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REGIONAL DIFFERENTIATION OF ENVIRONMENTAL RISKS AND ENVIRONMENTAL PROTECTION FINANCING IN UKRAINE BASED ON OPEN DATA

Purpose. To assess regional differentiation in environmental risks and environmental protection financing in Ukraine and to test a transparent risk-oriented screening approach for detecting oblasts where the relative level of environmental pressure is not matched by an adequate financial response.

Methods. The empirical analysis is based on open statistical and analytical data. Mathematical modeling is based on the differentiation of environmental risks and environmental financing, taking into account pollutant emissions from stationary sources, air pollution in cities, capital investments and current expenditures of enterprises on environmental protection. The risk index was formed by min-max normalisation of the emission and air-pollution variables.

Results. The problem is considered in the context of the spatial concentration of industrial emissions, the need for evidence-based allocation of environmental resources, and the growing importance of recovery planning under wartime constraints. A pilot sample of four oblasts was selected: Dnipropetrovsk, Donetsk, Zaporizhzhia and Kyiv. These regions were chosen because comparable environmental and financial indicators were simultaneously available for them. For each region, the regional share of national emissions, the maximum urban air pollution index, the cumulative financial response for 2014-2023, the share of this response, the environmental pressure-to-finance ratio and an integrated risk index were calculated. The selected regions together accounted for the largest number of pollutant emissions from stationary sources in 2021, confirming the pronounced spatial concentration of industrial atmospheric pressure. Dnipropetrovsk oblast ranked first by the integrated risk index, and also had the largest share of cumulative financial response. Donetsk oblast ranked second by risk, but demonstrated the strongest imbalance between pressure and financing. Zaporizhzhia oblast also showed an imbalance, Kyiv oblast had a lower atmospheric risk profile but a relatively higher financial share.

Conclusions. Open data can be used for preliminary diagnostics of regional discrepancies between environmental pressures and environmental protection financing. The proposed approach does not replace a full environmental assessment, but it can serve as an initial analytical module for identifying territories that require more detailed verification, targeted monitoring and priority consideration in regional environmental programmes. Further research should extend the model to a full panel of oblasts and include wartime environmental damage, waste, water, budget expenditure, environmental tax and socio-economic control variables.

KEYWORDS: *environmental risk, environmental protection financing, open data, regional differentiation, risk index, environmental safety*

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Introduction

Aligning environmental pressure with an adequate financial response is one of the key issues of regional environmental management. For Ukraine, this issue has a dual nature. On the one hand, the historically established industrial specialisation of individual oblasts has resulted in a spatial concentration of emissions, waste generation and risks for public health. On the other hand, the full-scale war has significantly changed the spatial structure of environmental threats by increasing the role of damage to industrial facilities, energy infrastructure, water management systems and territories affected by hostilities.

Open data make it possible to assess these imbalances in a transparent and reproducible way. The State Statistics Service of Ukraine publishes indicators of pollutant and greenhouse gas emissions, including regional indicators and indicators per person [1]. Separate datasets are available on environmental protection expenditure, capital investments and current expenditure [2], and these datasets can be accessed and integrated through official digital instruments such as the developer API [3]. Additional contextual information is provided by the strategic environmental assessment report for the draft Circular Economy Strategy of Ukraine [4], the EcoZagroza platform [5], the Open Budget portal [6], regional environmental reports [7] and open summaries of regional environmental investments [8].

Contemporary international practice also shifts the focus from the formal accounting of environmental expenditure to the assessment of its effectiveness and its alignment with environmental needs. In the System of Environmental-Economic Accounting, environmental protection expenditure is considered within a broader system of environmental activities that describes the relationship between the economy and the environment [9, 10]. The Eurostat handbook provides methodological guidance for environmental protection expenditure accounts [11]. Green budgeting is increasingly used in OECD countries as an instrument for integrating climate and environmental priorities into the budget cycle [12], while European and international datasets make it possible to compare environmental protection expenditure across countries and policy levels [13, 14].

At the regional level, green budgeting and environmental risk management are also connected with the quality of governance and the ability to direct financial resources to priority environmental needs [15, 16]. Empirical studies show that green credit, environmental protection investment and green finance can influence environmental sustainability and the financial behaviour of enterprises [17, 18]. For Ukraine and other transition economies, research on financial management in regional environmental systems, automation of investment calculations and the relationship between government expenditure and green innovation further emphasises the need to connect environmental risks, financial instruments and regional development priorities [19, 20, 21].

For Ukraine, however, the unresolved question is whether the spatial distribution of environmental protection expenditure corresponds to the spatial distribution of environmental risk. Available open data often differ in periodicity, level of detail and completeness, especially for the wartime period. Therefore, a first step should be a screening approach that identifies the most visible regional asymmetries and forms a basis for more detailed analysis.

The purpose of the article is to assess the regional differentiation of environmental risks and environmental protection financing in Ukraine on the basis of open data and to test indicators that make it possible to compare environmental pressure with the financial response. To achieve this purpose, the following tasks are set: to systematise open data sources; to form a screening set of indicators; to calculate an integrated environmental risk index; to assess the ratio between a region's share in emissions and its share in environmental protection financing; and to identify regions with potential financial-environmental imbalance.

Methods

The object of the study is the regional differentiation of environmental risks and environmental protection financing in Ukraine. The subject of the study is the relationship between the level of atmospheric environmental pressure and the accumulated financial response in the form of capital investments and current expenditure for environmental protection.

The empirical part has the format of a pilot screening study. Four oblasts are included in the analysis: Dnipropetrovsk, Donetsk, Zaporizhzhia and Kyiv. The choice is determined by the fact that, for these oblasts, open sources simultaneously provide aggregated indicators of pollutant emissions from stationary sources for 2021 and comparable indicators of environmental protection capital investments and current expenditure of enterprises for 2014-2023. This sample does not replace a full panel of oblasts, but it allows the proposed methodology to be tested and its analytical applicability to be demonstrated.

The basic environmental indicator is the regional share of pollutant emissions from stationary sources in 2021 (Table 1). According to open materials of the strategic environmental assessment for the draft Circular Economy Strategy of Ukraine, Dnipropetrovsk oblast accounted for 24.8% of such emissions, Donetsk oblast for 18.0%, Zaporizhzhia oblast for 11.6% and Kyiv oblast for 5.1% [4]. An additional risk indicator is the maximum air pollution index (API) recorded for cities within the corresponding region in 2021 [4].

The financial block is formed on the basis of data on capital investments and current expenditure of enterprises for environmental protection in 2014-2023. According to an open summary of State Statistics Service data, capital investments amounted to UAH 108.46 billion and current expenditure to UAH 234.47 billion during this period [8]. For each region, the cumulative financial response is calculated as the sum of capital investments and current expenditure.

AI tools were not used for data collection, statistical calculation or generation of empirical results. AI-assisted tools were used only for organisational support, language editing, structuring of the manuscript and technical formatting; all data, calculations, interpretations and conclusions were verified by the author.

The regional share in the financial response is calculated as follows:

$$FS\_i = ((CI\_i + CE\_i) / \Sigma\_i(CI\_i + CE\_i)) \times 100\%, \quad (1)$$

where FS_i – the share of i-region in cumulative environmental protection expenditure;

CI_i – capital investment in i-region;

CE_i – current expenditure in i-region;

Σ_i(CI_i + CE_i) – the total amount of capital investment and current expenditure in i-region Ukraine for 2014-2023.

To assess imbalance, the environmental pressure-to-finance ratio is used:

$$PFR\_i = ES\_i / FS\_i, \quad (2)$$

where ES_i is the share of i-region in emissions from stationary sources and FS_i is the share of i-region in the financial response. A PFR_i value above 1 means that the region's share in environmental pressure exceeds its share in the financial response.

The integrated risk index is calculated as the average of two normalised indicators: the regional share of emissions and the maximum API of cities in the region. Min-max normalisation is applied:

$$x'\_\{ij\} = (x\_\{ij\} - \min(x\_j)) / (\max(x\_j) - \min(x\_j)), \quad (3)$$

$$RI\_i = (ES'\_i + API'\_i) / 2. \quad (4)$$

For classification of regions, median values of the integrated risk index and the share of the financial response are used.

Table 1

Initial indicators for assessing environmental pressure and financial response

Region	Emissions 2021, thous. t	Emission share, %	Max. API	Capital investments, UAH bn	Current expenditure, UAH bn	Total, UAH bn
Dnipropetrovsk oblast	556.1	24.8	14.7	31.00	71.62	102.62
Donetsk oblast	403.4	18.0	15.7	10.84	15.93	26.77
Zaporizhzhia oblast	260.3	11.6	8.0	7.49	20.88	28.37
Kyiv oblast	113.7	5.1	4.3	30.08	9.39	39.47

Note. Compiled by the author based on data from [4, 8].

Results of Research

The dataset shows a significant concentration of industrial atmospheric pressure in a small group of regions (Table 1). The four analysed oblasts accounted for 59.5% of pollutant emissions from stationary sources in 2021. Dnipropetrovsk oblast had the largest share, 24.8%. Donetsk and Zaporizhzhia oblasts jointly formed another 29.6%. This confirms the thesis that industrial environmental risks are concentrated in eastern and south-eastern regions.

Comparison of environmental pressure and environmental protection financing revealed an asymmetry (Table 2). Dnipropetrovsk oblast has high environmental risk, but also the highest share of accumulated financial response, 29.9% of the total amount of capital investments and current expenditure of enterprises for 2014-2023. By contrast, Donetsk oblast has 18.0% of emissions but only 7.8% of the financial response, resulting in a PFR of 2.31. For Zaporizhzhia oblast, the PFR is 1.40, which also indicates that the share of environmental pressure exceeds the share of financing.

Kyiv oblast has the opposite profile: its share of emissions is 5.1%, whereas its share of the financial response is 11.5%. This may be related to infrastructure, wastewater treatment or municipal projects that are not fully reflected by the atmospheric emissions indicator. This result demonstrates the need to include not only air emissions in a complete model, but also waste, water risks, the condition of wastewater treatment facilities, the impact of hostilities and other components of environmental safety.

Table 2

Calculation of environmental risk and environmental protection finance adequacy indicators

Region	Finance share, %	Pressure/ finance	Risk index	Risk rank	Finance rank	Type and interpretation
Dnipropetrovsk oblast	29.9	0.83	0.956	1	1	High risk - high financial response; finance share is not lower than pressure share
Donetsk oblast	7.8	2.31	0.827	2	4	High risk - lower financial response; imbalance
Zaporizhzhia oblast	8.3	1.40	0.327	3	3	Lower risk - lower financial response within the sample; imbalance
Kyiv oblast	11.5	0.44	0.000	4	2	Lower risk - high financial response; finance share is not lower than pressure share

Note. A pressure-to-finance ratio above 1 means that the region's share in environmental pressure exceeds its share in the financial response.

The integrated risk index (Fig. 1) produces the following sequence: Dnipropetrovsk oblast, 0.956; Donetsk oblast, 0.827; Zaporizhzhia oblast, 0.327; and Kyiv oblast, 0.000. Accordingly, in the risk-financing matrix, Dnipropetrovsk oblast belongs to the group 'high risk - high financial response', Donetsk oblast to the group 'high risk - lower financial response', Zaporizhzhia oblast to the group 'lower risk - lower financial response' within the sample, and Kyiv oblast to the group 'lower risk - high financial response'.

In terms of the air pollution index in 2021 (Table 3), the most problematic cities were Mariupol, Kamianske, Dnipro, Odesa and Kryvyi Rih. Within the selected sample, this strengthens the risk positions of Donetsk and Dnipropetrovsk

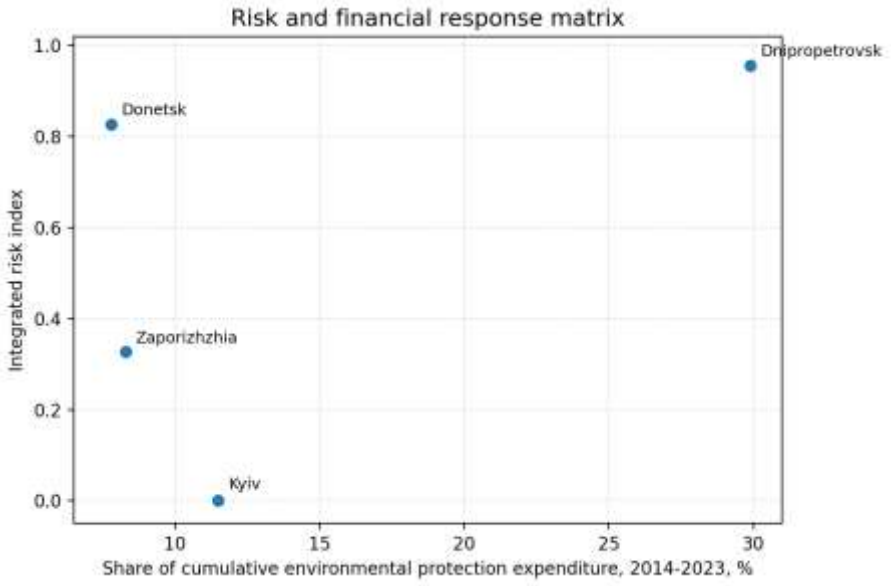

Fig. 1 - Matrix of integrated risk and financial response

Table 3

Cities with the highest air pollution index in 2021

Rank	City	Region	API
1	Mariupol	Donetsk oblast	15.7
2	Kamianske	Dnipropetrovsk oblast	14.7
3	Dnipro	Dnipropetrovsk oblast	12.8
4	Odesa	Odesa oblast	12.5
5	Kryvyi Rih	Dnipropetrovsk oblast	12.1
6	Kyiv	City of Kyiv	8.6
7	Mykolaiv	Mykolaiv oblast	8.5
8	Zaporizhzhia	Zaporizhzhia oblast	8.0
9	Kherson	Kherson oblast	7.8
10	Kremenchuk	Poltava oblast	7.5

Note. An API level above 14.0 is classified as very high; 7.0-14.0 as high; 5.0-7.0 as elevated; and less than 5.0 as low [4].

oblasts. The highest maximum API was recorded for Donetsk oblast through Mariupol, 15.7; for Dnipropetrovsk oblast through Kamianske, 14.7; for Zaporizhzhia oblast through Zaporizhzhia, 8.0; and for Kyiv oblast through Bila Tserkva, 4.3.

Discussion

The obtained results have a screening character, but they demonstrate the practical usefulness of open data for the preliminary diagnosis of regional financial-environmental imbalances. The most important result is not the absolute ranking of regions, but the identification of different types of relationships between environmental pressure and financial response.

Dnipropetrovsk oblast is an example of a region where a high level of risk is accompanied by a significant environmental protection

financial response. This does not mean that financing is sufficient, but it indicates the presence of large environmental protection expenditures that are comparable with the industrial profile of the region. Donetsk oblast, by contrast, demonstrates the largest gap between its share in emissions and its share in financing. Given wartime restrictions, damage to industrial and environmental infrastructure and incomplete statistics after 2022, this result should be interpreted carefully, but regions with such profiles should be the subject of priority monitoring.

For Zaporizhzhia oblast, the imbalance is less pronounced, but a PFR value above 1 indicates the need to strengthen the environmental protection response or to analyse the structure of expenditure in greater detail. Kyiv oblast demonstrates a higher financial share compared with the atmospheric risk indicator, which may result from the fact that financing is directed not only towards the reduction of industrial emissions, but also towards other environmental protection areas.

The scientific novelty of the study consists in testing a simple index approach that integrates open environmental and financial indicators into a risk-financing matrix. In contrast to traditional descriptive analysis of emissions or expenditure separately, the proposed approach makes it possible to formulate a management question: whether the relative amount of environmental protection expenditure corresponds to the relative level of environmental pressure.

The practical significance of the results lies in the possibility of using this approach as a preliminary module for regional environmental programmes, budget planning, recovery strategies and the formation of environmental priorities for communities. In an extended version, the model should include budget expenditure by functional classification, EcoZagroza data on wartime environmental damage, indicators of waste generation and disposal, discharges of polluted wastewater, the condition of protected areas and socio-demographic variables.

The main limitation of the study is the use of different time horizons: environmental indicators are taken for 2021, whereas financial indicators are cumulative for 2014-2023. This limitation is determined by the availability of open regional data. Additional limitations include incomplete coverage of oblasts, insufficient updating of indicators for the wartime period and the impossibility, within a pilot study, of including all components of environmental risk.

Conclusions

Open data make it possible to form a preliminary toolkit for assessing the regional differentiation of environmental risks and environmental protection financing in Ukraine. The most suitable sources are State Statistics Service data on emissions and environmental protection expenditure, strategic environmental assessment materials, the Open Budget portal, EcoZagroza and regional environmental reports.

Within the pilot sample, the concentration of industrial atmospheric pressure in Dnipropetrovsk, Donetsk and Zaporizhzhia oblasts is confirmed. The four analysed oblasts jointly accounted for 59.5% of pollutant emissions from stationary sources in 2021.

The calculated environmental pressure-to-finance ratio shows the largest imbalance for Donetsk oblast, where the share in emissions is 2.31 times higher than the share in cumulative environmental protection expenditure. For Zaporizhzhia oblast, the ratio is 1.40. Dnipropetrovsk oblast has high risk but also a high financial response, whereas Kyiv oblast has a lower atmospheric risk with a relatively high share of financing.

The proposed risk index and risk-financing matrix can be used as an instrument for preliminary prioritisation of regions for further environmental analysis. They should be applied not as a final ranking, but as a diagnostic module that identifies territories for in-depth verification.

A prospect for further research is the formation of a full panel dataset in the format 'oblast-year' for 2019-2024 with the inclusion of budget expenditure, environmental tax, data on waste, water, atmospheric air, wartime environmental damage and socio-economic control variables. Such a dataset would make it possible to move from screening analysis to econometric assessment of the determinants of environmental protection financing.

Conflict of interest

The authors declare that there are no conflicts of interest in the publication of this manuscript. In addition, the authors fully complied with ethical standards, including plagiarism, data falsification, and double publication.

Authors Contribution: all authors have contributed equally to this work.

AI Statement

During preparation of this manuscript, artificial intelligence tools ChatGPT-5.5 (OpenAI, 2026) were used for organisational support, language editing, text structuring, technical formatting and preliminary checking of the logic of presentation. All data, sources, calculations, interpretations and conclusions were verified by the author; the author is responsible for the content of the manuscript.

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РЕГІОНАЛЬНА ДИФЕРЕНЦІАЦІЯ ЕКОЛОГІЧНИХ РИЗИКІВ ТА ПРИРОДООХОРОННОГО ФІНАНСУВАННЯ В УКРАЇНІ НА ОСНОВІ ВІДКРИТИХ ДАНИХ

Мета. Оцінювання регіональної диференціації екологічних ризиків і природоохоронного фінансування в Україні та апробація прозорого ризик-орієнтованого скринінгового підходу до виявлення областей, у яких відносний рівень екологічного тиску не відповідає належній фінансовій реакції.

Методи. Емпіричний аналіз ґрунтується на відкритих статистичних та аналітичних даних. Математичне моделювання базується на диференціації екологічних ризиків та природоохоронного фінансування з врахуванням викидів забруднюючих речовин від стаціонарних джерел, забрудненні атмосферного повітря в містах, капітальних інвестицій та поточних витрат підприємств на охорону навколишнього природного середовища. Індекс ризику сформовано шляхом мінімаксної нормалізації показників викидів і забруднення повітря.

Результати. Проблему розглянуто в контексті просторової концентрації промислових викидів, потреби в доказовому розподілі природоохоронних ресурсів і зростання значення планування відновлення в умовах воєнних обмежень. До пілотної вибірки включено Дніпропетровську, Донецьку, Запорізьку та Київську області, для яких одночасно доступні зіставні екологічні й фінансові показники. Для кожної області розраховано частку у загальнонаціональних викидах, максимальний міський індекс забруднення атмосферного повітря, сукупну фінансову відповідь за 2014-2023 рр., частку цієї відповіді, коефіцієнт співвідношення екологічного тиску та фінансування, а також інтегральний індекс ризику. На вибрані області разом припадало найбільша кількість викидів забруднюючих речовин від стаціонарних джерел у 2021 році, що підтверджує виражену просторову концентрацію промислового атмосферного тиску. Дніпропетровська область посіла перше місце за інтегральним індексом ризику зі значенням і водночас мала найбільшу частку сукупної фінансової відповіді. Донецька область посіла друге місце за рівнем ризику однак продемонструвала найсильніший дисбаланс між тиском і фінансуванням. Запорізька область також мала дисбаланс, Київська область характеризувалася нижчим атмосферним ризиком, але відносно вищою фінансовою часткою.

Висновки. Можливе використання відкритих даних для попередньої діагностики регіональних невідповідностей між екологічним навантаженням і природоохоронним фінансуванням. Запропонований підхід не замінює повної екологічної оцінки, проте може слугувати початковим аналітичним модулем для визначення територій, що потребують детальнішої перевірки, цільового моніторингу та пріоритетного врахування у регіональних природоохоронних програмах. Подальші дослідження доцільно спрямувати на розширення моделі до повної панелі областей із включенням воєнної шкоди довкіллю, відходів, водних ризиків, бюджетних видатків, екологічного податку та соціально-економічних контрольних змінних.

КЛЮЧОВІ СЛОВА: *екологічний ризик, природоохоронне фінансування, відкриті дані, регіональна диференціація, індекс ризику, екологічна безпека*

Конфлікт інтересів

Автори заявляють, що конфлікту інтересів щодо публікації цього рукопису немає. Крім того, автори повністю дотримувались етичних норм, включаючи плагіат, фальсифікацію даних та подвійну публікацію.

Декларація про використання ШІ

Під час підготовки цього рукопису для організаційної підтримки, мовного редагування, структурування тексту, технічного форматування та попередньої перевірки логіки викладу використовувалися інструменти штучного інтелекту ChatGPT-5.5 (OpenAI, 2026). Усі дані, джерела, розрахунки, інтерпретації та висновки були перевірені автором; автор несе відповідальність за зміст рукопису.

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