regulatory bodies should be involved in system design to ensure that the resulting model is technically viable, legally enforceable, operationally efficient, and socially acceptable.

Authors' Contributions

Authors equally contributed to this article.

Ethical Considerations

All procedures performed in this study were under the ethical standards.

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Conflict of Interest

The authors report no conflict of interest.

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