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Structural modelling for assessing the effectiveness of system for countering legalization of illicit money

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Abstract. The article suggests a scientific and methodological approach to the evaluation of the infrastructural component's effectiveness in the anti-money laundering system due to digitalization. Structural modelling is the basis for the mentioned approach implementation, which consists of several steps. First, the input data is selected in terms of the effective regulation of the financial services market, law enforcement and judicial activities, and digitalization. Next, the

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moving average method is used to identify the growth rate of missing values in the available data series. Then, the selection of relevant factors for financial services market regulation, law enforcement activity, judicial activity and digitalization is based on the principal component analysis. After reducing the input array of data to a comparable form, a structural equations system can be constructed to reflect the impact of the digitalization level on the latent integral characteristics of the directions of anti-money laundering work done by regulatory authorities. Finally, the model is checked for adequacy. The result of this research can serve as an information base for further strengthening the digital vector in the development of regulation institutions and law enforcement agencies overseeing the financial services market, as well as for the radical transformation of courts in Ukraine since digitalization currently negatively affects them.

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1. INTRODUCTION

The effective functioning of the democratic state should, first, ensure equal rights and freedoms for its citizens. Having adopted the Constitution of Ukraine on June 28, 1996, and ratified the European Convention on Human Rights, Ukraine has also become a member of such international organizations as the Council of Europe, the United Nations and others. Domestic bodies of legislative, executive, and judicial power must carry out their activities while prioritizing the protection of the native population. It includes the physical preservation of citizens' health, which is especially relevant in the conditions of war in Ukraine and the protection of the economic rights of the population. The latter direction of ensuring the rights and freedoms of Ukrainians meansestablishing an effective anti-money laundering system is of particular interest. According to UNODC estimates, 2-5% of the global GDP, or 800 million - 2 trillion US dollars, is legalized worldwide. Ukraine, as a part of the global financial and economic system, is actively involved in international schemes for money laundering. According to the State Financial Monitoring Service, 3793,73 million US dollars were potentially legalized in Ukraine in 2021. The legalization process, its mechanisms, participants, and losses incurred by the budget of Ukraine violate the legal rights of individuals and legal entities in the state. A multi-level institutional network for anti-money laundering was created in response to existing Ukrainian problem. The National Bank of Ukraine and the National Securities and Stock Market Commission regulate the activities of the participants in the financial services market. The State Financial Monitoring Service accumulates information on possible money laundering cases, verifies the information and forms generalized materials based on the collected data. Pre-trial investigation bodies (the National Anti-Corruption Bureau of Ukraine, the Bureau of Economic Security of Ukraine, the National Police, the Security Service of Ukraine, and the State Bureau of Investigation) and the prosecutor's office collect evidence, form indictments, and submit cases related to money laundering to court. Courts consider cases on their merits and determine whether there is enough evidence to convict the accused of a crime. The existing anti-money laundering system was formed throughout the Ukrainian independence and underwent significant transformations. The annual development of digital technologies does not allow each link of these institutions to stop in their development. For example, the popular cryptocurrency expands money laundering at their layering and integration stages significantly. Thus, the active implementation of digitalization in the work of anti-money laundering system is an integral component of its effective work and further strategic development. However, reforming each subject in the anti-money laundering system should be based on an individual approach regarding the digitalization impact on it and the current level of involvement in this process. To solve this task more effectively, it is advisable to - develop an appropriate economic and mathematical model, which is a structural modelling.

2. LITERATURE REVIEW

The impact of digitalization on social, economic and political processes in the state has been widely disclosed in recent years in scientific research. However, many countries' public administration processes in digitalisation are at the initial stages of their development. Thus, the digitalization of public institutions was considered by (Borg M. et al., 2018), who concluded that the software for government should be thought out and protected since errors can lead to significant losses. Providing services by the state in an electronic format is new for many countries. (Spacek, D. et al., 2020), point out that digital obedience in the Czech Republic, Romania and Hungary is low and that it is necessary to support digitalization projects in public services. (Lopez B.S. and Alcaide A.V., 2020) investigated how such modern technologies as blockchain, artificial intelligence, and the Internet of Things affect public administration and crisis management capabilities during emergencies. Chen P.-K. et al., (2022) proved that, in addition to the blockchain, the technology of smart contracts has a wide range of applications.

Studying scientific works devoted to the impact of digitalization on the anti-money laundering system, we note that digitalization increases the quality of financial monitoring in banks (Vovk, V. et al., 2020), and promotes more effective implementation of FATF recommendations in the field of anti-money laundering. Said, K. and Karimi, D. (2022) made the same conclusions noting that the automation of banking processes increases the financial security in banks and improves financial monitoring. A particularly strong impact of digitalization on the money laundering can be observed through a decrease in the amount of cash in circulation (Kobushko I. et al., 2021). Recent studies show that fintech is widely implemented in banks in developing countries (Boiko A. et al., 2021), allowing financial institutions to join the global anti-money laundering system much faster. Many scientists (Djalilov & Hölscher, 2016; Djalilov & Hartwell, 2021) concluded that the introduction of complex digital technologies improves banking capabilities and affects the possibility of prompt detection of illegal transactions. In addition to the above, one should know that digitalization speeds up the work of an employee from the relevant body of the anti-money laundering system: an interactive search replaces long leafing through papers, i.e., man-hours of work are saved (Kuzior et al., 2022; Antonyuk N et al., 2022).

Addo, A. and Senyo, P.K. (2020), Simovic, M. (2021), Linhartova, V. and Halásková, M. (2022) studied the impact of digitalization on law enforcement activities, namely the fight against corruption. They consider digitalization is a powerful anti-corruption tool. Denis de Castro Halis (2019) researched examples of the use of digital technology in prosecutorial activity. The author notes that by increasing the document processing speed simultaneously, digitalization means also form the basis for their direct control, ensuring the investigation's independence and compliance with its laws. The use of modern technologies in judicial activity is worth considering. Yusep Mulyana (2021) notes that the digitalization of courts begins with electronic document flow but is not limited to it; all processes related to cases can be served in an electronic court. For example, courts can be conducted in an online format, which speeds up the process.

Digitalization ensures transparency and quality of public administration (Faid G. et al., 2020). Public authorities must be open to citizens (Mynenko & Lyulyov, 2022; Androniceanu, 2021). Kostetskyi P. (2021) concludes that digitalization and transparency have a causal relationship. It is important to provide public authorities with electronic services (Kuzior et al., 2021). The private sector is being transformed under the influence of digitalization leading to legislative changes since many regulatory acts do not consider possible digitalization (Burlaka et al., 2019). According to recent studies, digitalization positively affects macroeconomic stability (Tiutiunyk et al., 2021). Digitalization changes approach to understanding medicine (Kuc-Czarnecka M., 2020), agriculture (Hennyeyová et al., 2021), the functioning of socio-economic networks (Sliwa P. et al., 2021), communication between people (Raišienė et al., 2021), decision-making (Lustigová et al., 2021), employment (Beňo, 2021), etc.

It is also necessary to mention the negative impact of digitalization in the financial sphere. Separately, innovations in the digital sphere influence the growth of cybercrimes (Kuzmenko O. et al., 2021), and the state should be ready to fight them. The risk of cyber fraud increases (Koibichuk V. et al., 2021) when using modern financial instruments since not all participants of the exchange can be informed about novelties, or the possible information leakage, physical hacking or obtaining data using social engineering. Technological solutions must be sufficiently protected against cyberattacks, and the data organization must prevent their leakage (Skrynnyk, 2020). On the other hand, any system must be ready to y integrate modern innovation systems successfull (Skrynnyk, 2021). The topic of implementation was also discussed by León-Gómez A. et al. (2022) and the quality assessment of information technologies was discussed by Zamir Z. and Kim D. (2022). Lyeonov S. et al. (2019) emphasizes the importance of increasing the cyber security of transactions in anti-money laundering. In addition, the widespread use of information technologies has a negative impact on the emotional state of users and leads to stress (Jurek, P. et al., 2021).

Analysing publications on the use of economic and mathematical modelling, we note that they have been actively used in recent times in scientific research devoted to the determination of the development peculiarities of various processes, as well as the identification of the impact made by multiple techniques on each other. For example, the Neurofrontier modelling can be used to model social development (Vasilyeva T. et al., 2021) or in forecasting tourist demand (Çuhadar M., 2020). The Hodrick-Prescott filter highlights the trend from the time series of direct foreign investment (Moskalenko B. and Mitev P., 2020). The data envelopment analysis is used in the study of the of the information security system effectiveness of the state (Yarovenko H. et al., 2020). The Sedov-Taylor model enables to assess the impact of information bursts at the global level (Kuzmenko O. et al., 2021). The correlation and cluster analyses can be used to study the relationship between information security, innovation, and the public administration quality on the country's prestige (Petroye O. et al., 2020; Mačiulytė-Šniukienė A. et al., 2022). The cluster analysis is also used by Vasilyeva T. et al. (2021) to study the impact of digitalization on the anti-money laundering processes. Several scientists used GARCH models to model the cryptocurrency market (Obeng C., 2021) and oil market volatility (Musetescu R. et al., 2022).

Focusing directly on the use of economic-mathematical tools studying processes related to the anti-money laundering system, we note that the risk of funds legalization in developing countries was defined based on the analysis of cyclical time indicators called Fourier analysis (Levchenko V. et al., 2019). The effectiveness of the anti-money laundering system was evaluated based on the Cobb-Douglas function (Lieonov S. et alal., 2021). Rambharat B.R. and Tschirhart A.J. (2015) assessed the riskiness of the bank s client regarding involvement in money laundering using panel data regression modelling and log-linear modelling,. The Data Mining methods, namely the bifurcation analysis, determine the participation of financial institutions in the money laundering process (Kuzmenko O. et al., 2020; Papík M., and Papíková L., 2021). Subeh M. A. and Boiko A. (2017) demonstrate an interesting approach to modelling an effective financial monitoring system based on the mass service systems approach.

Econometric models help to carry out more in-depth studies, which are devoted to the transformational changes of economic systems at the macro level, resulting in the loss of balance in the financial sector. It was established that the money laundering system affects the macroeconomic stability of the country due to the increase in the shadow economy (Lyulyov O. et al., 2021; Sedmikova E. et al., 2021;

Buszko A. 2022) especially in transition economies (Gamal, A.A.M. et al., 2022; Nguen T.A.N. and Nguen K.M. 2021), on the stability of the financial sector: banks (Vasileva T. and Lasukova A., 2013) and banking system (Vasilyeva T. et al., 2016; Kuznyetsova A. et al., 2017), other financial intermediaries (Brychko M. et al., 2021; Fedajev A. et al., 2022). The financial instability causes vulnerabilities in national security (Yarovenko, H., 2020; Shpak N. et al., 2020) and investment attractiveness of the country (Moskalenko B. et al., 2022; Kozmenko S. and Vasilyeva T., 2008). The increase in economic security as a component of national security is especially important in post-pandemic times (Kuznyetsova A. et al., 2021). Vasilyeva T. et al. (2020) studied the country's financial security problems.

While studying the use of mathematical tools selected as a research method, we note that structural equation modelling is widely used in many fields of science since it is a universal approach to determining hidden relationships between phenomena characterized by groups of variables (Nikolenko U. et al., 2021). The peculiarities of structural modelling were investigated by Wang Y.A. and Rhemtulla M. (2021) in psychology, where scientists raised the question regarding an appropriate sample size in modelling to obtain meaningful results. The use of structural modelling in the study of tax behaviour (Samusevych Y. et al., 2021) allowed to reveal of new information about the impact of taxation on national security. The effectiveness of the approach in modelling consumer behaviour has been proven by Hair J.F. et al. (2019). The methodology of applying structural equations is constantly being studied and improved. The issue of improving fit indices in structural modelling was considered by (Savalei V., 2020) and the greater efficiency of modelling with categorical data was proven. (Henseler J. et al., 2015) provided recommendations for solving the issue of the discriminant validity assessment.

According to this method, various software is used in calculations: Lavaan (R Package) (Yeves Rosseel, 2012), Python (Kim H. et al., 2021), STATISTiCA software (Kerimkulova D. et al., 2021) etc.

3. METHODOLOGY

The research information base consists of two groups of indicators. The first includes indicators that characterize the system of combating the legalization of criminal income. The second is the state of digitalization of the country. Thus, the first group includes indicators: the number of reports on suspicious transactions (units) taken into account by the State Financial Monitoring Service; Number of materials (units) summarized by the State Financial Monitoring Service; Amount of funds related to legalization and other criminal offenses, which is indicated in the summarized materials (million UAH); Amount of property seized and transferred to state income (million UAH); Number of criminal proceedings that were opened or developed with the use of new materials (units); Number of indictments sent to court (units). To the second group: Gross domestic product of the information and telecommunications sector, in actual prices (million UAH); Export of information and telecommunication goods (% of all exports of goods); Import of information and telecommunication goods (% of all imported goods); Export of information and telecommunication services (% of all exported services); Number of mobile phone users (units); Number of Internet users (%).

Analytical calculations were made based on relative indicators, namely: Number of recorded suspicious transactions per material (units/units); Number of recorded suspicious transactions per one UAH of the funds involved (units/million UAH). Other indicators do not require generalization or transformation.

Structural modelling is the methodological basis of the research. It is based on a system of joint, simultaneous equations (or structural form of the model) and usually contains endogenous and exogenous variables. Endogenous variables are dependent variables, the number of which is equal to the number of equations in the system, and which are denoted by y. Exogenous variables are variables that affect endogenous variables, but are independent of them. They are denoted by x.

The structural form of the model in the right part contains coefficients b_{ij} for endogenous variables and coefficients a_{ij} for exogenous variables, which are called structural coefficients of the model. All variables in the model are expressed in deviations from the average level, that is, *x* means $x - \bar{x}$, and *y* means y$-\bar{y}$, so there is no free term in this equation.

The system of structural equations has the following generalized form:

$$\begin{cases} y_1 = b_{12}y_2 + b_{13}y_3 + \cdots + b_{1m}y_m + a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n + \varepsilon_1 \\ y_2 = b_{21}y_1 + b_{23}y_3 + \cdots + b_{2m}y_m + a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n + \varepsilon_2 \\ y_3 = b_{31}y_1 + b_{32}y_2 + \cdots + b_{3m}y_m + a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n + \varepsilon_2 \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ y_m = b_{m1}y_1 + b_{m2}y_2 + \cdots + b_{m,m-1}y_{m-1} + a_{m1}x_1 + a_{m2}x_2 + \cdots + a_{mn}x_n + \varepsilon_n \end{cases} \quad (1)$$

The impact made by digitalization on the effectiveness of the regulatory bodies' work in anti-money laundering was analysed based on indicators of the financial services market regulation, law enforcement activities and judicial activities. Processing gaps in the input database of statistical data was carried out using the moving average method. For each group of input indicators to regulate the financial services market, law enforcement activities, judicial activities and digitalization, relevant factors were selected applying the principal components method. Structural modelling of the impact of a 1% change in the latent variable of the digitalization development on the latent integral characteristics of the areas of work of supervisory bodies in the anti-money laundering field was held using the Statistica software.

4. EMPIRICAL RESULTS AND DISCUSSION

We note that the scientific-methodical approach to evaluating the effectiveness of the anti-money laundering system through the prism of digitalization , consists of six stages. So, let us consider each of them in more detail.

In the first stage, the input information base of statistical data to study the impact of digitalization on the regulatory bodies' effectiveness in the anti-money laundering field is formed. Its implementation is proposed to be carried out based on indicators of the regulation of the financial services market, law enforcement activities, and judicial activities in the dynamics from 2000 to 2021.

It is proposed to consider the following indicators, grouped by clusters:

1) Regulation of the financial services market: RMFS1 - Number of recorded suspicious transactions per material (units/units); RMFS2 - The number of recorded suspicious transactions per one UAH of the funds involved (units/million UAH); RMFS3 - Amount of property seized and transferred to state income (million UAH);

2) Law enforcement activity: LS1 - Number of criminal proceedings that were opened or developed with the use of new materials (units); LS2 - Number of indictments sent to court (units); LS3 - Amount of property seized and transferred to state income (million UAH);

3) Judicial activity: CS1 - Number of cases with a guilty verdict (units); CS2 - Amount of property seized and transferred to state income (million UAH);

4) Digitalization: DG1 - Gross domestic product of the information and telecommunications sectors, in actual prices (million UAH); DG2 - Export of information and telecommunication goods (% of all exports of goods); DG3 - Import of information and telecommunication goods (% of all imported goods); DG4 - Export of information and telecommunication services (% of all exported services); DG5 - Number of mobile phone users (units); DG6 - Number of Internet users (%).

Given the fact that the available information base is characterized by no data for certain years, it is proposed to determine them using the moving average method at the second stage:

- forecast values of the i-indicator of digitalization for 2021 based on available data from 2003 to 2020:

$$DG_{it+1} = DG_{it} \cdot \sqrt[t-4]{\frac{DG_{it}}{DG_{i4}}} \quad (2)$$

where DG_{it+1} – the forecast value of i-indicator of digitalization for (t+1)-year;

DG_{it} – the actual value of i-indicator of digitalization for (t)-year.

- the forecast values for regulating the financial services market, law enforcement activity, judicial activity in the middle of the series level:

$$RMFS_{it} = \frac{RMFS_{it-1} + RMFS_{it+1}}{2}$$

$$LS_{it} = \frac{LS_{it-1} + LS_{it+1}}{2} \quad (3)$$

$$CS_{it} = \frac{CS_{it-1} + CS_{it+1}}{2}$$

- the forecast values for regulating the financial services market, law enforcement activities, judicial activities, and digitalization at the beginning of the considered time series:

$$DG_{it-1} = DG_{it} / \sqrt[t-j]{\frac{DG_{it}}{DG_{ij}}}$$

$$RMFS_{it-1} = RMFS_{it} / \sqrt[t-j]{\frac{RMFS_{it}}{RMFS_{ij}}}$$

$$LS_{it-1} = LS_{it} / \sqrt[t-j]{\frac{LS_{it}}{LS_{ij}}} \quad (4)$$

$$CS_{it-1} = CS_{it} / \sqrt[t-j]{\frac{CS_{it}}{CS_{ij}}}$$

where DG_{ij} –the value of i-indicator of digitalization for the first available j-year;

$RMFS_{ij}$ – the value of i-indicator for regulating the financial services market for the first available j-year;

LS_{ij} – the value of i-indicator of the legal system for the first available j-year;

CS_{ij}- the value of i-indicator of court system for the first available j-year.

Within the framework of modeling any process, the key stage is to find relevant variables. Considering the need to achieve maximum simplicity of calculations, the task fulfillment at the fourth stage of the methodology implemented for evaluating the impact of digitalization on the effectiveness of the regulatory bodies in the anti-money laundering field is significant.. Therefore, the relevant factors in each group of input indicators in the regulation of the financial services market, law enforcement activity, judicial activity and digitalization are selected based on the principle components method. We will use the Statistica program,particularly, Statistics/Multivariate Exploratory Techniques/Principal Components and Classification Analysis.

Based on the obtained eigenvalues of the correlation matrix (table 1 and Fig. 1), in particular the accumulated total variance (the last column of table 1), it is possible to assert the expediency in terms of the first two factors for further practicality of the relevant indicators of input data in regulating the financial services market.

Table 1

Eigenvalues of correlation matrix, and related statistics to regulate the financial services market

Value number	Eigenvalue	Total variance, %	Cumulative Eigenvalue	Cumulative, %
1	1,9656	65,5197	1,9656	65,5197
2	0,7561	25,2048	2,7217	90,7244
3	0,2783	9,2756	3,0000	100,0000

Source: own calculation

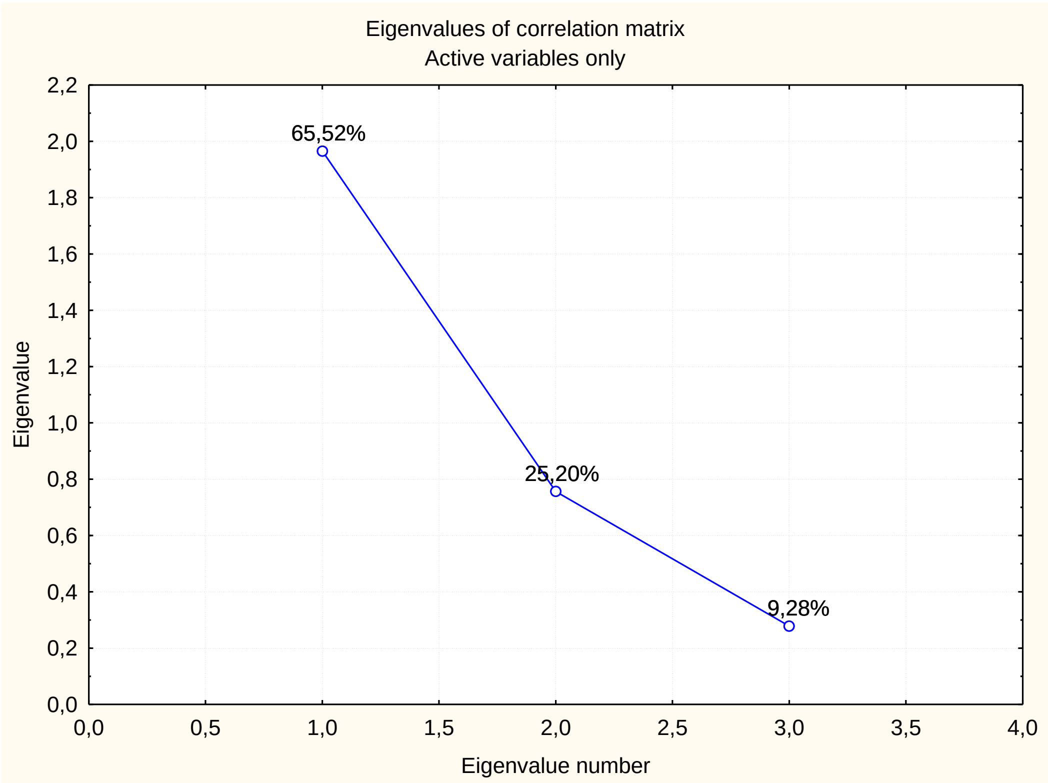

Figure 1. The scree plot of % of the total variation of factors for regulating financial services market

Source: own calculation

Having considered variables based on correlation for regulation of the financial services market in terms of the first two factors ("Factor 1" and "Factor 2" columns of Table 2) and considering the percentages of variation due to these two factors, we conclude that RMFS1 and RMFS2 should be recognized as relevant.

Table 2

Variable contributions, based on correlations for regulating financial services market

Indicator	Factor 1	Factor 2	Factor 3
RMFS1	0,2227	0,7241	0,0533
RMFS2	0,4207	0,0249	0,5544
RMFS3	0,3566	0,2511	0,3923

Source: own calculation

Having conducted a similar approach to the above analysis on the indicators relevance of the law enforcement activities based on the data from Tables 3 and 4 and Fig. 2, it is appropriate to assert the need to recognize LS1 and LS2 indicators as relevant.

Table 3

Eigenvalues of correlation matrix, and related statistics for law enforcement activity

Value number	Eigenvalue	% Total variance	Cumulative Eigenvalue	Cumulative %
1	1,6569	55,2286	1,6569	55,2286
2	1,0031	33,4351	2,6599	88,6637
3	0,3401	11,3363	3,0000	100,0000

Source: own calculation

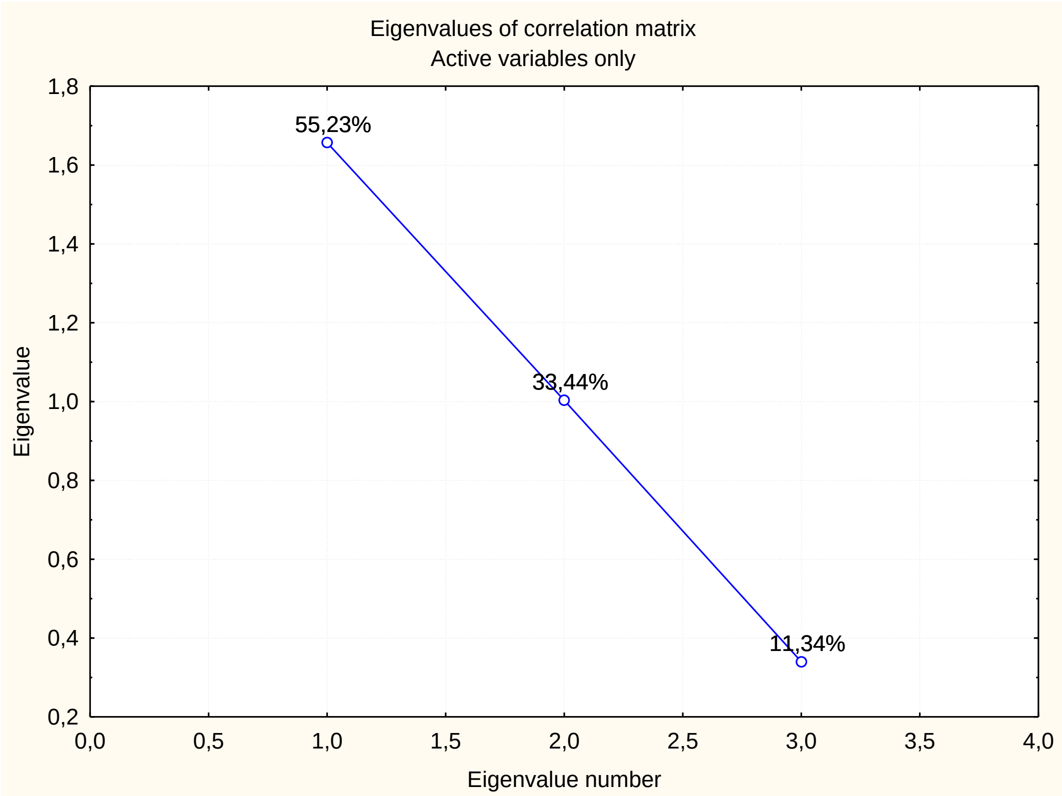

Figure 2. The scree plot of % of the total variation of factors in law enforcement activity

Source: own calculation

Table 4

Variable contributions, based on correlations in law enforcement activity

Indicator	Factor 1	Factor 2	Factor 3
LS1	0,5011	0,0001	0,4988
LS2	0,4750	0,0520	0,4730
LS3	0,0239	0,9479	0,0282

Source: own calculation

Given the fact that the input array of statistical information consists of indicators of different measurement, it is reasonable, at the fourth stage of the proposed study, to standardize the value of the digitalization impact assessment on the effectiveness of the regulatory bodies' work in the anti-money laundering field . We use the Statistica program, in particular the Data/Standardize command, involving the following formula:

$$\widetilde{DG_{\iota t}} = \frac{DG_{it} - \overline{DG_{\iota t}}}{\sigma_{DG_i}} \quad (5)$$

$$\widetilde{RMFS_{\iota t}} = \frac{RMFS_{it} - \overline{RMFS_{\iota t}}}{\sigma_{RMFS_i}}$$

$$\widetilde{LS_{\iota t}} = \frac{LS_{it} - \overline{LS_{\iota t}}}{\sigma_{LS_i}}$$

$$\widetilde{CS_{\iota t}} = \frac{CS_{it} - \overline{CS_{\iota t}}}{\sigma_{CS_i}}$$

where $\widetilde{DG_{\iota t}}$ – the standardized value of i-indicator of digitalization for t-year;

$\overline{DG_{\iota t}}$ – the average value of i-indicator of digitalization for t-year;

σ_{DG_i} – the mean square deviation of i-indicator of digitalization for the observed period.

The results of calculations carried out according to equations (5) are presented in Table 5.

At the fifth stage of the proposed approach, we will carry out structural modeling of a 1%- change impact in the latent variable of the digitalization development on the latent integral peculiarities of the regulatory bodies' work in the anti-money laundering field using the Statistica program. We will use the Statistica program, in particular, Statistics/Advanced linear/nonlinear Models/Structural Equation Modeling. A clear definition and justification of the relationships between groups of indicators is a prerequisite for conducting structural modeling. So, further, we define the system of linear paired and multiple regression equations, introducing the following assumptions:

- the regulation of the financial services market affects the law enforcement system;
- the state of the law enforcement system determines the judicial system;
- the level of digitalization defines the development of the financial services market regulation and the state of the law enforcement and judicial systems;
- as an endogenous variable, it is proposed to choose an implicit latent variable of the digitalization level, which is determined by three explicit indicators of digitalization, while all other variables are exogenous.

Table 5

Standardized values of the input indicators for the assessment of the digitalization impact on the effectiveness of the regulatory bodies in the anti-money laundering field

Year	Indicators								
	RMFS1	RMFS2	LS1	LS2	CS1	CS2	DG1	DG5	DG6
2000	1,51	-0,59	-1,32	-0,98	-1,02	-0,51	-0,92	-1,91	-1,07
2001	1,51	-0,55	-1,32	-1,02	-1,03	-0,49	-0,90	-1,85	-1,05
2002	1,36	-0,51	-1,31	-0,97	-1,01	-0,47	-0,88	-1,79	-1,03
2003	1,08	-0,49	-1,30	-1,02	-1,03	-0,46	-0,86	-1,66	-0,99
2004	-0,32	-0,44	-1,23	-0,97	-1,01	-0,44	-0,81	-1,34	-0,97
2005	-0,68	-0,40	-0,71	-0,87	-1,01	-0,42	-0,76	-0,62	-0,96
2006	-0,80	-0,41	-0,55	-0,89	-1,01	-0,41	-0,71	0,23	-0,94
2007	-0,79	-0,39	-0,03	-0,35	-0,51	-0,41	-0,62	0,50	-0,87
2008	-0,84	-0,44	0,37	0,95	0,57	-0,55	-0,51	0,52	-0,71
2009	-1,02	-0,48	1,10	1,51	1,45	0,63	-0,48	0,49	-0,47
2010	-0,93	-0,42	0,33	0,76	0,32	-0,52	-0,42	0,44	-0,28
2011	-0,80	-0,36	-0,36	1,37	-0,26	-0,49	-0,33	0,52	-0,10
2012	-0,91	-0,60	-0,14	1,93	1,03	-0,46	-0,25	0,68	0,13
2013	-0,94	-0,67	2,60	1,96	1,36	-0,44	-0,17	0,82	0,33
2014	-0,84	-0,74	1,27	0,31	2,22	0,09	-0,11	0,76	0,52
2015	0,11	0,35	0,38	-0,04	0,43	0,61	0,20	0,74	0,61
2016	0,98	2,44	-0,04	-0,31	-0,05	4,08	0,55	0,57	0,75
2017	1,10	2,37	0,14	0,04	1,36	0,15	0,91	0,52	0,96
2018	0,96	-0,15	0,47	-0,48	-0,59	0,37	1,43	0,44	1,08
2019	1,41	2,11	0,37	0,23	0,59	0,59	2,17	0,48	1,35
2020	-0,26	0,82	0,18	-0,38	-0,45	0,01	2,39	0,44	1,52
2021	-0,89	-0,45	1,12	-0,77	-0,36	-0,46	1,08	1,00	2,20

Source: own calculation

Based on the given assumptions, we will build a model of structural equations, the parameters and statistical characteristics of which are listed in Table 6.

Table 6

Model estimates of the digitalization impact on the regulatory bodies' effectiveness in the anti-money laundering field

	Parameter Estimate	Standard Error	T Statistic	Prob. Level
(DG)-1->[DG1]	0,905	0,170	5,317	0,000
(DG)-2->[DG5]	0,675	0,194	3,489	0,000
(DG)-3->[DG6]	0,993	0,159	6,257	0,000
(DELTA1)-->[DG1]				
(DELTA2)-->[DG5]				
(DELTA3)-->[DG6]				
(DELTA1)-4-(DELTA1)	0,181	0,077	2,334	0,020
(DELTA2)-5-(DELTA2)	0,544	0,172	3,171	0,002
(DELTA3)-6-(DELTA3)	0,014	0,064	0,217	0,828
(RMFS)-->[RMFS1]				
(RMFS)-7->[RMFS2]	1,461	0,705	2,074	0,038
(LS)-->[LS1]				
(LS)-8->[LS2]	0,641	0,167	3,827	0,000
(CS)-->[CS1]				
(CS)-9->[CS2]	0,176	0,215	0,821	0,412
(EPSILON1)-->[RMFS1]				
(EPSILON2)-->[RMFS2]				

	Parameter Estimate	Standard Error	T Statistic	Prob. Level
(EPSILON3)-->[LS1]				
(EPSILON4)-->[LS2]				
(EPSILON5)-->[CS1]				
(EPSILON6)-->[CS2]				
(EPSILON1)-10-(EPSILON1)	0,691	0,246	2,810	0,005
(EPSILON2)-11-(EPSILON2)	0,339	0,281	1,205	0,228
(EPSILON3)-12-(EPSILON3)	0,000	0,000		
(EPSILON4)-13-(EPSILON4)	0,589	0,182	3,240	0,001
(EPSILON5)-14-(EPSILON5)	0,000	0,000		
(EPSILON6)-15-(EPSILON6)	0,969	0,299	3,240	0,001
(ZETA1)-->(RMFS)				
(ZETA2)-->(LS)				
(ZETA3)-->(CS)				
(ZETA1)-16-(ZETA1)	0,219	0,186	1,178	0,239
(ZETA2)-17-(ZETA2)	0,384	0,201	1,908	0,056
(ZETA3)-18-(ZETA3)	0,420	0,130	3,240	0,001
(DG)-19->(RMFS)	0,301	0,182	1,659	0,097
(DG)-20->(LS)	0,926	0,290	3,189	0,001
(DG)-21->(CS)	-0,088	0,179	-0,490	0,624
(LS)-22->(CS)	0,811	0,178	4,563	0,000
(RMFS)-23->(LS)	-1,076	0,635	-1,694	0,090

Source: own calculation

Thus, data presented in Table 6 help to formalize the economic andmathematical model of the structural equations of the digitalization impact on the regulatory bodies' effectiveness in the anti-money laundering field as follows:

$$\begin{cases} DG1 = 0.905 \cdot DG + 0.181 \\ DG5 = 0.675 \cdot DG + 0.544 \\ DG6 = 0.993 \cdot DG + 0.014 \\ RMFS1 = RMFS + 0.691 \\ RMFS2 = 1.461 \cdot RMFS + 0.339 \\ LS1 = LS \\ LS2 = 0.641 \cdot LS + 0.589 \\ CS1 = CS \\ CS2 = 0.176 \cdot CS + 0.969 \\ RMFS = 0.301 \cdot DG + 0.219 \\ LS = 0.926 \cdot DG - 1.076 \cdot RMFS + 0.384 \\ CS = -0.088 \cdot DG + 0.811 \cdot LS + 0.420 \end{cases} \quad (6)$$

where DG – the latent implicitly specified (defined by the system of structural equations) variable that characterizes the generalizing level of digitalization;

$RMFS$ – the latent variable of the development of financial services market regulation;

LS – the latent variable of the development of the law enforcement system;

CS – the latent variable of the judicial system development.

Therefore, the analysis of system (6) allows making the following conclusions regarding the digitalization's impact of on the regulatory bodies' effectiveness in the anti-money laundering field:

- with an increase in the digitalization level by 1%, the level of regulation development of the financial services market will increase by 0.30%;
- a 1%-increase in the digitalization level has a positive effect on the development of the law enforcement system, which will increase accordingly by 0.93%;
- there is a negative impact of digitalization on the judicial system, the level of which will decrease by 0.09% with a 1%-increase in the digitalization level;
- a directly proportional influence was found in terms of the dependence of the law enforcement and judicial systems, i.e. with an increase in the level of the law enforcement system development by 1%, the level of judicial system development will increase by 0.81%;

The sixth stage is the last one. It is one of the most important stages in the proposed methodology. It consists in assessing the adequacy of all the above calculations. To confirm the adequacy of the detected dependencies, it is necessary to analyze the adequacy criteria (table 7).. The minimum value of the disagreement function is 4.09, while the Maximum Residual Cosine, Maximum Absolute Gradient, ICSF Criterion and ICS Criterion indicators come to zero levels. It indicates the adequacy of the constructed model. In addition, the value of the Chi-Square criterion is relatively high and takes the value of 85.88, which is significantly higher than the critical permissible level. The adequacy of the constructed model of structural equations is also confirmed by the value of the p-level, which come to zero level.

Table 7

Basic Summary Statistics

	Value
Discrepancy Function	4,089566
Maximum Residual Cosine	0,003074
Maximum Absolute Gradient	0,012139
ICSF Criterion	0,000313
ICS Criterion	0,007515
ML Chi-Square	85,880895
Degrees of Freedom	22,000000
p-level	0,000000
RMS Standardized Residual	0,254755

Source: own calculation

In addition, the statistical significance of the parameters of the linear paired and multiple equations inthe system (6), confirmed by the Student's test ("T Statistic" column of Table 6) and Prob. Level of the rejection probability of the statistical insignificance hypothesis regarding the corresponding parameter is an important criterion in the model adequacy. The values of p-levels for most parameters do not exceed the 0.05-level, and the value of the Student's criterion takes a level not lower than the critically admissible.

Starting the analysis of the next essential criterion of the adequacy and accuracy of the structural equations model regarding the digitalization impact on the regulatory bodies' work effectiveness in the anti-money laundering field, i.e., to the conformity with the normal law of distribution of the normalized model residuals (Fig. 3), we note the proximity of the actual points to the line that defines the normal distribution law.

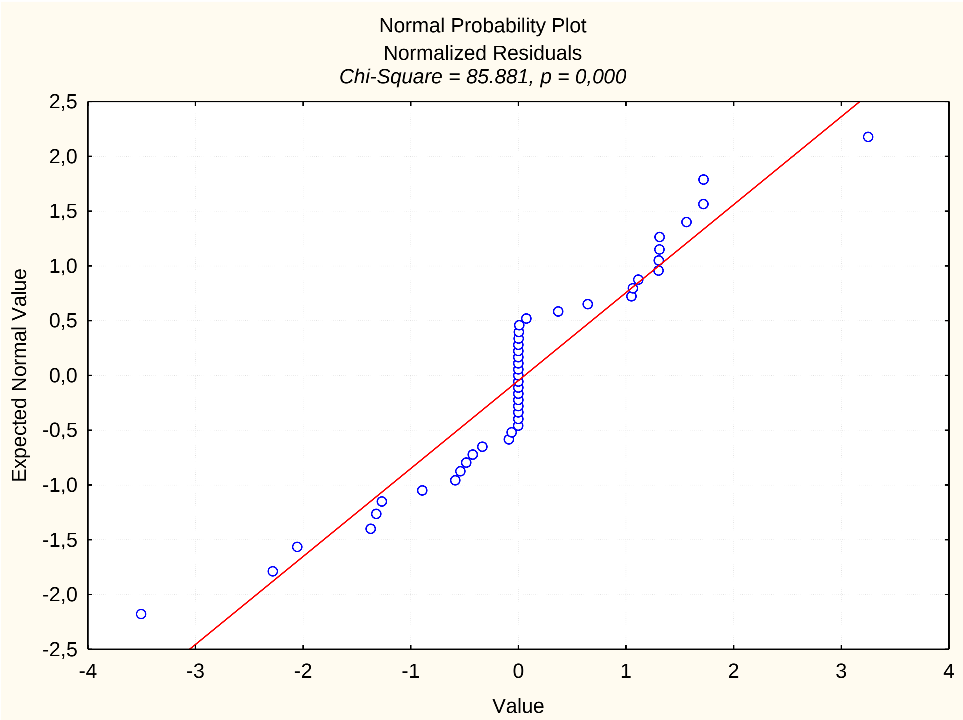

Figure 3. A fragment of compliance with the normal law of the distribution of the normalized model residuals

Source: own calculation

The reflector matrix, presented in Table 9, is one of the criteria in the structural equation model sensitivity regarding the digitalization impact on the regulatory bodies' effectiveness in the anti-money laundering field. Based on the data analysis in Table 9, it can be argued that the model is insensitive to changes in the scale of input data since the values of the matrix come to zero levels.

Table 9

Reflector Matrix

	RMFS1	RMFS2	LS1	LS2	CS1	CS2	DG1	DG5	DG6
RMFS1	0,002	-0,001	0,646	0,570	0,480	0,022	0,281	0,908	0,444
RMFS2	0,005	-0,002	-0,428	-0,409	-0,612	-0,803	-0,374	-0,602	-0,282
LS1	0,300	0,106	0,008	0,283	0,141	-0,262	-0,180	-0,407	-0,225
LS2	0,357	0,177	0,000	0,000	-0,459	0,175	0,372	-0,157	0,357
CS1	-0,082	-0,312	0,003	-0,627	0,000	-0,029	0,122	-0,115	0,058
CS2	-0,344	-0,680	-0,017	0,145	0,000	0,000	-0,319	-0,166	-0,296
DG1	-0,955	-0,895	0,740	0,657	0,752	-0,110	-0,000	0,475	-0,007
DG5	1,048	0,158	-0,744	-0,903	-0,715	-0,058	0,158	-0,000	-0,002
DG6	0,205	0,653	-0,179	0,301	0,020	0,296	-0,088	-0,075	-0,006

Source: own calculation

Thus, it is fair to conclude that the calculations obtained from thepractical implementation of proposed methodology are adequate and can become an information base for effective management decisions. The findings can be used by the executive authorities and public oversight bodies in the annual review of the reforms' effectiveness and the transformation of the digitalization impact on the regulatory bodies' work effectiveness in the financial sphere, law enforcement agencies and courts.

5. CONCLUSION

Digitalization significantly affects the functioning of law enforcement and financial system regulatory bodies in Ukraine. This research confirmed the hypothesis that it can increase the anti-money laundering effectiveness by developing information technologies. Digitalization has the strongest impact on the law enforcement system. Collecting evidence and forming documents on the case is naturally more effective via information technologies. The effectiveness of the bodies that control the financial services market development is also gradually increase. Thus, the maximum transfer of all payments into a non-cash form allows state regulatory bodies to form an effective financial monitoring system.

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