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Characterisation of public green finance instruments and modelling their environmental impact

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Abstract: The article reveals the essence and key features of financial instruments of green finance utilized by public authorities in achieving environmental goals for sustainable development. It is proposed to classify these financial instruments into fiscal, regulatory, and universal categories. The leading fiscal instrument in Ukraine is the environmental tax, which has numerous shortcomings and is insufficiently effective. The prospects for developing the emissions trading market, as well as debt-for-nature and debt-for-climate swap schemes, are substantiated. Even during wartime, Ukraine operates numerous budget programs for environmental protection. Modelling demonstrated a strong correlation between budget expenditure indicators on environmental protection and environmental condition indices. Significant error in the model is caused by the instability of Ukraine's economic situation, periods of socio-political upheaval, and economic crises. Regulatory financial instruments within green finance include fiscal preferences, restrictions, and sanctions. These are developing in Ukraine in line with European trends.

Keywords: green finance, public finance, financial instruments, environmental taxation, green bonds, grants, budget expenditures, financial sanctions, financial incentives.

1. Introduction

The complex challenges facing the State and society in the transition to a green economy model require restructuring of financial relations, and the development of financial instruments for the formation and use of financial resources to meet the objectives of environmental development in the corporate sector and the public administration system. As a result, a new concept of green finance was introduced into financial terminology, which has not yet received a thorough theoretical

explanation, and understanding of its scope. There are selective scientific developments on state participation in the development of green finance, and the specifics of financial instruments used by public authorities in forming and using financial resources to meet environmental development objectives. The insufficient development of the theoretical basis for green finance and its public component complicates the organisation of effective management, reducing the effectiveness of finance's impact on the restructuring of the economic system towards environmental neutrality.

2. Object and subject of research

The object of the study is public green finance instruments. These instruments are used by public authorities to influence the formation and use of financial resources to achieve sustainable development's environmental goals. They include ecological taxes, green bonds, budget environmental programmes, fiscal incentives, fiscal sanctions and other instruments. The subject of the study is the theoretical foundations of public green finance instruments, the signs of their classification, and the impact of these instruments on the environmental state.

3. Target of research

The article's objective is to reveal the key features and specifics of the use of instruments of the public component of green finance in Ukraine. It involves identifying the features that determine whether financial instruments belong to the public component of green finance, the criteria for their classification, tendencies and prospects for their use in Ukraine.

4. Literature analysis

The current period is marked by an increase in the scholar's attention to the study of theory and practice of green finance both in Ukraine and abroad. In particular, J. Kantorowicz, M. Collewet, M. DiGiuseppe, H. Vrijburg [14] reveal the socio-political advantages of using debt instruments to finance green initiatives compared to environmental taxes. R. Kharb, C. Shri, P. Singh and other scholars consider the barriers that hinder the development of green finance and reduce its effectiveness in achieving environmental sustainability [15]. The foreign literature is dominated by an applied approach to understanding green finance, namely its impact on various aspects of achieving sustainable development goals. It has also spread to Ukrainian science. Among the most recent publications on green finance, it is worth noting the work of V. Chala and B. Demidov [4], who reveal the theoretical foundations of green finance, namely, characterising its instruments. O. Sholudko, O. Hrytsyna, and O. Rubai [17] highlight the advantages and disadvantages of these instruments in terms of their practical use. However, there is a noticeable bias in favour of studying market-based green finance instruments in scientific publications, while their public component remains without due attention.

5. Research methods

The study employs general scientific and special methods of knowledge; methods of theoretical generalisation are used to elucidate scientific views on the nature and classification of public green finance instruments, determining the place of public finance instruments among them. Comparative analysis and modelling are utilized to determine the impact of specific public green finance instruments on the dynamics of environmental indicators. The graphical method is used for the visual presentation of research results, and generalisation is applied in the formulation of research results.

6. Research results

The implementation of the environmental component of sustainable development within the framework of public green finance is manifested through various financial relations involving the state: environmental taxation and a system of financial sanctions for violations of environmental legislation; issuance of green bonds by public authorities, attraction of loan and grant financing for green projects; financing of projects for the rational use of natural resources, promotion of climate-neutral production; implementation of energy saving projects, etc. These financial relationships are accompanied by cash flows. They result from the use of various financial instruments by the government. They express the ways and parameters of the formation and use of financial resources by public authorities to achieve the goals of the environmental component of sustainable development.

A generalisation of scientific publications on green finance instruments shows that green instruments are most often defined as those related to the formation of targeted financial resources to finance green projects, i.e. projects with a pronounced environmental focus. The basis for an instrument to be classified as public green finance should be the presence of one of the following features: its use to generate or use the state's financial resources with an environmental focus; the use of this financial instrument for regulation, i.e., to influence the generation and use of financial resources of other economic entities, which will have positive environmental consequences. Public green finance instruments can meet one or both of these criteria, i.e., they can be classified as fiscal, regulatory or universal. These groups organise green public finance instruments according to the nature of their action.

Fiscal instruments of public green finance are primarily represented by environmental taxes, green bonds issued by public authorities, green loans and grants, including those from global environmental funds. They are intended to accumulate resources in centralised monetary funds to implement environmental projects and achieve the state's environmental policy objectives. Unlike green bonds, green loans and grants are universal, as they can also be used at the state's financial resources using stage. In particular, in pursuing its environmental policy, the state uses lending and grant funding programmes for environmental projects at the expense of budgetary funds.

The green bond market is expanding rapidly in the current period, which is establishing itself as a leading tool for raising financial resources in corporate and public sectors in major economies. However, in countries with an underdeveloped financial market, environmental taxes are the most important instruments for raising financial resources to achieve environmental development goals. The object of taxation is the use of natural resources and emissions of harmful substances, including CO_2. An important prerequisite for the effective use of this green finance instrument is the development of a perfect methodology for determining the tax base, which does not provide for opportunities to manipulate the volume of tax liabilities, as well as the relationship between the amount of tax paid and expenditures on environmental measures. According to V. Fedchyshyn, the environmental tax in Ukraine has none of these features. The tax base is determined using a methodology that allows pollutant emitters to reduce their emissions. At the same time, 45% of the environmental tax goes to the state budget general fund, i.e. it is not earmarked for environmental policy measures [8]. Another problem is the low level of environmental tax rates, in particular for CO_2 emissions, which are significantly lower than in the EU [16]. The main driver of greenhouse gas emissions reduction in Ukraine in recent years is not the government's fiscal policy, but large-scale Russian aggression, which leads to a drop in production in energy-intensive segments of the domestic economy.

A promising fiscal instrument of green public finance is the greenhouse gas emissions trading system, the implementation of which is envisaged in the EU-Ukraine Association Agreement. This system has been implemented in the EU and other countries. It provides for the distribution of free emission permits following established limits and the sale of additional quotas on the market. Expert studies show that shortcomings in the distribution of free allowances and the grace period when

introducing the emissions trading system significantly reduced the effect of this innovation. A significant number of emitters do not have fiscal liabilities for harmful emissions and also have the opportunity to earn additional revenues from the sale of excess allowances [2]. Therefore, the prospects for modernising the European emissions trading system include a reduction of free allocation volumes and a gradual transition to the sale of allowances exclusively. These proceeds go to the European Structural Funds (Innovation Fund and Modernisation Fund) and are a source of environmental project funding. However, increased fiscal pressure on greenhouse gas emitters increases the risk of relocating production to so-called ‘pollution havens’, i.e. jurisdictions with weak or no environmental regulation.

Ukraine's involvement in schemes for the conversion and partial cancellation of the state's debt obligations in exchange for a commitment to invest in green projects has significant prospects for increasing the volume of financial resources for environmental goals of sustainable development implementation. Schemes such as debt-for-nature and debt-for-climate swaps are becoming increasingly popular in international practice. In particular, in 2023, the government of Ecuador signed such an agreement worth an estimated USD 1.6 billion. It is based on the government's debt obligations conversion into new blue bonds with more favourable terms, and Ecuador is to use the savings to finance large-scale environmental projects [13]. The target group of the debt-for-nature and debt-for-climate swaps initiatives in countries that are at high risk of not being able to service their debt obligations. The International Institute for Environment and Development estimates that in countries with the greatest debt problem, this scheme will free up $103.4 billion in debt to be used for environmental projects [5]. The calculation period of these indicators is limited to 2022 when Ukraine was not among the countries with problematic debts. However, during the period of the full-scale invasion, Ukraine's environmental damage from the hostilities reached $71 billion [12]. During the war, the public debt increased to USD 159.7 billion, and the debt burden doubled to 96% of GDP [1]. Given Ukraine's difficult debt situation, enormous environmental losses, and the priority of public spending on infrastructure restoration, Ukraine's participation in environmental swap schemes to raise financial resources for environmental projects is essential.

Budgetary financing of development projects and environmental budget programmes plays a leading role among green public finance instruments at the using financial resources stage. One of the largest budget programmes in terms of funding in modern conditions is the programme for the elimination of the consequences of the Chornobyl accident, in particular, ‘Maintaining the safe condition of the units and the Shelter and measures for decommissioning the Chornobyl NPP’ and others. Even during the war, in 2024, more than UAH 1.8 billion from the state budget was allocated for these purposes [3]. Budget funds are also used to implement regulatory programmes that should encourage other economic actors to reallocate their resources in favour of environmental projects. In recent years, such programmes have been of not only environmental but also security importance. They are aimed at reducing Ukraine's dependence on imported energy resources and maintaining the energy system in a functional state. “The largest government programme, Warm Loans, provided an opportunity to receive reimbursement for the costs of raising and repaying loans for energy efficiency measures. The amount of such reimbursement was 20-70% of the project budget (depending on the depth of energy modernisation and the level of energy consumption savings)” [10]. Although these programmes are intended to help reduce energy consumption through investments in energy efficiency measures, an additional effect of this is to reduce the environmental impact on society and CO_2 emissions reduce.

A similar principle is also incorporated in the Clean Energy and Green Business grant programmes. They were launched in 2024 using budgetary resources and funds from international grant programmes. These programmes provide partial coverage of the costs of installing renewable energy sources for households and small and medium-sized businesses [11]. The main idea behind the introduction of these programmes is the need to compensate for the loss of energy capacity due to missile attacks and to avoid the collapse of the country's energy system. However, another effect of fiscal incentives will be to increase clean energy production and reduce CO2 emissions.

The general purpose of various budget programmes for environmental protection is to help improve the human environment and the environmental situation in the country. To evaluate the effectiveness of this task, we will build a model of the impact of public expenditures on environmental protection (EnEx) [3] on environmental quality indicators. In international practice, many indicators are used to assess the quality of the environment; for modelling purposes, we will use the Environmental Performance Index (EPI) [7], calculated by Yale University researchers, and the Natural Environment Index (NEI) as a component of the Legatum Prosperity Index [18]. The dynamics of these indicators are shown in Table 1.

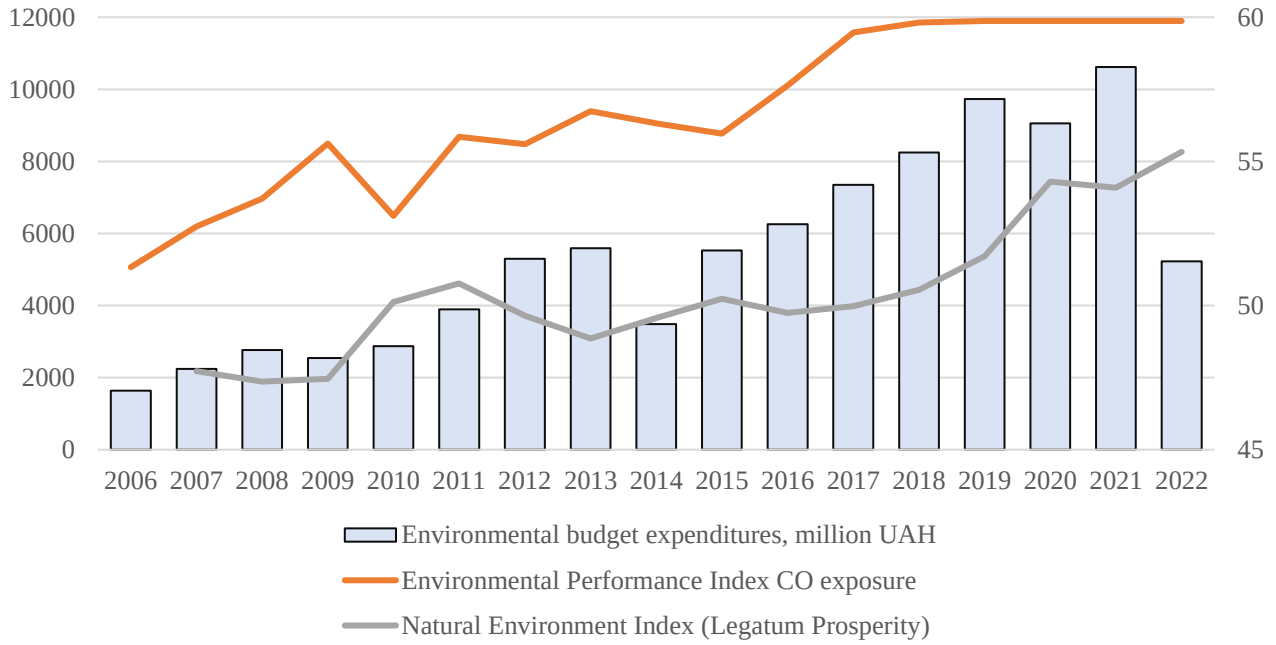

Figure 1. Indicators of budget expenditures on environmental protection and environmental quality indices for Ukraine in 2006-2022.

Source: based on [3; 7; 18].

A preliminary assessment of the dynamics of the indicators shows a time lag when the volume of budget expenditures on environmental protection will affect the values of environmental quality indicators. In 2022, a sharp drop in budget expenditures is associated with the start of a large-scale invasion of Ukraine, while the improvement in environmental indicators is caused by both the time lag effect and the destruction of industries that emit harmful emissions during the war. To improve the objectivity of the model, we exclude data for 2022 from the calculation. The correlation coefficients r = 0.92749 (for the logarithmic EPI/EnEx model) and r = 0.82246 (for the polynomial NEI/EnEx model) indicate a tight correlation between the data sets. Using the built-in Data Analysis option of the MS Excel function, we will build models of the dependence of environmental quality indicators on the dynamics of expenditures of the consolidated budget of Ukraine on environmental protection.

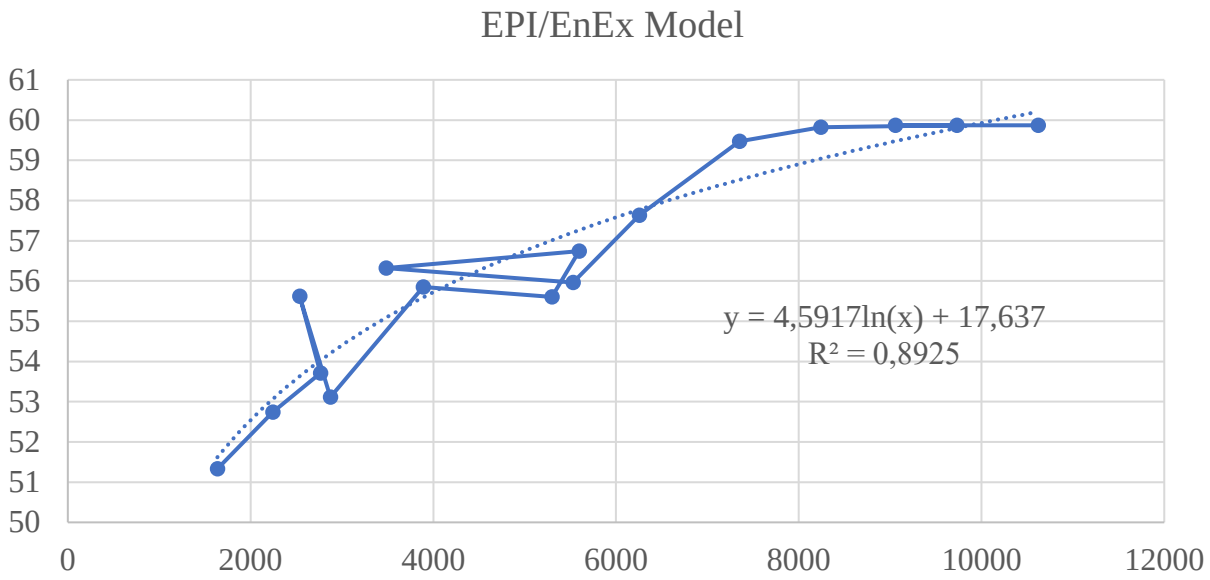

Figure 2. A pairwise regression model of budget expenditures on environmental protection and the Environmental Performance Index (EPI/EnEx).

Source: based on [3; 7].

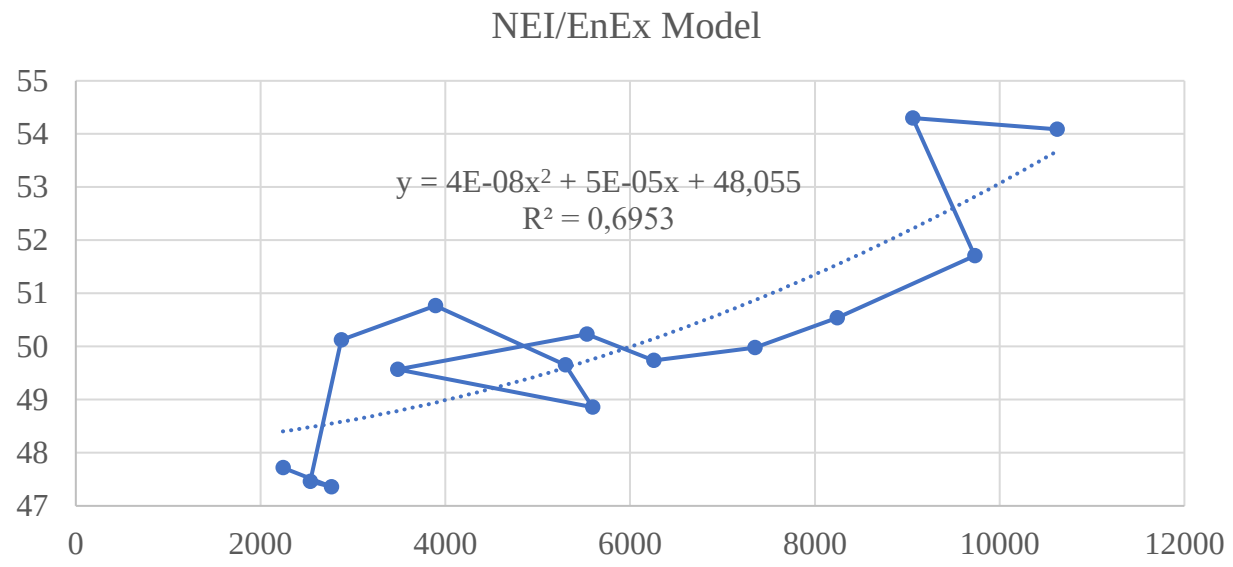

Figure 3. Model of pairwise regression of budget expenditures on nature protection and Natural Environment Index (NEI/EnEx).

Source: based on [3; 18].

The obtained economic and mathematical models characterise the influence of the factor attribute (x – the volume of budget expenditures on nature protection) on the change in the resultant attribute (y – Environmental Performance Index in the EPI/EnEx model, Natural Environment Index in the NEI/EnEx model). The adequacy of the first model is characterised by a high coefficient of determination R2, which determines the extent to which the data set describes these factors. For the second model, the value of the coefficient of determination is insufficient to define it as adequate. This indicates the complexity of regression modelling of the relationship between data sets. A significant error in the model is caused by the instability of the economic situation in Ukraine, periods of socio-political turmoil and economic crises. In particular, Fig. 2 shows that a significant shift in indicators from the general line was observed in 2009 (a deep economic crisis accompanied by a drop

in production and budget expenditures), 2014 (a period of socio-political turmoil, the outbreak of war with Russia and the occupation of part of Ukraine's industrial regions).

A special place among the financial instruments of public green finance is occupied by quasi-fiscal operations, namely the use of a green tariff for the purchase of electricity generated from renewable sources. Today, Ukraine's feed-in tariff is one of the highest in Europe, which creates conditions for a quick payback of investments in green energy. The obligation to purchase renewable electricity is assigned to the State Enterprise 'Guaranteed Buyer' [20]. Thus, quasi-fiscal operations combine the features of regulatory and fiscal instruments, as they indirectly subsidise green energy producers at the expense of budgetary resources.

Regulatory financial instruments within green finance are represented by fiscal preferences, restrictions and sanctions. They are based on the idea of indirect state influence on the parameters of formation and use of financial resources of economic entities, which will have positive environmental consequences. Ukraine has introduced several fiscal incentives to promote energy efficiency, the use of environmental technologies and climate-neutral energy. In particular, to stimulate environmental transformation, passenger electric vehicles in Ukraine are exempt from value-added tax and customs duties until the end of 2025. This stimulates the rapid growth of the segment of environmentally neutral cars in Ukraine. At the same time, "several fiscal instruments (tax exemptions, reduced tax rates) encourage the use of alternative fuels (bioethanol and motor fuels with its addition). On the other hand, low octane fuels with higher levels of harmful substances are taxed at higher rates" [9, p. 296]. Fiscal restrictions in the form of higher tax rates on environmentally harmful types of economic goods are introduced to reduce profitability and deter interest in conducting relevant economic activities.

An important regulatory instrument of green finance is financial sanctions for violations of environmental regulations. In Ukraine, such sanctions are imposed for unauthorised mining, air and water pollution, unauthorised burning, damage and destruction of vegetation and other types of environmental offences. The number of financial sanctions reaches UAH 150-170 thousand [19]. The strengthening of financial sanctions for violations of environmental regulations is part of a pan-European trend. In particular, in 2024, the European Parliament approved new rules for combating environmental crimes. They provide for fines of 3-5% of the company's annual turnover (EUR 24-40 million) and obligations to restore the damaged environment [6]. Financial sanctions are regulatory instruments, as they are introduced to influence the behaviour of a business entity and punish it for environmental offences. Fiscal consequences in the form of budget revenues are a side effect of these sanctions.

7. Prospects for further research development

Prospects for further research on public green finance instruments are to study the internal and external factors that affect the feasibility of their use. It is also important to develop a formalised methodology for assessing the effectiveness of using these instruments for the improvement of the environmental state.

8. Conclusions

The growing public attention to environmental protection has led to an increase in the number of scientific studies of green finance. However, the public component of green finance does not have a proper theoretical basis. These relations involving the state have specifics in terms of instruments for the formation and use of financial resources and their intended purpose.

In the process of public green finance functioning, various financial instruments are used, which are divided into fiscal, regulatory and universal ones according to their key features. Environmental taxes are the leading fiscal instrument of public green finance in countries with underdeveloped financial markets. In Ukraine, these taxes have significant drawbacks that reduce their effectiveness

in influencing environmental development indicators. Modelling the dependence of environmental quality on nature protection budget expenditures has confirmed the need to increase budget funding for nature protection. It was also found that political instability and economic crises hurt the relationship between budget expenditures and the environmental situation in Ukraine.

The system of greenhouse gas emissions trading has dubious prospects for implementation in Ukraine, as it has significant problems in European countries. Instead, innovative schemes for attracting financial resources for environmental development projects, such as debt-for-nature and debt-for-climate swaps, quasi-fiscal operations, etc. have significant potential. In a time of war, the use of green public finance instruments is not only of environmental but also security importance. This is due to the need to protect Ukraine's national interests in a period of uncertainty and security challenges to the statehood.

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