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MODELING TAX ADMINISTRATION EFFICIENCY IN THE CONTEXT OF DIGITALIZATION OF PUBLIC FINANCES

Abstract

The article explores the theoretical and methodological principles and applied aspects of assessing the efficiency of tax administration in the context of digital transformation of public finances. The feasibility of using a fuzzy multiple-criteria approach as a tool for integral assessment of tax administration effective-

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ness, taking into account the multifactorial nature and uncertainty of fiscal processes, is substantiated. The dynamics of key indicators of the functioning of the tax system of Ukraine are analyzed. A fuzzy-multiple model for integral assessment of tax administration efficiency is developed using a system of linguistic variables, membership functions and a rule base, which allows formalizing the relationships between fiscal, technological and behavioral parameters of efficiency. It has been established that the use of digital technologies in the field of public finance, in the process of modeling the efficiency of the tax payment administration system for budgets at all levels, combined with innovative approaches to tax compliance, creates the institutional prerequisites for ensuring the stability and growth of budget revenues, thereby expanding the opportunities for socio-economic development.

Key Words:

budgetary potential, digitalization, financial resilience, fiscal policy, fuzzy-multiple approach, integral evaluation, public finance, sustainable economic development, tax administration, tax compliance.

JEL: H21, H26, H83, C44, C51.

1 table, 7 figures, 31 references.

Problem Statement

Modern transformation processes in the field of tax policy are characterized by changes in the configuration of interbudgetary relations, increased requirements for the transparency, adaptability and effectiveness of the tax system, which necessitates the formation of new methodological approaches to assessing the efficiency of tax payment administration. In this context, the use of intelligent information technologies, in particular the fuzzy multiple-criteria approach, as a tool for formalizing the processes of analysis and managerial decision-making in the field of tax administration is of particular importance.

For Ukraine, the relevance of this study is heightened by wartime and post-war challenges, which necessitate ensuring the stability of budget revenues and strengthening the resilience of the financial system. This, in turn, underscores the need to update the scientific substantiation of the role of intelligent information technologies in enhancing the efficiency of tax payment administration, strengthening the fiscal potential of the state, and ensuring the resilience of the tax system.

In the modern geofinancial environment, increasing the efficiency of tax administration is driven by global trends in the digitalization of public finances, strengthening international tax coordination, increasing the scale of cross-border financial flows and the need to combat tax evasion in the context of the development of the digital economy. The implementation of initiatives by international organizations, in particular the OECD and the European Union, aimed at ensuring the transparency of tax systems, automatic exchange of financial information and tax risk minimization, creates new requirements for analytical tools for assessing the effectiveness of tax administration. In such conditions, the use of intelligent analytical data-processing methods that can take into account the uncertainty, multifactorial nature and nonlinearity of financial processes becomes particularly relevant, which justifies the feasibility of using the fuzzy-multiple approach to form objective and adaptive models for assessing the efficiency of tax payment administration.

The purpose of the article is to develop and test a fuzzy multiple-criteria model for the integrated assessment of the efficiency of tax administration in Ukraine in the context of the digitalization of public finances, based on a combination of fiscal indicators, indicators of the use of information technologies, and tax compliance parameters, with the subsequent identification of practice management benchmarks for strengthening budgetary potential, enhancing fiscal resilience, and ensuring the sustainable development of the state.

Literature Review

The issue of improving the efficiency of tax payment administration occupies a prominent place in modern scientific research, as it determines the level of the state's financial potential, the stability of the budget system and the effectiveness of fiscal policy implementation (Ubago Martínez et al., 2022). In financial science, the issues of optimizing tax systems are considered through the prism of ensuring the balance of the tax burden and increasing the efficiency of tax reforms (Carroll et al., 2024). The theoretical foundations of economic transformation in the context of information paradigm are substantiated in the works of J. Stiglitz, who emphasizes the decisive role of information factors in the development of financial and economic systems (Stiglitz, 2002). Modern scholarly ap-

proaches focus on digitalization as a key driver of the transformation of the financial sector and tax administration. The introduction of digital technologies contributes to greater transparency in tax procedures, lower transaction costs, and stronger tax compliance (Krysovatyy et al., 2024; Pantielieieva, 2022; Krynytsia, 2025). The development of information and analytical support for taxation and the use of digital platforms are considered an important prerequisite for increasing the efficiency of tax payment administration and ensuring the financial security of the state (Desyatnyuk, Krysovatyy, et al., 2025).

In the literature, digital platforms are regarded as an important factor in the transformation of financial systems and management processes, thereby creating a theoretical basis for improving tax administration and enhancing its efficiency, transparency, and consistency with modern models of digital governance (Łasak & Wyciślak, 2025; Kovalenko et al., 2024). At the same time, the introduction of electronic services, in particular of the taxpayer's electronic account, confirms the positive impact of digitalization on the voluntary fulfillment of tax obligations (Ivanovska & Havrik, 2025). Research proves that the digitalization of tax administration, the development of e-government, and the implementation of IT audit are important factors that contribute to higher tax efficiency, reduced corruption risks, and greater transparency of public finances (Umbet et al., 2025).

An important area of research is the impact of financial technologies on the mobilization of tax revenues. The findings of scientific studies indicate that the development of digital payment instruments contributes to the expansion of the tax base and the growth of budget revenues (Apeti & Edoh, 2023). In international practice, considerable attention is paid to the adaptation of tax systems to the digital economy, in particular the reform of the VAT system (Merkx et al., 2023), as well as the introduction of data-driven approaches to tax risk management (OECD, 2023).

The digitalization of financial services and the development of digital financial literacy are important factors in increasing the efficiency of tax administration, as they contribute to better interaction between taxpayers and the state's digital services and support the transparency of public finances (Rani et al., 2025).

Along with digitalization, an important area of research is the study of the behavioral aspects of the functioning of the tax system, primarily tax compliance as a key factor in the stability of budget revenues. The use of information systems and analytical tools allows for a more accurate assessment of taxpayer behavior and for forecasting tax revenues (Lipianina-Honcharenko et al., 2023).

The digitalization of public services contributes to reducing the administrative burden and increasing the transparency and quality of public finance management. At the same time, the experience of Thailand shows that, in order to achieve a real increase in the efficiency of tax administration, the systematic assessment of the financial results of digital projects, data integration across institu-

tions, and the development of digital competencies are essential (Caplanova & Szakadatova, 2025).

The increasing complexity of socio-economic processes and the presence of uncertainty necessitate the use of modern economic and mathematical methods of analysis. Studies have substantiated the feasibility of using artificial intelligence and intelligent data analysis methods for modeling economic systems and supporting managerial decision-making (Osadchyi et al., 2017; Rossikhina et al., 2025). The use of interval analysis methods makes it possible to increase the accuracy of assessing economic indicators under complex conditions. Machine learning also contributes to the systematic assessment of business risks by automating data analysis and identifying patterns that improve the accuracy and validity of managerial decisions (Chumachenko et al., 2020).

Digital financial technologies and machine learning methods enhance the effectiveness of financial decision-making, expand analytical capabilities, improve the adaptability of resource management systems, and at the same time represent a promising tool for improving tax administration, particularly in the areas of analytics, forecasting, and strengthening the sustainability of public finances (Lyzun et al., 2025).

The digitalization of public finances, including the introduction of e-invoicing, artificial intelligence, cloud technologies, data science, chatbots, and electronic payments, significantly increases the efficiency and productivity of tax administration. For modeling the efficiency of tax authorities, this indicates the feasibility of taking into account multidimensional digital factors as key determinants of tax administration performance in the context of the digital transformation of public finances (Rezaei & Jablonsky, 2025).

A special place in the modern scientific paradigm is occupied by fuzzy set theory, which makes it possible to account for the ambiguity of economic processes and to integrate quantitative and qualitative indicators. Scientific studies have demonstrated the effectiveness of fuzzy models in the analysis of macroeconomic indicators (Samodol et al., 2020), the optimization of economic processes (Kumar et al., 2024), the development of decision-support systems (Meza et al., 2018), as well as in the monitoring and evaluation of enterprise activities (Febriansyah et al., 2022).

The digitalization of the public sector can improve the quality of audits and the effectiveness of control procedures in tax administration; however, it also requires the development of digital competencies and careful consideration of data privacy risks (Mahouat et al., 2025). Thus, the analysis of scientific sources indicates the existence of a significant number of studies devoted to the problems of the digitalization of tax administration, the formation of tax compliance, and the application of economic and mathematical methods in the field of public finance. At the same time, the issues of the comprehensive assessment of tax payment administration efficiency using a fuzzy multiple-criteria approach, which makes it

possible to integrate heterogeneous indicators and account for the uncertainty of the economic environment, remain insufficiently studied. This necessitates further research aimed at developing an integrated model for assessing the efficiency of tax administration using modern economic and mathematical modeling tools.

Methodology

The research materials consist of official statistical data on the revenues of the Consolidated Budget of Ukraine and tax revenues, in particular indicators of the digitalization of tax administration, as well as tax compliance parameters in the areas defined by the Tax Code of Ukraine. The information base was formed through the systematization of data and the construction of a generalized table showing the dynamics of the indicators for further modeling.

The methodological basis of the research is a combination of financial-economic, systemic, and economic-mathematical approaches to assessing the efficiency of tax payment administration as a complex, multicomponent category of public finance. The research methods include statistical analysis (comparison, grouping, analysis of dynamics and structural changes), financial-economic analysis of budget revenue formation indicators, as well as economic-mathematical modeling using fuzzy set theory tools to formalize the relationships among fiscal, digital, and behavioral efficiency parameters. Fuzzy multiple-criteria modeling was implemented in the MATLAB environment (Fuzzy Logic Toolbox, MATLAB R2018a) through the development of a fuzzy inference system for the integral assessment of tax payment administration efficiency.

Research Results

In the modern context, the digitalization of tax payment administration appears as a complex multilevel process that combines economic, information, technological, institutional and social dimensions. Institutional and methodological support for monitoring the impact of intelligent information technologies on the effectiveness of tax payment administration should be considered as a prerequisite for increasing tax revenues, strengthening the budget potential, social development and resilience of the Ukrainian economy in the context of war and post-war challenges.

In Ukraine, the core of digital tax administration is the online services of the State Tax Service of Ukraine, primarily the «Taxpayer's Electronic Cabinet», which provides access to key functions of interaction with tax authorities (informa-

tion services, support for the fulfillment of reporting obligations, etc.) (Ivanovska & Havrik, 2025). An important digital component of the tax environment is the system of electronic settlement documents and software-based cash registers. In particular, E-Receipt is positioned as a technological alternative to traditional cash registers, with the ability to register transactions and transmit reporting information to the State Tax Service (Pantielieieva, 2022). Such tools, combined with analytical modules, create data for risk analysis and compliance monitoring in near real time. This context corresponds to the international experience of using software, digital platforms, information products for tax payment administration (e-invoicing, e-reporting, VAT in the Digital Age) (Merkx et al., 2023). This indicates the strengthening of the analytical capacity of tax authorities, the development of compliance-oriented administration and the increase of fiscal efficiency through data and standards (Krynytsia, 2025).

Given the growing role of intelligent information technologies in shaping the modern architecture of tax administration, there is a need to quantitatively verify their impact on fiscal results and the efficiency of the tax system (Desyatnyuk, Chereshnyuk, et al., 2025). This necessitates the transition from conceptual understanding of machine learning capabilities to empirical analysis of dynamic indicators, which allows assessing the actual effects of digitalization and determining the nature of the relationships between the level of implementation of intelligent technologies and the effectiveness of tax administration.

The fuzzy multiple-criteria approach to assessing the effectiveness of tax payment administration is based on the principles of fuzzy set theory and fuzzy logic, which allow formalizing complex socio-economic phenomena under conditions of uncertainty and ambiguity of statistical information. Its application involves building a system of linguistic variables and membership functions, which allows integrating multidirectional indicators of fiscal effectiveness, the level of digitalization and tax compliance into a single generalized assessment (Samodol et al., 2020). The feasibility of using fuzzy-multiple tools in the study of financial processes is confirmed by modern scientific publications, which substantiate its ability to increase the analytical flexibility of models and the adequacy of assessing complex economic systems (Meza et al., 2018).

In order to identify trends and structural shifts in the system of tax payment administration to the Consolidated Budget of Ukraine, a generalized table of the dynamics of the relevant indicators (Table 1) was compiled (State Budget Web Portal for Citizens, n.d.). This approach provides an information basis for the further formation of a fuzzy model for assessing the efficiency of tax payment administration and allows us to trace the relationship between the digitalization of the tax environment and the level of fiscal effectiveness (OECD, 2023).

Table 1

System of indicators for assessing the efficiency of tax payment administration used to build a fuzzy multiple-criteria model

	2018	2019	2020	2021	2022	2023	2024	2025
Revenues of the Consolidated Budget of Ukraine, UAH million	1184278.1	1289779.8	1376661.6	1662242.7	2196273.3	3104306.6	3587789.5	4337978.2
Tax revenues, UAH million	986348.5	1070321.8	1136687.2	1453804.1	1343225.0	1638085.0	2088283.8	2520339.2
Share of tax revenues, %	83.3	82.9	82.6	87.5	61.2	52.8	58.2	58.1
Filing of tax returns using ICT, %	74.5	78.1	82.3	87.5	91.5	94.4	95.6	97
Number of users of the electronic account of the State Tax Service of Ukraine, million persons	1.3	1.8	2.3	3.2	5	5.4	5.8	6.1

Source: authors' calculations based on data from State Budget Web Portal for Citizens (n.d.) and OECD (2023).

Analysis of the data in Table 1 shows an overall increase in fiscal indicators during 2018-2025, in particular, the revenues of the Consolidated Budget and tax revenues increased more than threefold, which reflects the expansion of fiscal potential and the influence of macroeconomic factors. At the same time, in 2022-2023, there was a significant decrease in the share of tax revenues in the structure of budget revenues, which is associated with a change in the structure of budget resources during the wartime period and an increase in the role of external financial support. Digitalization indicators demonstrate stable positive dynamics: the level of filing tax returns using information technologies increased to 97%, and the number of users of the Electronic Taxpayer's Cabinet increased almost fivefold. This context indicates an increase in the digital maturity of the tax system

and creates the prerequisites for increasing the efficiency of tax administration and increasing the level of tax compliance of taxpayers (Krysovatyy et al., 2024). The results obtained confirm the feasibility of using the fuzzy multiple-criteria approach for the integrated assessment of the efficiency of tax processes, taking into account the multifactorial nature of their development.

In order to assess the efficiency of tax payment administration, a thorough analysis of four factors was carried out, since they affect compliance indicators, namely the share of tax revenues in the revenues of the Consolidated Budget of Ukraine; the level of filing tax returns using information technologies; the number of users of the taxpayer's electronic cabinet and tax compliance. Given modern analytical requirements, MATLAB is effective for assessing and forecasting quantitative indicators (Febriansyah et al., 2022; Anand & Hota, 2020) because it combines the processing of quantitative and qualitative indicators in one environment. The method of assessing the quality of the functioning of an information system based on fuzzy logic is an effective approach, since makes it possible to integrate quantitative and qualitative indicators and take into account uncertainty to obtain a substantiated comprehensive assessment (Vasylkiv et al., 2020).

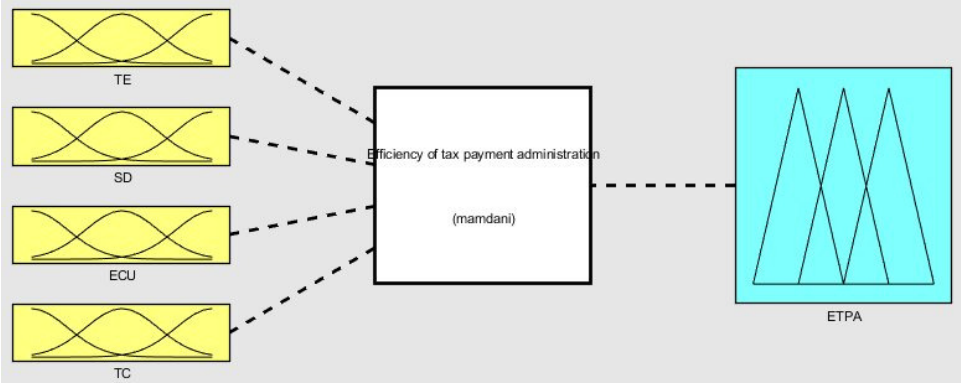
This is critical for tax administration, as indicators are often multifactorial, uneven in time, with seasonality, structural breaks, while simultaneously being subject to strict legislative regulation. Matlab R 2018a was used to develop a fuzzy system. The general view of the proposed system is presented in Figure 1.

To develop the model, the trapezoidal membership function was selected, as it is used in fuzzy modeling when it is necessary to define linguistic indicators such as «low,» «medium,» and «high» in a way that provides a zone of stable membership within a class. This is especially relevant for a model assessing the efficiency of tax payment administration, where many indicators have normative ranges of acceptability. The trapmf membership function was used to formalize the linguistic terms of the efficiency indicators of tax payment administration, since it ensures the presence of an interval of full membership (a plateau) corresponding to normative or target ranges. The trapezoidal membership function was chosen because it represents a range of values within which an indicator is considered fully acceptable according to established standards or targets.

The share of tax revenues in the revenues of the Consolidated Budget of Ukraine (TE) in the MATLAB model serves as an integral indicator of fiscal capacity and tax administration efficiency, affecting the assessment of the stability and effectiveness of revenue mobilization. For the TE variable, the membership function boundaries are defined as follows: low, $s \in [0;0.25)$; medium, $m \in (0.1;0.85)$; and high, $h \in (0.7;1]$. As TE increases, the tax «self-sufficiency» and resilience of the budget, as well as the predictability of revenues for expenditure planning, generally improve. Figure 2 shows the general form of the membership function for the TE variable.

Figure 1

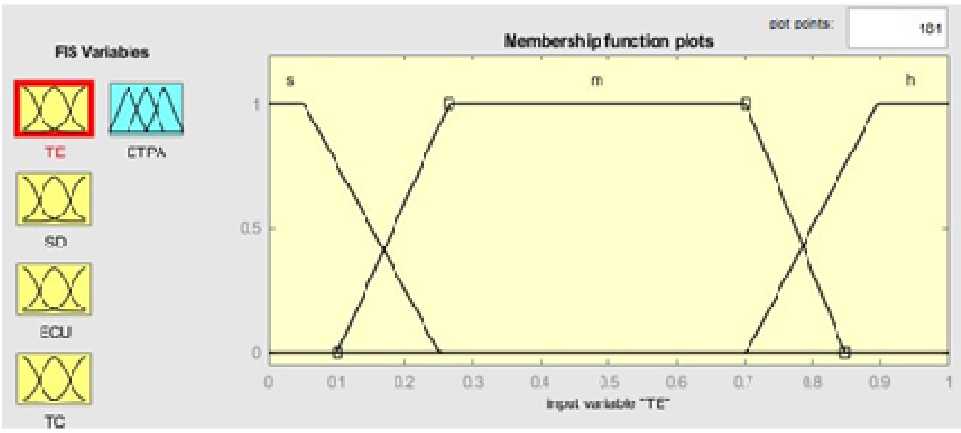
The general view of the fuzzy system of efficiency of tax payment administration



Source: authors' own elaboration.

Figure 2

Membership functions of the variable TE

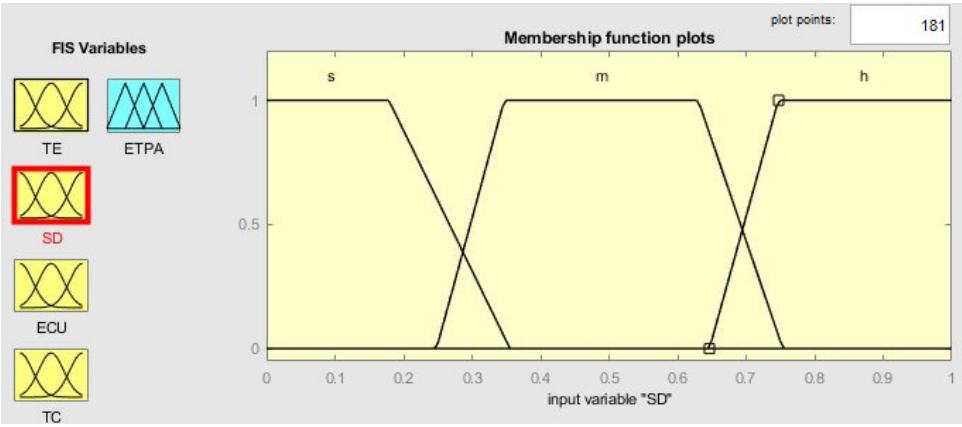


Source: authors' calculations.

The level of tax filing using information technology (SD) in the model reflects the degree of digitalization of taxpayers' interaction with tax authorities and affects the timeliness, accuracy, and costs of tax payment administration. The membership function boundaries for the SD variable are defined as follows: low, $s \in [0;0.35)$; medium, $m \in (0.25;0.75)$; and high, $h \in (0.65;1]$. As SD increases, the timeliness and completeness of filing generally improve, while errors and processing costs decrease and the transparency of risk-based control increases. Figure 3 shows the general form of the membership function for the SD variable.

Figure 3

Membership functions of the variable SD

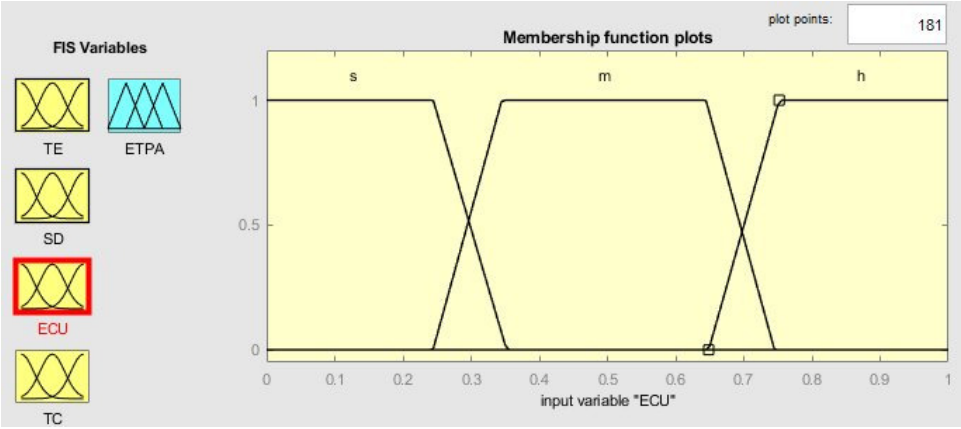


Source: authors' calculations.

The number of users of the electronic taxpayer account (ECU) in the model reflects the level of taxpayer engagement with digital services and is associated with the accessibility, speed, and quality of tax administration. The membership function boundaries for ECU are defined as follows: low, $s \in [0;0.35)$; medium, $m \in (0.25;0.75)$; and high, $h \in (0.65;1]$. As ECU increases, the timeliness and completeness of tax obligations generally improve, while administrative costs decrease (Figure 4).

Figure 4

Membership functions of the variable ECU



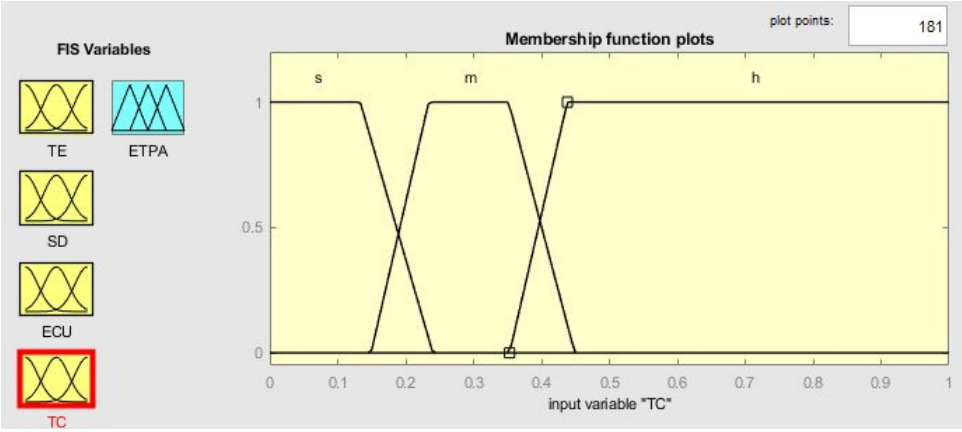
Source: authors' calculations.

Tax compliance (TC) in the model reflects the level of taxpayers' voluntary compliance with tax rules and characterizes the effectiveness and sustainability of tax payment administration. The membership function boundaries for TC are defined as follows: low, $s \in [0;0.25)$; medium, $m \in (0.15;0.45)$; and high, $h \in (0.35;1]$. As TC increases, tax evasion and tax debt generally decrease, while control costs are reduced (Figure 5).

The ETPA model generates an integral index of tax administration efficiency by aggregating quantitative and qualitative KPIs into a single score suitable for comparison over time, across regions, or among segments of taxpayers. The input variable is assigned the trapmf membership function for the extreme terms s and h, and the trimf membership function for the intermediate term m (trapmf provides a region of full membership (Kumar et al., 2024)). For the output variable, a trapezoidal membership function is assigned to the extreme terms s and h, and a triangular membership function to the intermediate value m. The level boundaries are defined as follows: $s \in [0;0.35)$, $m \in (0.15;0.85)$, $h \in (0.65;1]$ (Figure 6).

Figure 5

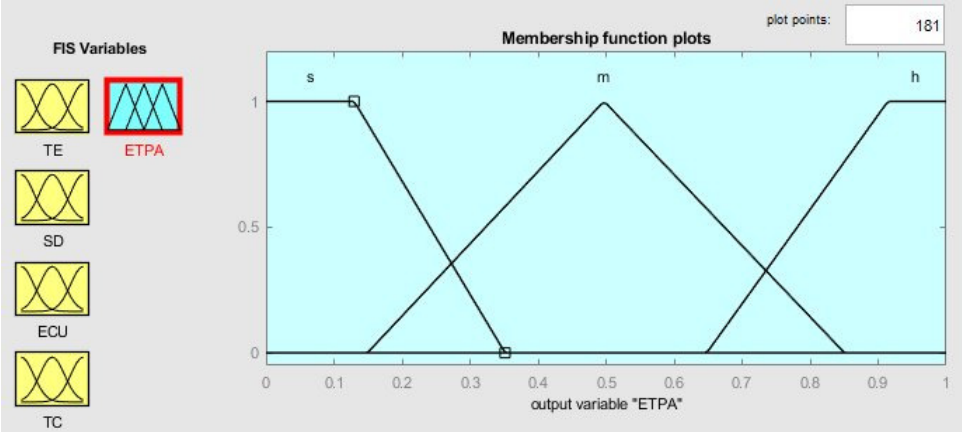
Membership functions of the variable TC



Source: authors' calculations.

Figure 6

Membership functions of the output ETPA

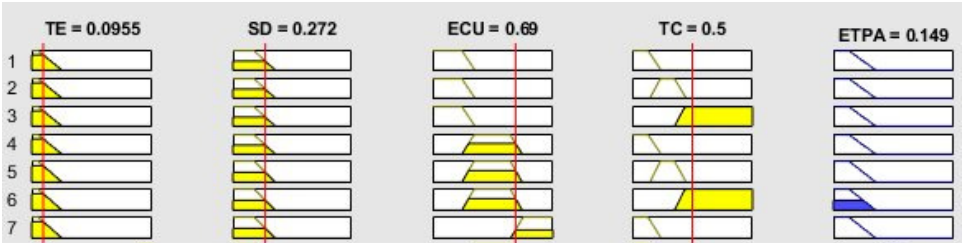


Source: authors' calculations.

Each input variable has three states, as well as an additional state corresponding to missing information. If data are missing for two variables, this indicates a high level of risk in the system, whereas the absence of data for three variables makes a correct assessment impossible. A total of 256 rules were defined to construct the fuzzy system. Figure 7 shows an example of the development of a rule base for a fuzzy model for assessing tax payment administration efficiency.

Figure 7

Fuzzy tax payment administration efficiency assessment model



Source: authors' calculations.

The application of the tax payment administration efficiency assessment model improves the quality of managerial decision-making by enabling the assessment of both quantitative and qualitative indicators in order to identify key influencing factors. It also provides early warning of risks and makes it possible to determine priority control, service, and IT measures, as well as to monitor digital transformation and conduct scenario forecasting of changes. The model may be useful for management and analytical departments of tax authorities, the Ministry of Finance of Ukraine in the budget planning process, risk management and internal audit units, as well as for researchers and consultants assessing the effectiveness of fiscal policy and tax administration.

Conclusions

The conducted research confirmed that the efficiency of tax payment administration is a multidimensional economic category that is formed under the influence of fiscal, technological and behavioral factors and cannot be adequately assessed solely through the dynamics of tax revenues. Analysis of indicators for 2018-2025 showed an overall increase in absolute revenues of the Consolidated Budget of Ukraine and tax revenues, which reflects the expansion of the state's fiscal potential, while structural changes in 2022-2023 led to a significant decrease in the share of tax revenues in budget revenues, which is associated with a change in the architecture of budget resources during the war and the growth of the role of external financing.

It was found that the indicators of digitalization of tax administration are characterized by stable positive dynamics, in particular, the growth of the level of tax reporting submission using information technologies and the increase in the number of users of the Taxpayer's Electronic Cabinet indicate an increase in the digital maturity of the tax system and the formation of institutional prerequisites for strengthening tax discipline and increasing the level of tax compliance. This confirms the transformation of the model of interaction between fiscal authorities and taxpayers in the direction of service-oriented administration.

The feasibility of using the fuzzy multiple-criteria approach as a tool for integral assessment of the effectiveness of tax payment administration is substantiated, which allows taking into account the vagueness of the boundaries between the states of economic processes, combining heterogeneous indicators and formalizing the expert logic of making management decisions. The implementation of the model in the MATLAB environment using membership functions and a system of rules provides the possibility of obtaining a generalized quantitative assessment of the effectiveness of tax administration, which increases the analytical validity of the assessment of fiscal processes.

The practical significance of the results obtained lies in the possibility of using the developed model as a tool for analytical monitoring of the effectiveness of tax administration and supporting management decision-making in the field of tax policy. It is proposed to institutionalize the integral performance indicator as an element of the analytical framework of assessing the activities of tax authorities, to expand the system of tax compliance indicators by operationalizing them, and to deepen the use of digital services aimed at increasing the voluntariness of tax compliance.

The prospects for further research should be associated with improving the parameterization of membership functions based on empirical data, expanding the set of digital transformation indicators, and testing the model for the scenario analysis of the impact of management decisions on the level of tax administration efficiency in the context of public finance transformation.

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