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Aleksandra Kuzior
D.Sc. in Economics, Professor of the Department of Applied Social Sciences, Silesian University of Technology, Zabrze, Poland;
e-mail: aleksandra.kuzior@polsl.pl
ORCID: 0000-0001-9764-5320
(Corresponding author)

Ján Užík
PhD in Economics, Assistant of the Department of Accounting and Auditing, University of Economics in Bratislava, Bratislava, Slovakia;
ORCID: 0000-0001-6678-2285

Tetiana Dotsenko
PhD in Economics, Department of Health Care Management, Technical University of Berlin, Berlin, Germany;
ORCID: 0000-0001-5713-2205

Rostyslav Riabyi
PhD in Economics, Assistant of the Department of Finance and Credit, Financial-Legal College, Kyiv, Ukraine;
ORCID: 0009-0000-0319-1170

Hanna Filatova
PhD in Economics, Assistant of the Department of Accounting and Taxation, Sumy State University, Sumy, Ukraine;
ORCID: 0000-0002-7547-4919

Yaroslav Reshetniak
Department of Economics, Entrepreneurship and Business Administration, Sumy State University, Sumy, Ukraine;
ORCID: 0000-0003-0806-0801

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ASSESSMENT OF IMPLICIT AND EXPLICIT ILLICIT REGION FINANCIAL FLOWS, CONDUCTED THROUGH THE FRAUDULENT ACTIONS OF LOCAL AUTHORITIES: THEORETICAL BASIS

ABSTRACT

Estimating illicit financial flows is crucial for increasing transparency and fighting corruption at the regional level. This study aims to develop a comprehensive methodology for assessing both hidden and overt illicit financial flows arising from the fraudulent activities of local authorities. The proposed methodology involves modelling and estimating the volume of illicit financial capital based on the convergence of elements of descriptive and canonical analysis, as well as the Minkowski metric. The scientific and methodological approach considers 30 relevant indicators that allow for the most complete assessment of illicit financial flows mediated by public officials. The algorithm of the developed methodology provides for the following steps: (1) formation of a data sample of 30 factors; (2) division of factors into four groups by means of logical analysis: the first group – factors for assessing the loss of financial resources from implicit illegal financial flows; the second group - factors for assessing the loss of financial resources from explicit illegal financial flows; the third group – factors for assessing the probability of accumulation of implicit illegal capital flows; the fourth group – factors for assessing the probability of accumulation of implicit illegal capital flows; (3) checking the data for multicollinearity; (4) determining the presence of intergroup relationships and the direction of influence for the formed groups of factors based on canonical analysis; (5) normalizing the input statistical database; (6) optimizing the number of relevant factors by means of factor analysis, principal component analysis; (7) construction of an integral indicator, based on the Minkowski metric; (8) construction and graphical visualization of the rating of quantitative categories of illicit financial flows by the level of the integral indicator; (9) formalization of qualitative categories of the level of illicit financial capital based on the Harrington scale for assessing illicit financial flows.

Keywords: fraud, corruption, implicit financial flows, explicit financial flows, illicit financial capital, descriptive analysis, canonical analysis, Minkowski metric, loss of financial resources, probability of illegal capital flows, financial monitoring

JEL Classification: H83, K42, R51, D73

INTRODUCTION

Fraudulent activities in the financial sector undermine the legal economy. At the same time, the illegal turnover of funds generated by illicit actions of government officials is an acute problem that significantly affects the welfare of society, leading to social inequality, uneven distribution of wealth, and worsening the population's quality of life. It indicates the existence of corruption in government agencies, abuse of power by civil servants, and a significant concentration of resources among a limited number of individuals.

Manifestations of corruption, such as the concealment of the process of issuing licenses, permits, and contracts or their simplification, can lead to the redistribution of resources not in favour of the public interest but only to particular elected officials. The use of government officials' powers for personal gain leads to a decline in public trust in gov-

ernment institutions, which may further hinder the implementation of necessary reforms. In general, a country with a high level of corruption loses its investment attractiveness, affecting all sectors of its economy.

Illegal financial transactions carried out by local authorities also have a negative impact on business activities, leading to additional business costs (bribes and other illicit payments), unfair competition (as the advantage is given to those to whom the authorities are «more loyal»), and, in general, to the shadowing of the economy and increased obstacles. Thus, illegal financial transactions have devastating consequences for the country's economy, as such transactions do not pay taxes, do not comply with economic standards, or comply with legal requirements, causing significant financial losses to the state.

One of the critical obstacles to identifying illegal financial transactions is that such transactions are often disguised as legal transactions by using complex schemes, tricky algorithms, shell companies, offshore accounts, and other tools that ensure anonymity. In addition, financial reports often do not contain detailed decryption of the intended use of funds or final beneficiaries; they only contain information on the total volume of transactions, which complicates detecting fraud due to lack of information.

In addition, the problem of detecting and assessing illicit financial flows is the lack of fully effective analysis methods to detect implicit anomalies. In general, traditional methods of monitoring and auditing, firstly, may not be adapted to complex schemes and algorithms of illegal financial transactions (especially hidden ones); secondly, monitoring and auditing are often conducted by related authorities on the principle of "institutional collusion" (i.e., concealment of violations or crimes committed by colleagues to maintain the status quo or to gain their benefits).

Thus, the analysis of illicit financial trafficking arising from illegal actions of local authorities is a topical issue that requires further research, as it has severe consequences for the country's stability, security, and economic development. However, for effective analysis, it is essential to develop a scientific and methodological approach that would allow assessing not only apparent illegal financial flows but also taking into account latent ones to further develop a transparent response at the level of local authorities, at the national level and the international level, to improve the structure and systems of supervision, control, and responsibility in government.

LITERATURE REVIEW

The negative impact of illicit financial flows is significant and multifaceted, as they lead to economic destabilization, reducing the investment attractiveness of regions and causing a loss of state budget revenues due to tax evasion. Therefore, it is not surprising that the issue of illicit financial flows is addressed in the works of many scholars and practitioners trying to study and prevent this phenomenon from various aspects. In particular, the general theoretical issues of the concept of financial fraud, corruption, and their micro- and macroeconomic impact on the country's economy are addressed in the studies of Djouadi et al. (2024), Djouadi et al. (2023), Vasylieva and Kasyanenko (2013), Zolkover et al. (2022).

Global trends in the formation of illicit financial flows were considered by Kuzmenko et al. (2023a).

Bilan et al. (2020a) and Bilan et al. (2020b) studied the threats of shadowing the economy, which, among other things, were formed by a significant number of illicit financial flows. In their studies, the authors emphasize that the higher the level of the shadow economy, the lower the level of stability of the country's economic system.

Kuzior et al. (2021) examined the relationship between the volume of illicit financial flows and the ability of a country to achieve sustainable development, noting that this relationship is inversely proportional.

Pozovna et al. (2023), Sheliemina (2023), Wright (2023), Ray (2024) and Melnyk et al. (2024) argued that illegal financial transactions mediated by the authorities have a devastating impact not only on the country's economy but also on society as a whole, leading to social inequality and a decline in the quality of life.

It should be noted that a considerable number of researchers (Leonov et al., 2019; Kuzmenko et al., 2023a) agreed that the best preventive method of preventing illegal financial transactions is an effectively developed monitoring and control system.

In general, scientists and practitioners propose various methodologies and techniques to identify, monitor, evaluate, control, and quantify the impact of illicit financial flows.

Many of these methodologies are theoretical and based on understanding the nature of economic processes and cause-and-effect relationships in economic models (Mazurenko et al., 2023a). The other part involves the convergent use of

theoretical knowledge of the structure of the country's financial and economic system and the use of statistical and economic-mathematical methods and models to detect and prevent fraud (Kovbasyuk et al., 2024).

In the context of detecting illicit financial flows and assessing their negative impact, methods of data mining (Kuzmenko et al. (2023b)) and forensic accounting (Asare & Samusevych, 2023) deserve close attention. However, these methods have both their advantages (they are used to extract and analyze large amounts of financial data to detect fraud and potential illegal activities) and disadvantages (as they require significant time and can sometimes be subjective in their assessment of phenomena).

Also, a common methodology for assessing the impact of illegal financial transactions among practitioners is the use of the integral method. The essence of this method is to assess the negative effects of such operations on the country's economy (Dobrovolska et al., 2024a), its investment potential (Vasylieva and Kasyanenko, 2013) or society (Didenko et al., 2023) with one generalized indicator. This method is effective in the process of generalized assessment of the impact of phenomena but requires the collection and processing of a significant amount of data to take into account all the resulting factors for an objective assessment of the situation.

Currently, methods that not only allow us to assess the result of illegal transactions but also provide an opportunity to detect and prevent them are becoming increasingly important. To achieve such goals, researchers usually use a variety of methods: statistical (such as regression analysis, cluster analysis, ANOVA method, etc.), economic and mathematical methods (game theory, stochastic modelling, linear programming, etc.) and others (decision tree, neural networks, artificial intelligence). The idea is to optimize and facilitate the process of detecting anomalies that indicate fraud, as well as to try to predict the behaviour of fraudsters (Kozhushko, 2023). In addition, as correctly noted by Lyeonov et al. (2019), such methods are extremely valuable in terms of their ability to process large amounts of data in a shorter time frame than traditional methods of evaluation and analysis, as well as to identify hidden patterns in this data.

The statistical method of data analysis - clustering - is currently becoming increasingly relevant and widespread, as it allows for identifying patterns that indicate fraudulent activities. This method allows for analyzing large amounts of data and, by grouping them, identifying common features and patterns for each cluster and, based on this, developing separate strategies for preventing and combating illegal financial transactions (Kuzmenko et al., 2023b). It should be noted that quite often, in scientific research, this method is used in convergence with the integral method of assessing illicit financial flows. Since estimating all illicit financial flows with one generalized indicator is impossible, researchers usually first cluster them according to specific characteristics (e.g., types of illegal financial activities, etc.) and only then assess using the integral indicator calculated for each cluster.

The rapid development of technology has led to a scientific debate among researchers on the use of artificial intelligence in tracking, preventing, and detecting illegal financial transactions (Zámek and Zakharkina, 2024). Artificial intelligence algorithms do indeed allow for the analysis of large amounts of data in just a few minutes, identifying patterns of anomalies that indicate fraudulent activity. However, as correctly noted by Lyeonov et al. (2021), Midor et al. (2021), and Mańka-Szulik et al. (2024), the development of such an algorithm requires considerable effort, taking into account the numerous factors that must be prescribed in the algorithm code and, accordingly, significant financial investments in its development.

With the emergence of cryptocurrencies and a large number of illegal financial transactions with them, researchers have begun to pay more and more attention to blockchain technology. The use of this can ensure the transparency of financial transactions, reducing the likelihood of illegal activities (Springs (2024a), Springs (2024b), Kuzior et al., 2022).

A particular area of research is the scholarship on the role and place of authorities, including local authorities, in implementing illegal financial transactions through their direct involvement or negligence.

Studies have shown that the lack of transparency in the activities of government officials, as well as even isolated cases of corruption, have an extremely negative impact on both public trust in the government and the overall criminalization of society (Barannyk et al., 2021; Filatova et al., 2022; and Balas & Kaya, 2024). In general, as Mentel et al. (2018) and Mazurenko et al. (2023b) have correctly noted, corruption in local government creates an environment in which various forms of financial fraud, including embezzlement, bribery, and nepotism, are actively disseminated.

Empirical and case studies provide evidence of local government involvement in illicit financial flows, such as research by Filemon, at el. (2024) demonstrated how local government officials can manipulate banking transactions for money laundering, leading to significant financial losses and negative socio-economic consequences.

Dluhopolskyi & Danyliuk (2023), Posadnieva & Sidelnykova (2024), and Morin & Burrell (2024) have shown that illegal transactions carried out by government officials lead to devastating consequences for society, including increased social inequality, a decrease in the quality of life, and the loss and undermining of democratization.

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Other studies by Bijańska et al. (2018) and Dobrovolska et al. (2024b) emphasize the pervasive nature of corruption in local governments and the need to establish reliable monitoring and evaluation mechanisms.

Although this issue is widely represented in the scientific literature, the vector of assessing implicit and explicit illicit financial flows, with local authorities' direct and indirect participation, still needs to be studied more.

AIMS AND OBJECTIVES

This article aims to develop a methodology and tools for assessing implicit and explicit illicit financial flows in the region mediated by fraudulent actions of local authorities.

To achieve this goal, the following tasks were set:

- to analyze existing methodologies for analyzing illegal financial transactions to select the most relevant one;
- to determine the list of relevant indicators for identifying and assessing illegal financial flows in the region;
- to develop a step-by-step algorithm for assessing implicit and explicit illicit financial flows carried out by representatives of local authorities;
- to provide recommendations on the peculiarities of an empirical study of applying the developed model in actual conditions.

METHODS

The development of a methodological and methodological basis for assessing the volume and probability of implicit and explicit illicit financial flows with the direct and indirect participation of representatives of local authorities involves modelling the assessment of illicit financial capital based on the convergence of elements of descriptive and canonical analysis, as well as the Minkowski metric, which is implemented by a number of successive stages of the model, clearly presented in the form of a structural and logical scheme (Figure 1).

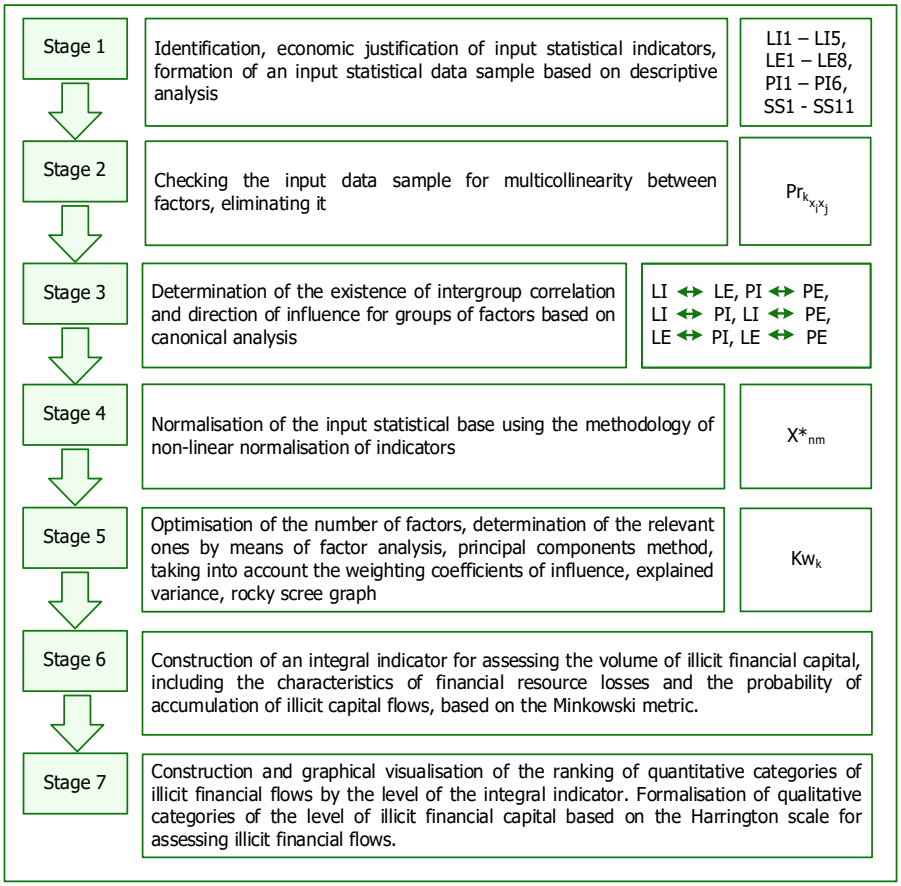

Figure 1. Structural and logical scheme of modelling the estimation of illicit financial capital.

The methodology involves estimating illicit capital flows by m (30) factors. The descriptive analysis allowed us to systematically describe and consolidate the main characteristics of the statistical sample of indicators of the issue under study, identify logical patterns and interrelationships, and generate hypotheses.

Factors were divided into four groups and two types using logical analysis:

- the first group of factors, LI, describes the factors for assessing the loss of financial resources from implicit illicit financial flows: State financing of municipal enterprises (LI1), UAH billion, stimulant; Number of municipal enterprises (LI2), units, stimulant; Index of trust in courts (LI3), points, stimulant; General interaction of enterprises with local authorities (LI4), points, stimulant; Share of party majority in the regional council (LI5), %, stimulant;
- the second group of LE factors, which describes the factors for assessing the loss of financial resources from explicit illicit financial flows: Approval of police activities (LE1), points, stimulant; Approval of prosecutor's office activities (LE2), points, stimulant; Approval of regional council parties activities (LE3), points, stimulant; Expenditures of the population (LE4), UAH million, stimulant; Regional budget revenues (LE5), UAH million, stimulant; Regional budget expenditures (LE6), UAH million, stimulant; Salaries of regional heads (LE7), UAH, stimulant; Gross regional product (LE8), UAH per capita, stimulant;
- the third group of PI factors describes factors that determine the likelihood of accumulation of implicit flows of illicit capital: Interaction of enterprises with local authorities in starting a business (PI1), points; Interaction of enterprises with local authorities in obtaining construction permits (PI2), points, stimulant; Interaction of enterprises with local authorities in land registration (PI3), points, stimulant; Interaction of enterprises with local authorities on connection to the power grid (PI4), points, incentive; Interaction of enterprises with local authorities on payment of taxes (PI5), points, incentive; Interaction of enterprises with local authorities on electronic services (PI6), points, incentive;
- the fourth group of PE factors describes factors that determine the probability of accumulation of explicit illicit capital flows: Number of districts in the region (PE1), units, stimulus; Number of communities in the region (PE2), units, stimulus; Number of settlements in the region (PE3), units, stimulus; Regional Digital Transformation Index (PE4), points, stimulus; Government Transparency Rating (PE5), points, stimulus; Government Accountability Rating (PE6), points, stimulus; Gini index (PE7), points, stimulus; Level of responsibility of regional government officials (PE8), %, stimulus; Level of responsibility of local government officials (heads of regional councils) (PE9), %, stimulus; Sense of security in the region (PE10), points, stimulus; Approval of the work of regional media (PE11), points, stimulus.

RESULTS

Thus, as part of the first stage of the proposed methodology, statistical indicators characterizing illicit financial flows are selected from open information sources: The State Statistics Service, the Ministry of Finance, the International Republican Institute IRI, the Better Regulation Delivery Office BRDO, etc. select and analyze statistical indicators characterizing illicit financial flows (Table 1).

First, the indicators were divided into two general groups: factors of loss of financial resources and factors of the probability of accumulation of illicit capital flows through fraudulent actions of local authorities.

In the second step, we identified additional groups that characterize financial flows in terms of implicit and explicit features within each group. Thus, implicit flows of illicit capital are unexpressed, hidden, secret, illegal ways of capital circulation that are difficult to detect, evaluate, and control. They can cover various aspects, including hidden or non-transparent financial interactions, informal transactions, and other situations that are not clearly reflected or remain outside official reporting and statistics but are determined by indirect evidence. Explicit illicit capital flows are explicit, clear paths of capital movement with measurable, traceable flows. They can be identified through official financial statements, official data sources, and statistical indicators.

In addition, the factors were divided into four groups: LI (LI1, LI2, LI3, LI4, LI5); LE (LE1, LE2, LE3, LE4, LE5, LE6, LE7, LE8); PI (PI1, PI2, PI3, PI4, PI5, PI6); PE (PE1, PE2, PE3, PE4, PE5, PE6, PE7, PE8, PE9, PE10, PE11). Of these, 3 factors (LE4, LE6, LE7) – are destimulants, and 27 factors (LI1 - LI5, LE1 - LE3, LE5, LE8, PI1 - PI6, PE1 - PE11) – are stimulants.

Next, an input statistical data sample for analysis is formed, which includes data from "m" (30) factors for assessing illicit financial flows by «n» objects (regions).

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Table 1. Input statistical indicators characterizing illicit financial flows.

Factor	Symbolic designation	Units of measurement	Type stimulant-S/destimulant	Group
State financing of public utilities	LI1	UAH billion	S	LI (factors for assessing the loss of financial resources from implicit illicit financial flows)
Number of municipal enterprises	LI2	Units	S	
Index of trust in the courts	LI3	Points	S	
Overall interaction of enterprises with local authorities	LI4	Points	S	
Share of party majority in the regional council	LI5	%	S	
Approval of police performance	LE1	points	S	LE (factors for assessing the loss of financial resources from explicit illicit financial flows)
Approval of the work of the prosecutor's office	LE2	points	S	
Approval of the work of the parties of the Regional Council	LE3	points	S	
Expenditures of the population	LE4	UAH million	D	
Regional budget revenues	LE5	UAH million	S	
Regional budget expenditures	LE6	UAH million	D	
Salaries of heads of regions	LE7	UAH	D	
Gross regional product	LE8	UAH per 1 person	S	
Interaction of enterprises with local authorities in starting a business	PI1	points	S	PI (factors for the probability of accumulation of implicit illicit capital flows)
Interaction of enterprises with local authorities in obtaining construction permits	PI2	points	S	
Interaction of enterprises with local authorities in obtaining land plots	PI3	points	S	
Interaction of enterprises with local authorities in connection to the electricity grid	PI4	points	S	
Interaction of enterprises with local authorities on payment of taxes	PI5	points	S	
Interaction of enterprises with local authorities on electronic services	PI6	points	S	
Number of rayons in the region	PE1	units	S	PE (factors for the probability of accumulation of explicit illicit capital flows)
Number of communities in the region	PE2	units	S	
Number of settlements in the region	PE3	units	S	
Regional digital transformation index	PE4	points	S	
Government transparency rating	PE5	points	S	
Government accountability rating	PE6	points	S	
Gini index	PE7	points	S	
Level of responsibility of local government officials	SS8	%	S	
Level of responsibility of local government officials	PE9	%	S	
Sense of security in the region	SS10	points	S	
Approval of the work of regional media	SS11	points	S	

The input data sample is checked for multicollinearity between the factors and its elimination at *the second stage.* At this stage, the composition of the factors is adjusted by excluding «c» indicators with a high degree of correlation between them based on checking the data sample for multicollinearity in Statistica (Correlations tool). Multicollinearity is the phenomenon of linear relationships and dependence (high degree of correlation) between independent variables in a multivariate regression model. Mathematically, the essential characteristic of multicollinearity is expressed by the correlation formula, where the correlation coefficient modulo tends to 1 (formula 1):

$$\left|r_{k_{x_i x_j}}\right| \to 1, i \neq j, \quad (1)$$

Where $\left|r_{k_{x_i x_j}}\right|$ *– is the modulo correlation coefficient of the number* $r_{k_{x_i x_j}}$.

To identify linear dependencies between factors, tests for determining the phenomenon of multicollinearity based on separate methods are used. This methodology involves testing by calculating the linear Pearson correlation coefficients according to the following formula (formula 2):

$$Pr_{k_{x_i x_j}} = (\overline{x_\iota * x_j} - \overline{x_\iota} * \overline{x_j}) * (\delta_{x_i} * \delta_{x_j})^{-1}, \quad (2)$$

where $Pr_{k_{x_i x_j}}$ *– is Pearson's linear correlation coefficient;* x_i *and* x_j *– are the first and second factors under study;* δ_{x_i} *and* δ_{x_j} *– are the standard deviations of the first and second factors studied;* $\overline{x_\iota * x_j}$ *– average value of the sum of factors;* $\overline{x_\iota}$ *and* $\overline{x_j}$ *– are the average values of the first and second factors.*

Next, multicollinearity is eliminated based on the approach of rejecting factors with high correlation. The values of the linear correlation coefficients indicate the presence or absence of a close, statistically significant relationship between the factors. The results of the analysis of the size of the calculated Pearson's linear correlation coefficients indicate that it is advisable to exclude from the data sample the number of factors «c» that have correlation coefficients more significant than 0,9 ($Pr_{k_{x_i x_j}} > 0{,}9$) to eliminate multicollinearity. After that, factors x_i, where i = 1…(m-c), will remain in the sample for further analysis.

In the third stage, the existence of intergroup correlation and the direction of influence for the formed groups of factors characterising illicit capital are determined on the basis of canonical analysis. Canonical analysis is a method of statistical analysis that allows to study dependencies and relationships between sets of variables; to assess the degree of influence of one set of factors on another, to substantiate the statistical significance of the relationships; it is a causal analysis between groups of factors; identification of the most correlated groups of factors.

The steps of statistical analysis involve a specific algorithm of actions:

- formulation of a scientific hypothesis about possible relationships between sets of factors;
- determination of data for analysis, components of factor sets;
- calculation of the correlation matrix for the factor sets;
- determination of linear dependencies between groups of variables (between canonical variables), which determines the canonical roots;
- formation and analysis of canonical correlation coefficients, checking their statistical significance;
- determination of «complete redundancies» and their analysis.

Mathematically, the essence of canonical analysis is to determine the correlation between the weighted sums of groups of factors, i.e., the so-called linear combinations of factors called canonical variables, from each group of factors that make up the causal and consequential characteristics. Canonical analysis is performed in Statistica software (Multivariate Exploratory Techniques – Canonical Analysis tool).

The authors hypothesized that there are interrelationships between groups of factors characterizing illicit capital: LI (factors of loss of financial resources from implicit illicit financial flows); LE (factors of loss of financial resources from explicit illicit flows); PI (factors of probability of accumulation of implicit illicit capital flows); PE (factors of probability of accumulation of explicit illicit capital flows). Confirmation or refutation of the hypothesis through canonical analysis allows the hypothesis to be mathematically accepted or rejected.

Next, the data for the analysis and the constituent sets of factors are determined. For this purpose, the statistical sample of data formed at the first stage is used.

A necessary prerequisite for canonical analysis is a correlation analysis between the selected groups of factors. The correlation analysis is based on the second stage's correlation matrix. This analysis makes it possible to select from the sample the factors between which there is a statistical relationship, preferably a close relationship. The relationship density is estimated by the values of the correlation coefficients: 0 - 0.3 – weak correlation; 0.3 - 0.5 – moderate; 0.5 - 0.7 – medium; 0.7 - 0.9 - strong; 0.9 - 1.0 – close.

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After that, linear dependencies between groups of variables (between canonical variables) are determined. Such dependencies make it possible to assess the degree and significance of the relationships between the groups of factors under study, i.e., to determine the influence of groups of factors on each other. Moreover, mathematically, the assessment of dependencies between canonical variables can be represented as a system of equations (formula 3):

$$\begin{cases} F1 = a_1 * x1_1 + a_2 * x1_2 + \ldots + a_{m-c} * x1_{m-c} \\ F2 = b_1 * x2_1 + b_2 * x2_2 + \ldots + b_{m-c} * x2_{m-c} \end{cases}, \quad (3)$$

where $F1$ and $F2$ – are canonical variables; weighted sums of variables of each group of factors; they determine the canonical root; $x1$, $x2$ – a set of variables of each group of factors describing illicit financial flows in terms of losses of financial resources from illicit flows and the probability of accumulation of illicit capital flows in terms of implicit and explicit flows; a_1, a_2, …, a_{m-c}; b_1, b_2, …, b_{m-c} – weighting coefficients of the maximally correlated sets of factors.

Notably, the change in weighting coefficients determines the corresponding changes in canonical variables, which in turn is reflected in the change in canonical correlation coefficients that assess the relationship between two groups of factors, establish the density of the relationship between canonical variables, and are calculated using the following formula (formula 4):

$$Cr_k = cov(F1, F2) * (\sqrt{var(F1)var(F2)})^{-1}, \quad (4)$$

where, Cr_k – is the canonical correlation coefficient between two groups of factors, taking values modulo 0 to 1, the closer to 1, the stronger the correlation.

The statistical significance of the canonical correlation coefficients is checked using Pearson's criterion (χ^2; is a criterion of model adequacy; its value should be large enough and tend to infinity) and the significance level (ρ; is a criterion of the probability of rejecting the hypothesis of a relationship between groups of factors; its value tends to 0, but for economic research, its acceptable level should not exceed 0,05).

The key characteristic of the canonical analysis is «total redundancy» (TR, %), a value that describes the conditionality of the variation of one group of factors by the variation of another; it shows the strength of the intergroup relationship: 0% - 29% – no relationship, 30% - 49% – weak relationship, 50% - 69% – medium relationship, 70% - 100% – strong relationship. The economic interpretation of «total redundancy» is as follows: a group of factors with less «total redundancy» is a cause, and a group with more is an effect.

Thus, the result of the canonical analysis is, first of all, the construction of a table of relations between two groups of factors (Table 2) for each pair of groups LI and LE, PI and PE, LI and PI, LI and PE, LE and PI, LE and PE.

Table 2. An example of the relationship between two groups of factors.

	Canonical correlation coefficient	Cr_k
	Pearson's criterion	χ^2
	Significance level	ρ
	Left set of factors (L)	Right set of factors (R)
Number of factors	$(\mathrm{m}-\mathrm{c})_L$	$(\mathrm{m}-\mathrm{c})_R$
Total redundancy	TR_L %	TR_R%
Factors	Factor name of the left group	Factor name of the right group
1	L1	R1
2	L2	R2
…	…	…
m-c	L m-c	R m-c

In particular, for example, the analysis of the indicators in Table 2, firstly, reflects the size of the correlation coefficient (Cr_k) within the range (0;1), which determines the strength of the relationship between the studied groups of factors; the value of Pearson's criterion (χ^2), which tends to infinity, and which establishes the statistical significance of the canonical correlation coefficient; the value of the significance level (ρ) in the range (0;0.05). Secondly, the percentage of «complete

redundancy» of the left group of factors shows how much the group of indicators of the right group explains the variability of the indicators of the left group, and vice versa; and the group of factors with a higher percentage of «complete redundancy» is a consequence, and with a lower percentage is a cause.

Thus, the results of the canonical analysis confirm or refute the hypothesis that there are interrelationships between the groups of factors describing the loss of financial resources in the region and the likelihood of accumulation of implicit and explicit flows of illicit capital through fraudulent actions of local authorities: LI and LE, PI and PE, LI and PI, LI and PE, LE and PI, LE and PE, i.e., the conditionality of one group of factors by another, the influence of a certain group on another. At the same time, in the further study of factor groups, special attention should be focused on the causal factors.

In the fourth stage, the input statistical base is normalized using the methodology of non-linear normalization of indicators. Normalization of indicators is used when the studied indicators have significant differences in the scale of measurement, data are presented in different units of measurement, groups of indicators are in different conditions, indicators change over time, etc. In such cases, normalization facilitates data comparison and analysis. Since the input statistical indicators selected for the study are of different dimensions and with different units of measurement, it is advisable to bring them to a comparable form suitable for further calculations that will involve the construction of an integral indicator. It is proposed to reduce them to a single scale [0; 1] by normalizing them. For this purpose, the study applied the nonlinear normalization approach described by the formula (formula 5):

$$X_{nm}^{*} = \frac{1}{\left(1+e^{(\overline{X_m}-X_{nm})*\left(\delta_{X_m}\right)^{-1}}\right)} \quad (5)$$

where X_{nm}^{*} – is the normalised value of the nth object (region) of the mth factor; m – number of factors X; n – number of objects (regions); $\overline{X_m}$ – is the average value of the m-th factor; X_{nm} – the value of the nth object (region) of the mth factor X; δ_{X_m} – is the standard deviation of the m-th factor X.

In the fifth stage, the number of factors was optimized, and the relevant ones were identified through factor analysis using the principal components method, taking into account the influence weights, the explained variance, and the visual graph of the rocky scree. Factor analysis in a data sample identifies factors that describe common variations in observations and the structure of the data set, which allows to reduce the set of indicators, leaving important factors for further analysis and excluding unimportant changes. The method of factor analysis proposed to be used in this paper is the principal component method, which is used to estimate large-scale models. This method is also used to estimate model parameters with multicollinear variables. The principal component method is best suited to the nature of the data in the current multivariate study and its objectives. This stage of the study is performed using the Statistica software (Multivariate Exploratory Techniques – Principal Components & Classification Analysis tool).

The current stage of the study involves a certain algorithm of operations:

1. Calculation of an intermediate table of eigenvalues of conditional factors (γ_k), explained variances.
2. Plotting the rocky scree plot.
3. Determination of the optimal number of relevant factors based on the results of the eigenvalue table (eigenvalues in the table are ordered by the absolute value of the contribution of each principal component to the total variance), as well as the rocky road graph - the value of the cumulative sum of the variance of factors should be more than 70% for economic research.
4. Calculation of an intermediate table of factor loadings (Fl_{ik}).
5. Determination of the principal components – vectors of weighting coefficients of the integral assessment of the volume of illicit financial capital, i.e., calculation of weighting coefficients (Kw_i) for each factor of the studied sample based on the variances of the influence of conditional factors and factor loadings, based on the weighted average methodology.

Mathematically, the weighted average formula is determined by the following formula: (formula 6):

$$\bar{X} = (\sum_{i=1}^{m} x_i * f_i) * (\sum_{i=1}^{m} f_i)^{-1}, \quad (6)$$

where $\bar{X}$ – is the average value of the factor X; $x_i - i$ – the value of factor X, for i = 1...m; $f_i - i$ – the frequency value of factor X, for i = 1...m.

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Then the weighting coefficients are calculated by the formula (formula 7):

$$Kw_i = \left(\sum_{k=1}^{l} Fl_{ik} * \delta_k^2\right) * \left(\sum_{k=1}^{l} \delta_k^2\right)^{-1}, \quad (7)$$

where Kw_i – is the weighting factor for the i-th factor; $Fl_{ik} - i$ – is the i-th factor load of the k-th conditional factor, k = 1..l; σ_k^2 – is the variance of the k-th conditional factor, k = 1..l.

The sixth stage involves the construction of an integral indicator for assessing the volume of illicit financial capital, which includes the characteristics of financial resource losses and the probability of accumulation of illicit capital flows, based on the Minkowski metric.

Stage seven involves the construction and graphical visualization of the rating of quantitative categories of illicit financial flows by the level of the integral indicator. The qualitative categories of the level of illicit financial capital are formalized based on the Harrington scale for assessing illicit financial flows.

DISCUSSION

Thus, the results of this study demonstrate that the methodology proposed in this article, which involves modelling and estimating the volume of illicit financial capital based on the convergence of elements of descriptive and canonical analysis (Bayesian method), as well as the Minkowski metric, is effective for assessing overt and latent illicit financial transactions carried out by representatives of local authorities. The developed methodology is based on the results of previous studies while introducing new insights into the peculiarities of assessing fraudulent activities.

The innovation of the proposed scientific and methodological approach lies primarily in the ability to identify explicit (explicit) and hidden (implicit) illegal financial flows. Compared to traditional methods and methodologies that focus primarily on the analysis of explicit flows (e.g., Kuzior et al. (2021)), the methodology proposed in this article is more effective due to the ability to cover a broader range of fraudulent activities.

This study is consistent with previous research, which argues that illicit financial flows are often disguised as legitimate expenditures, so it is essential to develop an algorithm for their identification and assessment along with and simultaneously with explicit ones. Also, the results of this article are consistent with the findings of Bijańska et al. (2018), in particular, to identify implicit financial transactions, it is crucial to study the reporting of the authorities to identify anomalies and intentional misrepresentations.

In addition, the results presented in this study complement and extend the existing theoretical framework on the role of local authorities in facilitating illicit financial flows in the studies by Dobrovolska et al. 2024a, Zolkover et al. 2022, Vasylieva and Kasyanenko 2013. The findings of this article converge with the survey of Dluhopolskyi & Danyliuk (2023), which shows that manipulation of public funds is a relatively common practice of fraud.

In contrast to the study by Bouyacoub (2024), which is based on developing a methodology for assessing illicit financial transactions based solely on the characteristics of only one country, the proposed methodology is universal for most countries.

Unlike the study by Djouadi et al. (2024), this method does not involve the involvement of experts to verify the data and interpret the results, eliminating the risk of subjectivity and increasing the reliability of the developed methodology.

In addition, the results of this article are in line with the findings of Bilan et al. (2020a) and Mentel et al. (2018), who emphasize that despite the active development and desynthesis of methodologies and tools for detecting and assessing illicit financial transactions, most of them have common limitations and problems in their practical implementation. In particular, data limitations (i.e., the lack of complete and accurate data) create significant obstacles to effectively assessing illicit financial flows. In addition, the complexity and adaptability of illicit financial transactions make it difficult to develop effective tools, methods, and methodologies that can accurately detect, prevent, or predict fraudsters' actions. These limitations are partially characteristic of this study. In particular, while emphasizing the effectiveness of the proposed scientific and methodological approach to assessing illicit implicit and explicit financial flows, it should be noted that the developed methodology has certain limitations. First, its effectiveness largely depends on the quality and completeness of the data used for the assessment. The availability of incomplete or inaccurate data can lead to erroneous conclusions. Second, the methodology needs to be regularly updated and adapted to new forms of fraud and changes in legislation.

CONCLUSIONS

Within the framework of this study, a methodology for assessing implicit and explicit illicit financial flows in the region mediated by fraudulent actions of local authorities was developed based on the convergence of elements of descriptive and canonical analysis (Bayesian method), as well as the Minkowski metric.

The results of the study proved that such illegal financial transactions pose a significant threat to the economic stability, security, and further economic development of the country, and they are the basis for undermining public confidence in the authorities and the general criminalization of society. In addition, the study emphasized the importance of taking into account not only explicit but also hidden illicit financial flows, which, of course, complicates the process of their identification, but taking into account only explicit flows leads to the development of ineffective strategies to combat financial fraud.

The proposed methodology is based on the use of the Bayesian method, which involves the following stages of research: formation of the input statistical data sample based on descriptive analysis; checking the input data sample for multicollinearity and its elimination; determination of the existence of intergroup correlation and direction of influence for groups of factors based on canonical analysis; normalisation of the input statistical base using the method of nonlinear normalisation of indicators; optimisation of the number of factors, determination of relevant factors by factor analysis, principal components method, taking into account the weighting coefficients of influence, explained variance, and rocky slope graph; building an integral indicator for assessing the volume of illicit financial capital based on the Minkowski metric; construction and graphical visualisation of the rating of quantitative categories of illicit financial flows by the level of the integral indicator; formalisation of qualitative categories of the level of illicit financial capital based on the Harrington scale for assessing illicit financial flows.

Further research could be aimed at the practical implementation of the proposed methodology, for example, an actual calculation of implicit and explicit illicit financial flows mediated by local authorities in Ukraine could be carried out. It should be noted that such a study would be extremely relevant in the context of the war in Ukraine.

Studies of the adaptation of financial fraud schemes based on the active development of digital technologies should also be considered in further research. In particular, special attention should be paid to financial fraud with cryptocurrencies and to the use of blockchain technologies in the methodology for detecting hidden illegal financial flows.

In addition, future research could focus on additional factors that may influence the developed methodology, such as ethical or legal considerations, such as data privacy in identifying implicit flows.

Implementation of research in these areas can significantly improve the understanding of the problems of detecting and assessing illicit financial flows and contribute to developing effective strategies to prevent and combat them.

ADDITIONAL INFORMATION

AUTHOR CONTRIBUTIONS

Conceptualization: *Reshetniak Yaroslav, Aleksandra Kuzior, Ján Užík*

Data curation: *Filatova Hanna, Dotsenko Tetiana*

Formal Analysis: *Reshetniak Yaroslav, Filatova Hanna, Riabyi Rostyslav*

Methodology: *Reshetniak Yaroslav, Filatova Hanna, Dotsenko Tetiana*

Resources: *Dotsenko Tetiana, Aleksandra Kuzior, Filatova Hanna*

Supervision: *Aleksandra Kuzior, Ján Užík, Riabyi Rostyslav*

Validation: *Ján Užík, Riabyi Rostyslav*

Investigation: *Reshetniak Yaroslav, Filatova Hanna, Dotsenko Tetiana*

Visualization: *Aleksandra Kuzior, Dotsenko Tetiana*

Project administration: *Ján Užík, Aleksandra Kuzior*

Writing – review & editing: *Aleksandra Kuzior, Riabyi Rostyslav, Filatova Hanna, Ján Užík*

Writing – original draft: *Aleksandra Kuzior, Reshetniak Yaroslav, Filatova Hanna*

Writing – original draft: *Aleksandra Kuzior, Reshetniak Yaroslav*

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CONFLICT OF INTEREST

The Authors declare that there is no conflict of interest.

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Кужур А., Ужик Я., Доценко Т., Рябий Р., Філатова Г., Решетняк Я.

ОЦІНЮВАННЯ ІМПЛІЦИТНИХ ТА ЕКСПЛІЦИТНИХ НЕЗАКОННИХ РЕГІОНАЛЬНИХ ФІНАНСОВИХ ПОТОКІВ, ОПОСЕРЕДКОВАНИХ ШАХРАЙСЬКИМИ ДІЯМИ МІСЦЕВИХ ОРГАНІВ ВЛАДИ: ТЕОРЕТИЧНЕ ПІДҐРУНТЯ

Оцінювання незаконних фінансових потоків має вирішальне значення для підвищення прозорості та боротьби з корупцією на регіональному рівні. Це дослідження має на меті розробити комплексну методологію для оцінки й прихованих (імпліцитних), і явних (експліцитних) незаконних фінансових потоків, що виникають унаслідок шахрайських дій місцевих органів влади. Запропонована методологія передбачає моделювання та оцінювання обсягів незаконного фінансового капіталу, побудованого на засадах конвергенції елементів дескриптивного та канонічного аналізу, а також метрики Мінковського. Науково-методичний підхід передбачає врахування 30 релевантних показників, що дозволяють найбільш повно оцінити незаконні фінансові потоки за опосередкування державних службовців. Алгоритм розробленої методології передбачає покрове виконання таких дій: (1) формування вибірки даних із 30 факторів; (2) розподіл факторів на чотири групи шляхом логічного аналізу: перша група – фактори щодо оцінювання втрат фінансових ресурсів від імпліцитних незаконних фінансових потоків; друга група – фактори щодо оцінювання втрат фінансових ресурсів від експліцитних незаконних фінансових потоків; третя група – фактори щодо ймовірності нагромадження імпліцитних потоків незаконного капіталу; четверта група – фактори щодо ймовірності нагромадження експліцитних потоків незаконного капіталу; (3) перевірка даних на наявність мультиколінеарності; (4) визначення наявності міжгрупового зв’язку та напрям впливу для сформованих груп факторів на підставі канонічного аналізу; (5) проведення нормалізації вхідної статистичної бази даних із застосуванням методики нелінійної нормалізації показників; (6) проведення оптимізації кількості релевантних факторів шляхом факторного аналізу методом головних компонент з урахуванням вагових коефіцієнтів впливу, пояснюваної дисперсії, візуального графіка кам’янистого осипу; (7) побудова інтегрального індикатора оцінювання обсягів незаконного фінансового капіталу, що включає характеристики втрат фінансових ресурсів, а також імовірностей нагромадження потоків незаконного капіталу, на базі метрики Мінковського; (8) побудова й графічна візуалізація рейтингу кількісних категорій обсягів незаконних фінансових потоків за рівнем інтегрального показника; (9) формалізація якісних категорій рівня незаконного фінансового капіталу за шкалою Харрінгтона для оцінювання нелегальних фінансових потоків.

Ключові слова: шахрайство, корупція, імпліцитні фінансові потоки, експліцитні фінансові потоки, незаконний фінансовий капітал, дескриптивний аналіз, канонічний аналіз, метрика Мінковського, втрати фінансових ресурсів, імовірність потоків незаконного капіталу, фінансовий моніторинг

JEL Класифікація: H83, K42, R51, D73