FINANCIAL INSTRUMENTS FOR DEVELOPING EFFECTIVE WASTE MANAGEMENT MODELS*

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DOI: https://doi.org/10.30525/978-9934-26-562-4-14

Abstract. The subject of this research is the development and justification of complex models for effective waste management based on synergistic interaction of financial instruments, namely environmental taxes, tariffs, and tax incentives. The relevance of the topic is caused by the growing volume of waste and the need to move toward sustainable management of it in order to ensure ecological safety and sustainable economic development of Ukraine. The chapter underlines the limited efficiency of traditional administrative methods and justify the advantages of using financial instruments as a more adaptive and stimulating approach. The research methodology is based on a comprehensive application of scientific methods, including system and comparative analysis, modeling, and expert assessments. System analysis was used to explore the theoretical foundations of waste management and the role of financial instruments. Comparative analysis allowed to study international experience in applying these instruments. Modeling methods were applied for developing conceptual models of waste management, while expert assessments were used to define potential impact and complexity of implementing the proposed solutions. The aim of the study is to develop and justify models of effective waste management, based on the well-established interaction of environmental taxes, tariffs, and tax incentives.

*The research is supported by the budget of the Ministry of Education and Science of Ukraine (Research project № 0123U100112 "Post-war recovery of the energy industry of Ukraine: Optimization of waste management taking into account the health of the population, environmental, investment, tax determinants")

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To achieve this aim, theoretical and practical aspects of applying financial instruments were analyzed, potential synergistic effects of their combined use were identified, and three conceptual models were developed: "Circular Economy and Waste Minimization," "Green Innovations and Technological Development," and "Extended Producer Responsibility and Social Welfare." For each model, appropriate financial instruments were selected, and an assessment of their potential impact and implementation complexity was carried out. The conclusion of the study confirm the decisive role of integrated and well-thought-out use of environmental taxes, tariffs, and tax incentives in forming effective systems of waste management and stimulating the transition toward circular economy. The developed models demonstrate the potential of synergistic effect from the combined use of financial instruments, which may ensure a much greater positive impact compared to their isolated application. It is underlined the importance of adapting these mechanisms to the specific national conditions and industrial features to achieve sustainable waste management in Ukraine.

1. Introduction

The growth of waste volumes is one of the most urgent global problems, and Ukraine is not an exception. The constant increase in the amount of waste, especially hazardous ones, causes significant negative consequences for the environment, public health, and the economy due to pollution, resource depletion, and lost opportunities for secondary use. In this context, the transition to sustainable waste management and the implementation of circular economy principles becomes critically important for ensuring environmental safety and sustainable economic development.

In the field of waste management, traditional administrative methods often show limited effectiveness because of insufficient coverage and flexibility. Instead, financial instruments, such as environmental taxes, tariffs, and tax incentives, offer a more adaptive and motivating approach, generating economic signals for ecologically responsible behavior and innovations. However, the isolated application of these instruments may be not enough.

The novelty of the topic and the relevance of the scientific solutions lie in the development and justification of comprehensive models for effective waste management, based on the synergistic interaction of environmental taxes, tariffs, and tax incentives. Unlike the fragmented application of

separate tools, the study focuses on an integrated approach, which allows to maximize the positive impact on different aspects of waste management. The importance of the topic is highlighted by the urgent need to find effective mechanisms to overcome the growing waste crisis and move towards a circular economy in Ukraine.

The aim of the research is to develop and justify models of effective waste management based on well-established interaction of financial instruments – environmental taxes, tariffs, and tax incentives.

To achieve this goal, the following research objectives were defined:

– To analyse theoretical and practical aspects of using financial instruments in waste management.

– To identify potential synergistic effects from the combined use of environmental taxes, tariffs, and tax incentives.

– To develop conceptual models of effective waste management based on integration of financial instruments.

– To assess the potential impact and the complexity of implementation of proposed models and separate financial instruments.

The research methodology is based on the complex application of scientific methods, including: system analysis for examining the theoretical foundations of waste management and the role of financial tools; comparative analysis to study international experience in the application of financial instruments; modelling for the development of conceptual models of waste management; expert assessments to determine the potential impact and implementation complexity of the proposed solutions.

The logic of presenting the researched material includes a consistent review of the theoretical basis of financial tools in waste management, justification of the need for a synergistic approach, presentation of developed models of effective waste management based on integration of these instruments, analysis of their potential impact and complexity of implementation, as well as formulation of conclusions and practical recommendations.

It is the approach, which involves combined and coordinated use of environmental taxes, tariffs, and tax incentives, that forms the basis for developing effective waste management models capable to provide significantly higher positive impact compared to their isolated application. Such an integrated approach makes it possible to create a comprehensive

system of incentives and restrictions, covering different stages of the product life cycle and contributing to the achievement of sustainable waste management.

2. Environmental taxes, environmental tariffs, and tax incentives in scientific research

To understand how much and how the scientific community researches the influence of environmental tools on managing waste, we did a bibliometric analysis of scientific papers using the Scopus database. For doing this, we used a mix of keywords like "environmental taxes," "ecological taxes," "environmental tariffs," and "tax incentives" together with "waste management."

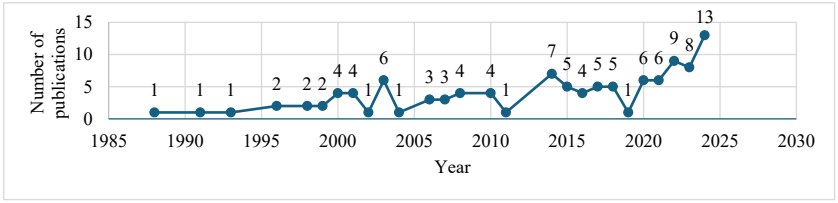

Figure 1. Number of articles by scientists who made a contribution to the research on the topic of environmental taxes, ecological tariffs in the context of waste management, ***built by the authors based on the Scopus database [1]***

The results what we got shows that there is a big scientific interest in this topic. Even though the first papers was published in 1988, the most growth in the number of publications is happening in the last few years. As of November 2024, the total amount of documents that fit our search is 109.

The quantitative analysis of scientific publications on the researched topic shows the variability of scientific interest during 1988-2024. After the initial stage of research establishment, characterized by a gradual increase in the number of publications, a period of stagnation was observed. However, starting from 2019, there is a renewal of scientific activity, which could be related to the relevance of the researched issue in the context of current environmental challenges.

Table 1

The most cited publications in the research topic

№	Article title	Authors of the article	Source of publication	Year	Number of citations
1	Evaluation of the economic feasibility for the recycling of construction and demolition waste in China-The case of Chongqing	Zhao, W., Leeftink, R.B., Rotter, V.S.	Resources, Conservation and Recycling, 54(6), pp. 377–389	2010	250
2	A model for assessing the economic viability of construction and demolition waste recycling – The case of Ireland	Duran, X., Lenihan, H., O'Regan, B.	Resources, Conservation and Recycling, 46(3), pp. 302–320	2006	177
3	COVID-19 and living space challenge. Well-being and public health recommendations for a healthy, safe, and sustainable housing	D'alessandro D., Gola M., Appolloni L., Dettori M., Fara G.M., Rebecchi A., Settimo G., Capolongo S.	Acta Biomedica, 91, pp. 61–75	2020	152
4	The Portuguese plastic carrier bag tax: The effects on consumers' behavior	Martinho, G., Balaia, N., Pires, A.	Waste Management, 61, pp. 3–12	2017	137
5	World trends in municipal solid waste management	Sakai S., Sawell S.E., Chandler A.J., Eighmy T.T., Kosson D.S., Vehlow J., Van Der Sloot H.A., Hartlén J., Hjelmar O.	Waste Management, 16(5-6), pp. 341–350	1996	137
6	Assessment of factors influencing the performance of solid waste recycling programs	Suttibak, S., Nitivattananon, V.	Resources, Conservation and Recycling, 53(1-2), pp. 45–56	2008	129

7	Worldwide commercial development of bioenergy with a focus on energy crop-based projects	Wright, L.	Biomass and Bioenergy, 30(8-9), pp. 706–714	2006	120
8	A dynamic model for construction and demolition (C&D) waste management in Spain: Driving policies based on economic incentives and tax penalties	Calvo, N., Varela-Candamio, L., Novo-Corti, I.	Sustainability (Switzerland), 6(1), pp. 416–435	2014	98
9	An economic analysis of household waste management	Choe, C., Fraser, I.	Journal of Environmental Economics and Management, 38(2), pp. 234–246	1999	94
10	Taxing virgin natural resources: Lessons from aggregates taxation in Europe	Söderholm, P.	Resources, Conservation and Recycling, 55(11), pp. 911–922	2011	78

Source: created by the authors based on the Scopus database [1]

The analysis of the most cited publications (Table 1) in the field of waste management and sustainable development shows the diversity of approaches to addressing environmental, economic, and social issues related to resource use and the implementation of environmental tariffs and taxes. The reviewed works cover both general global trends and specific examples of policy implementation in different countries, as well as social aspects of impact on health and consumer behaviour.

The analysis of international experience in waste management and resource use includes studies covering various aspects of this field. In particular, important are economic models that analyze the effectiveness of waste recycling and disposal, especially through tax mechanisms and other economic incentives. One direction is the study of the potential of bioenergy, based on renewable energy sources, which demonstrates the connection between sustainable development and energy crops.

Another important topic is the regional approach to waste management, which requires taking into account economic, social, and political factors. An example of such research is the analysis of the effectiveness of construction waste recycling in different countries, as well as the impact of tax measures on changing consumer behavior, such as the introduction of taxes on plastic bags.

Equally significant are studies that focus on the social aspects of environmental policy, particularly the impact of housing conditions on health. Considering socio-economic factors is key for developing successful recycling programs, as well as for ensuring sustainable and safe housing in the face of environmental challenges, especially in the context of global crises such as pandemics.

According to the Scopus database, the leaders in researching the relationship between environmental taxes, tariffs, and tax incentives in waste management are the United States and the United Kingdom, which account for 16 and 13 publications, respectively. China, Italy, and Spain also demonstrate significant scientific potential in this field. Ukraine, with 5 published works, has potential for further development of research in this area.

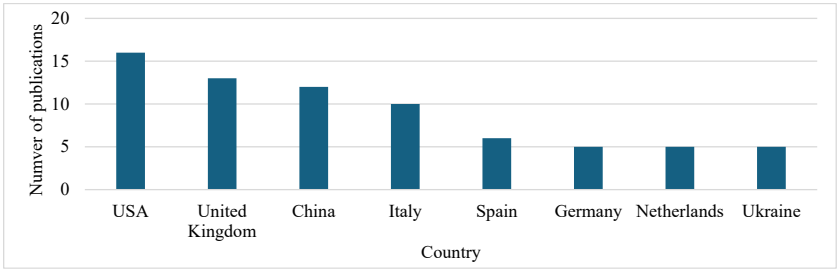

Figure 2. The number of publications discussing the topic of environmental taxes, tariffs, and tax incentives in waste management in different countries, *created by the authors based on Scopus data [1]*

The analysis of the thematic focus of scientific works (Figure 3) indicates a wide range of disciplines that explore the relationships between environmental taxes, tariffs, and tax incentives in waste management.

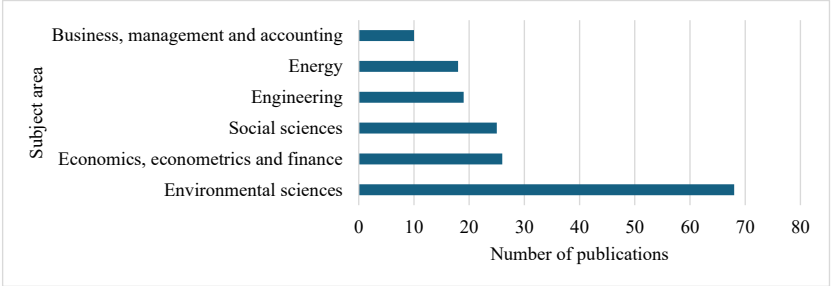

Figure 3. Distribution of studies by subject areas,
created by the authors based on the Scopus database [1]

The complexity of waste management issues requires the collaboration of various scientific fields. For this reason, the combination of economic tools is critically important for achieving efficiency in this area, as it touches on numerous aspects of our lives.

3/ Financial regulation tools in the field of waste management

Environmental taxes are an important tool of environmental policy, aimed at reducing pollution and supporting sustainable development. They are designed to internally eliminate external costs related to environmental damage, which encourage industries and individuals to implement more ecological practices [2, 3]. According to Articles 240–250 of the Tax Code of Ukraine, the environmental tax is a financial obligation imposed on enterprises and organizations for emissions, discharges, or waste disposal into the environment [4]. Environmental taxes are mainly justified by their ability to achieve environmental goals in an economically efficient way. They are applied in various sectors, including energy, transport, and waste management, and often require combination of different kinds of taxes to improve efficiency. In China, environmental taxes have contributed to the reduction of emissions from fossil fuel-based thermal power plants, in particular leading to significant decrease in such pollutants as sulfur dioxide and nitrogen oxide [5]. However, the effectiveness of these taxes can vary depending on regional regulatory norms and enterprise characteristics. Environmental taxes may motivate companies to adopt

more environmentally friendly technologies, although their response can differ depending on the level of taxation and the availability of subsidies or privileges, so the synergic interaction between all components – taxes, tariffs and incentives – is important for achieving positive result.

Table 2

Types of environmental taxes

Type of Environmental Tax	Description
Energy taxes	Imposed on the production, distribution or consumption of energy, especially fossil fuels, to reduce greenhouse gas emissions and promote energy efficiency. It is proven that such taxes have significant positive impact on fiscal space and debt sustainability in the EU [6; 7].
Transport taxes	Levied on vehicles and fuel to reduce emissions from the transport sector and encourage the use of environmentally friendly transport options.
Pollution and resource use taxes	Target specific pollutants or the use of natural resources in order to decrease environmental damage by making pollution and overuse more expensive.
Product taxes	Applied to goods that have significant negative impact on the environment during their life cycle, in order to reduce the consumption of harmful products. These taxes are aimed to decrease use of environmentally damaging goods and encourage development and adoption of more ecological alternatives [8].

Source: created by the authors based on [6–8]

Environmental taxes are recognized globally as an important financial tool for stimulating sustainable development and solving urgent environmental issues, and Ukraine is not an exception. Analyzing the dynamics of their revenues in specific countries makes it possible to evaluate the effectiveness of environmental policy and to identify trends in various sectors of the economy related to environmental pollution. The analysis of environmental tax revenue dynamics in Ukraine for the period 2019–2024, presented below, reveals a number of clear trends that reflect both the general increase in the fiscal role of these taxes and changes in the structure of environmental taxation.

The analysis of the dynamics of environmental tax revenues in Ukraine for the period 2019–2024 shows several distinct tendencies in different categories of tax income [9]. The total volume of environmental tax has demonstrated a tendency to grow, although with some fluctuations. The total revenue ranged from UAH 3 854 383 760,00 in 2019 to a peak of UAH 3 916 226 154,00 in 2024, with temporary decreases in 2020 and 2022.

Looking at individual components of the environmental tax, there is a clear trend of decreasing revenues from taxes on emissions of pollutants into atmospheric air by stationary sources (excluding carbon dioxide emissions). This type of revenue decreased from UAH 1 196 778 539,00 in 2019 to UAH 540 259 697,22 in 2024. A similar downward trend is observed in revenues from waste disposal in specially designated places, which declined from UAH 564 390 735,30 in 2019 to UAH 332 591 023,84 in 2024. Revenues from discharges of pollutants directly into water bodies also show a general upward trend, with some fluctuations, increasing from UAH 70 077 154,28 in 2019 to UAH 330 195 426,93 in 2024, with significant growth observed in 2022 and 2023.

On the contrary, revenues from the environmental tax on the generation and/or temporary storage of radioactive waste fluctuated without a clear direction, ranging from UAH 652 354 075,10 to UAH 1 071 668 367,00 during the analyzed period. At the same time, revenues from the environmental tax on carbon dioxide emissions from stationary sources show a pronounced upward trend since the introduction of this tax. These revenues increased from UAH 951 468 964,30 in 2019 to UAH 2 000 571 013,53 in 2024, indicating the growing role of the carbon tax in the overall structure of environmental tax revenues and reflecting stronger regulatory pressure on greenhouse gas emissions.

Environmental tariffs are an instrument of economic policy aimed at regulating international trade in order to protect the environment and encourage environmentally responsible economic activities. In essence, environmental tariffs are duties applied to goods and services based on their environmental impact throughout different stages of their life cycle. The main goal of their implementation is to create economic motivation for both producers and consumers to reduce their negative influence on nature, as well as to protect the domestic market from the import of products that do not meet internal environmental standards [10].

Types of environmental tariffs may differ depending on the object of regulation and the goals of environmental policy. They include import tariffs imposed on goods whose production causes considerable pollution or involves inefficient use of natural resources. Another example are tariffs on imported waste, which aim to limit cross-border movement of waste and support the development of domestic facilities for its processing and disposal. The use of environmental tariffs is seen as a possible tool to regulate international waste flows, helping to ensure more responsible waste management at the national level and reduce ecological risks linked with its transportation and landfilling [11].

Tax incentives in environmental policy are tools of fiscal policy aimed at encouraging economic agents to behave in an environmentally responsible way and to support technological innovations in the field of environmental protection. Their main purpose is to create positive economic motivations for businesses and consumers that would stimulate the reduction of negative impact on the environment, especially in the area of waste management [12].

There are various forms of tax incentives, including tax benefits that reduce the tax burden on environmentally responsible businesses, tax credits that allow to lower tax obligations when investing in environmental technologies, accelerated depreciation for eco-friendly equipment, and reduced tax rates for enterprises that actively use secondary raw materials and recycled inputs in their production process.

Environmental taxes, tariffs, and tax incentives are key instruments for effective waste management, encouraging environmentally responsible actions and technological development. Environmental taxes, as the analysis of their revenue dynamics in Ukraine shows, play a significant role in fiscal policy – particularly the growth of the carbon dioxide emission tax. Environmental tariffs help to regulate international waste flows, while tax incentives like benefits and credits motivate both companies and consumers to decrease their environmental footprint. For maximum efficiency, these instruments must interact properly and be adapted to regional conditions, which will support sustainable development and implementation of green technologies.

4. Economic mechanisms for stimulating effective waste management: interaction between environmental taxes, tariffs, and incentives

Environmental taxes and waste reduction. Environmental taxes act as an indicator of rising costs, making waste generation economically less attractive. By imposing taxes on waste generation or activities that pollute the environment, industries are incentivized to fundamentally rethink their production processes. This can manifest in several ways:

a) Taxes can encourage companies to invest in cleaner production technologies that minimize waste generation. For example, this approach is applied in European countries [13; 14]. Production processes can be re-engineered to be more resource-efficient, reducing the use of raw materials and by-products.

b) Taxes on specific materials or products can prompt manufacturers to shift toward developing products that are more durable, repairable, reusable, or made from materials suitable for recycling. This reduces the overall flow of waste, extending the life of products and facilitating their recycling at the end of their lifecycle.

c) Environmental taxes can motivate businesses to view waste not as a problem but as a potential resource. This encourages the exploration of waste valorization opportunities, such as using industrial by-products as raw materials in other processes, creating closed-loop systems within one industry and across industries.

For example, European countries, particularly those with reliable waste management systems like Germany and Sweden, effectively use landfill taxes and taxes on specific waste streams (such as packaging) [15]. These taxes have clearly contributed to a significant reduction in landfill waste and increased recycling and reuse rates. Industries in these regions are innovating to reduce waste generation in response to this economic pressure.

Environmental tariffs and environmental taxes. The interaction between tariffs and environmental taxes provides a nuanced approach to waste management in the context of international trade. They can function as strategic substitutes when it is necessary to carefully balance environmental goals and trade openness. This balance is crucial when pollution cannot be fully reduced through research and development [11].

a) Tariffs, which are usually imposed on imported goods, can be used to protect domestic industries from competition, but they can also increase

consumer prices and potentially hinder environmental progress if they protect less efficient sectors that pollute the environment. Environmental taxes, on the other hand, directly impact pollution and waste generation within the country. When used together, tariffs can be strategically lowered in sectors where domestic industries implement high environmental taxes and shift to cleaner production, while environmental taxes ensure that production within the country becomes more sustainable.

b) In scenarios where certain types of pollution or waste are inherently difficult to eliminate entirely through technological progress (even with R&D), combining tariffs and environmental taxes can be particularly effective. Tariffs can limit the import of goods from regions with low environmental standards, while domestic environmental taxes encourage local industries to minimize unavoidable pollution and invest in the best available technologies to combat it. This integrated approach helps address pollution problems related to both imports and domestic production.

For example, consider a hypothetical country that aims to reduce plastic waste and develop its domestic recycling industry while participating in international trade of plastic products. An import tariff on plastic products can be combined with environmental taxes on the production of primary plastic within the country. The tariff supports the development of the domestic recycling industry by making imported primary plastic less competitive, while the environmental tax prevents the overuse of primary plastic and encourages domestic producers to use recycled materials.

a)Tax incentives and Extended Producer Responsibility (EPR). Tax incentives are crucial for strengthening Extended Producer Responsibility (EPR) schemes, which place a significant responsibility for waste management directly on product manufacturers. Incentives make EPR more acceptable and effective [16]:

b) Tax incentives, such as reduced taxes or direct subsidies, can be offered to manufacturers who demonstrate reductions in emissions, improve the recyclability of products, or take responsibility for the disposal of their products after their useful life ends. This promotes eco-innovation by rewarding companies that go beyond regulatory requirements and actively contribute to waste reduction.

c)The combination of taxes (e.g., on polluting materials) and subsidies (incentives for recycling or eco-friendly production) creates a powerful joint

policy. Taxes remove incentives for polluting practices, while subsidies provide financial support for switching to more sustainable alternatives. Such a combination maximizes social welfare by internalizing environmental costs while encouraging beneficial behavior and technological progress.

Tax incentives can address the issue of indifference in the context of Extended Producer Responsibility. By making participation in EPR schemes financially attractive, incentives encourage broader implementation in industry and more effective deployment of waste recycling programs, recycling infrastructure, and sustainable development principles.

Tariffs reflecting costs. The introduction of tariffs that reflect costs, with profit distribution, can optimize waste management costs and generate economic surplus while simultaneously achieving environmental goals. This approach aligns with the goals of the circular economy and can be adapted to the current level of waste management efficiency [17].

Landfill taxes and enhanced waste management. Landfill taxes are one of the key factors influencing waste management efficiency [14]. However, the level of the landfill tax must be carefully calibrated to avoid unforeseen negative consequences and truly improve overall waste management:

a) High landfill taxes make waste disposal in landfills significantly more expensive than alternative waste management options such as recycling, composting, and energy recovery. This economic pressure can eventually become an incentive to redirect waste from landfills to more sustainable alternatives.

b) While high landfill taxes are crucial, excessively high taxes can potentially undermine incentives for "enhanced waste management," especially if alternative infrastructure is lacking or too expensive. For example, if recycling and composting infrastructure is insufficiently developed, extremely high landfill taxes can lead to illegal dumping or waste accumulation if proper alternative channels are not easily accessible and affordable.

c) The tax level should be set alongside investments in recycling infrastructure, composting, and educational campaigns to create a comprehensive and effective waste management system.

Countries like the United Kingdom and Denmark have gradually increased landfill taxes over several decades [18; 19]. This strategy contributed to a significant reduction in the number of landfills and attracted

substantial investments and innovations in alternative waste management technologies. However, these countries also invested significant funds in recycling and composting infrastructure alongside tax increases to ensure the availability of viable alternatives to landfill disposal.

5. Models of effective waste management based on the established interaction of financial instruments

As environmental challenges continue to grow, effective waste management has become a crucial element of sustainable development. The integration of environmental taxes, tariffs, and incentives into comprehensive models not only minimizes negative environmental impacts but also fosters the transition to a circular economy. Exploring optimal mechanisms for their interaction opens up new opportunities for creating effective waste management systems that meet modern environmental standards.

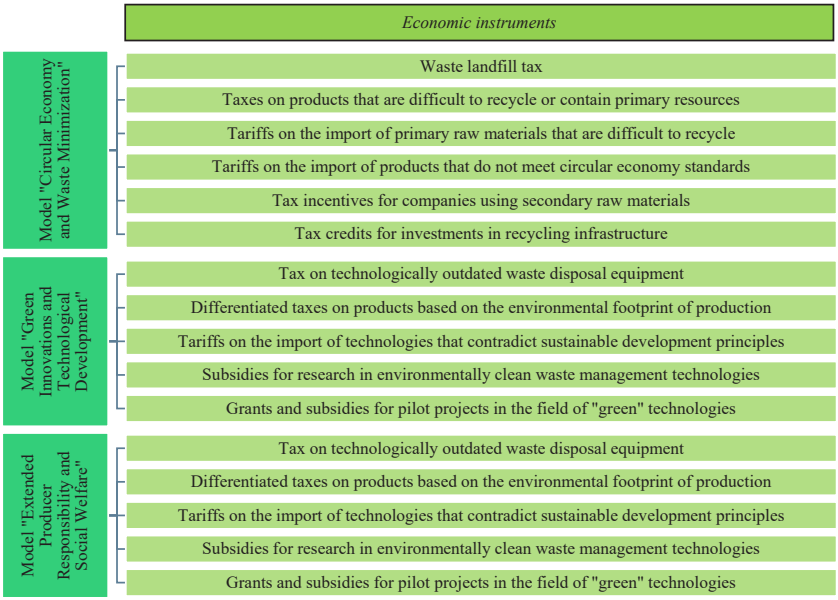

Figure 4. Models of effective waste management based on the use of financial instruments, *created by the authors*

The "Circular Economy and Waste Minimization" model is based on the transition from the linear "production-consumption-disposal" model to a closed loop, where resources are used for as long as possible and waste is transformed into secondary raw materials.

The key focus is on maximizing waste reduction, encouraging reuse and recycling, and forming markets for secondary raw materials.

In this model, environmental taxes play the role of tools that stimulate the transition to a circular economy. The waste disposal tax is set at a high level, making disposal economically unprofitable and encouraging recycling. Taxes on products that are difficult to recycle or contain primary resources urge manufacturers to engage in eco-design and use of secondary materials.

Environmental tariffs are used to protect the domestic market for secondary raw materials and stimulate its use. Tariffs on the import of primary raw materials limit competition with secondary raw materials, while tariffs on the import of products that do not meet circular economy standards encourage the import of environmentally friendly products.

Tax incentives are aimed at supporting companies that use secondary raw materials and investments in recycling infrastructure. Tax benefits reduce the cost of products made from secondary raw materials, tax credits support the creation and modernization of waste recycling companies, and subsidies for consumers stimulate demand for secondary products.

The feature of this model is its comprehensive impact on the entire value chain, synergy of tools, and focus on long-term sustainability. A high waste disposal tax makes recycling economically attractive, tax incentives support the development of this industry, and tariffs protect the domestic market from external competition. The model promotes not only waste reduction but also more rational use of resources and reduced dependence on primary raw materials.

The "Green Innovations and Technological Development" model focuses on stimulating technological innovations in waste management and the development and implementation of environmentally clean technologies for production, recycling, and waste disposal. It is based on the understanding that long-term and effective solutions to the waste problem require not only behavioral changes but also technological breakthroughs that will make production and consumption environmentally sustainable.

In this model, environmental taxes are used to stimulate technological renewal in the waste management industry. The tax on technologically outdated waste disposal equipment encourages businesses to switch to more efficient and environmentally friendly methods. Differentiated taxes on products, depending on the environmental footprint of production, promote "green" manufacturing and technological innovations in production processes.

Environmental tariffs are used to protect the domestic market from outdated technologies and promote the adoption of modern environmental solutions. Tariffs on the import of technologies that contradict the principles of sustainable development limit the import of outdated or environmentally inefficient technologies.

Tax incentives are aimed at supporting research and the implementation of "green" technologies. Grants and subsidies for pilot projects in the field of environmentally clean waste management technologies provide direct financial support for testing and implementing innovative solutions in real conditions.

The feature of this model is its focus on the long-term perspective, synergy of tools, and creation of an ecosystem for innovation. Taxes create pressure on outdated technologies and stimulate demand for new, environmentally friendly solutions. Tax incentives and direct support make innovative activities economically attractive and reduce risks for businesses. Tariffs protect the domestic market from technological imports that do not meet the principles of sustainable development. The model promotes not only waste reduction but also more rational use of resources and reduced dependence on primary raw materials.

The "Extended Producer Responsibility and Social Welfare" model is based on the principle of extended producer responsibility (EPR) and ensuring social justice in the implementation of waste management policies. Its goal is a fair distribution of the economic burden and social benefits from effective waste management. The model assumes that producers bear significant responsibility for the waste generated during the life cycle of their products and clearly defines their role in financing and organizing the waste management system.

In this model, environmental taxes are used for targeted financing of waste collection and recycling infrastructure within the framework of EPR.

Targeted taxes for financing waste collection and recycling infrastructure under EPR provide the necessary funds for developing and maintaining an effective waste management system.

Environmental tariffs are used to stimulate compliance with EPR principles by producers. Tariffs on the import of products from manufacturers that do not adhere to EPR principles create economic incentives for producers to comply with environmental standards and take responsibility for the waste generated by their products' life cycle.

Tax incentives are aimed at supporting producers participating in EPR schemes and achieving high recycling rates, as well as supporting organizations that focus on the social adaptation and employment of vulnerable groups in the waste management sector. Tax exemptions for producers participating in EPR schemes and achieving high recycling rates encourage active participation in waste management systems. Subsidies for organizations working on social adaptation and employment of vulnerable groups in waste management contribute to social integration and job creation.

The feature of this model is its focus on balancing environmental and social goals. It ensures not only the reduction of waste and pollution but also the creation of jobs, support for social enterprises, and protection for vulnerable population groups.

After creating the models, it is important to conduct a thorough analysis of the potential impact and the complexity of implementing the proposed instruments. This will allow for an assessment of the effectiveness of each instrument, identification of possible obstacles to their implementation, and the development of strategies to overcome them. Such an analysis will help ensure the successful implementation of the models and the achievement of the set goals in waste management.

It is considered advisable to conduct a detailed analysis of the potential impact and complexity of implementing the presented instruments for each of the three proposed models separately.

For the first model, "Circular Economy and Waste Minimization," 6 main instruments were identified. The Waste landfill tax is an economic instrument aimed at discouraging waste landfilling and encouraging its recycling and reuse. Its potential impact is assessed as medium, due to its ability to directly influence the economic attractiveness of landfilling; however, its maximum

effectiveness is limited by the presence of developed infrastructure for alternative waste treatment methods and the effectiveness of monitoring illegal dumping. The complexity of implementation is considered medium because it requires a thorough economic analysis to determine optimal rates that do not cause negative socio-economic consequences, as well as effective administrative mechanisms to control the volumes and locations of landfills.

Taxes on products that are difficult to recycle or contain primary resources have the potential to encourage producers to shift towards using more environmentally friendly materials and designing products with consideration for their future disposal. However, defining objective criteria for recycling difficulty and the share of primary resources is a methodologically challenging task, which results in a medium level of potential impact. The complexity of implementation is high due to the need to develop differentiated tax rates, establish complex systems for administration, and control the composition and characteristics of a wide range of products.

The introduction of tariffs on the import of primary raw materials that are difficult to recycle may aim to support the domestic market for secondary raw materials. However, in the context of global production chains and the availability of alternative sources, the potential impact of such a measure is assessed as low. The complexity of implementation is medium because it requires expert identification of the relevant raw materials and setting tariff rates that could face resistance from importers and require international coordination to achieve meaningful results.

Tariffs on the import of products that do not meet circular economy standards have significant potential to stimulate the global transition to more sustainable production and consumption practices, which determines a high level of potential impact. At the same time, the development and alignment of internationally recognized circularity standards, as well as the creation of effective mechanisms to ensure compliance, is an extremely challenging task, which results in a high level of implementation complexity.

Tax incentives for companies using secondary raw materials are a direct economic stimulus for the development of the secondary resource market. The potential impact of this instrument is assessed as medium, since its effectiveness depends on the size of the incentives and the actual availability

of quality secondary raw materials. The complexity of implementation is low, provided there are clear and transparent criteria for receiving such incentives.

Providing tax credits for investments in recycling infrastructure is an important mechanism to stimulate the development of the necessary recycling and resource reuse capacities. The potential impact is assessed as medium, since it depends on the amount of credits provided and the investment activity of economic entities. The complexity of implementation is medium, requiring the development of clear criteria for obtaining credits, expert evaluation of investment projects, and effective control over the targeted use of funds.

For the second model, "Green Innovations and Technological Development," five main instruments have been identified. The tax on technologically outdated waste disposal equipment aims to stimulate the modernization of the industry's technological base. However, its potential impact is assessed as low, especially in conditions where a significant portion of enterprises have already transitioned to using more modern technologies. The implementation complexity is medium, as it requires the definition of clear criteria for technological obsolescence and the creation of mechanisms for managing and controlling the existing equipment.

Differentiated taxes on products based on the environmental footprint of production have significant potential for stimulating environmentally responsible production and consumption, which determines a high level of potential impact. However, the objective definition and verification of the environmental footprint of a wide range of products is an extremely complex methodological task, leading to high implementation complexity.

The introduction of tariffs on the import of technologies that contradict sustainable development principles aims to prevent the implementation of environmentally harmful technologies. However, given the global exchange of technologies, its potential impact is considered low. The implementation complexity is high, as it requires a clear definition of criteria for technological non-compliance with sustainable development principles, which could be subject to expert debates and trade disputes.

Subsidies for research in environmentally clean waste management technologies are an important instrument for stimulating innovation. The potential impact is assessed as medium, as the successful development

and implementation of new technologies is a long-term process. The implementation complexity is medium, requiring effective distribution of funds, objective evaluation of scientific projects, and monitoring their implementation.

Table 3

Potential impact level and implementation complexity for the financial instruments of the "Circular Economy and Waste Minimization" model

Instrument	Potential Impact Level	Implementation Complexity	Brief Comments
Waste landfill tax	Medium	Medium	Stimulates a reduction in landfill volumes, but may lead to illegal dumping.
Taxes on products that are difficult to recycle or contain primary resources	Medium	High	May encourage producers to use more environmentally friendly materials and simplify recycling. Difficulty in defining criteria and rates.
Tariffs on the import of primary raw materials that are difficult to recycle	Low	Medium	May support the domestic market for secondary raw materials, but may have limited impact due to global supply chains. Requires international coordination.
Tariffs on the import of products that do not meet circular economy standards	High	High	Potentially strong tool for stimulating circularity, but difficult to apply due to defining standards and possible trade disputes.
Tax incentives for companies using secondary raw materials	Medium	Low	Encourages the use of secondary resources, simplifies recycling. Effectiveness depends on the size of incentives and availability of secondary raw materials.
Tax credits for investments in recycling infrastructure	Medium	Medium	Stimulates the development of necessary recycling infrastructure. Important to ensure transparency and targeted use of funds.

Source: created by the authors

The provision of grants and subsidies for pilot projects in the field of "green" waste management technologies promotes the practical implementation of innovative solutions. The potential impact is assessed as medium, as the successful scaling of pilot projects depends on many factors. The implementation complexity is medium, requiring the development of clear criteria for project selection and assessment of their effectiveness.

Table 4

Potential impact level and implementation complexity for economic instruments of the "Green Innovations and Technological Development" model

Instrument	Potential Impact Level	Implementation Complexity	Brief Comments
Tax on technologically outdated waste disposal equipment	Low	Medium	May stimulate technology renewal, but may have limited impact if such equipment is no longer widely used.
Differentiated taxes on products based on the environmental footprint of production	High	High	A powerful tool for promoting environmentally responsible production, but complex in calculating and verifying the environmental footprint.
Tariffs on the import of technologies that contradict sustainable development principles	Low	High	May prevent the implementation of outdated and harmful technologies, but may limit access to certain technologies. Difficult to determine which technologies contradict sustainable development principles.
Subsidies for research in environmentally clean waste management technologies	Medium	Medium	Supports innovation in waste management. It is important to ensure effective fund distribution and commercialization of developments.
Grants and subsidies for pilot projects in the field of "green" technologies	Medium	Medium	Supports the practical implementation of new environmental solutions. It is important to ensure clear selection criteria and project effectiveness evaluation.

Source: created by the authors

For the "Extended Producer Responsibility and Social Welfare" model, four main instruments have been identified. Targeted taxes to finance waste collection and recycling infrastructure within the framework of EPR are a key element in ensuring the financial sustainability of such systems, which determines a high potential impact. The implementation complexity is assessed as medium, as it requires determining optimal tax rates and creating effective mechanisms for managing the collected funds.

Tariffs on the import of products from manufacturers who do not comply with EPR principles may stimulate the adoption of these principles at the international level, which defines a medium level of potential impact. However, monitoring compliance with EPR principles by foreign manufacturers is a challenging task, resulting in a high implementation complexity.

Tax incentives for manufacturers participating in EPR schemes and achieving high recycling rates are a powerful incentive for increasing the efficiency of such systems, which defines a high level of potential impact. The implementation complexity is assessed as low, provided there are clear criteria for participation in EPR schemes and objective methods for verifying recycling achievements.

Subsidies for organizations involved in the social adaptation and employment of vulnerable groups in the waste management sector have an important social aspect and can contribute to the development of the industry. The potential impact is assessed as medium, as it combines both environmental and social goals. The implementation complexity is medium, requiring the development of criteria for selecting organizations, evaluating their social impact, and controlling the use of funds.

When analyzing the complexity of implementing the proposed instruments, it can be stated that the least difficult are the tax incentives for enterprises that use secondary raw materials, as well as tax incentives for manufacturers involved in EPR schemes and achieving high recycling rates. This is due to the relatively simple administration process, provided that clear criteria are established. The highest implementation complexity is demonstrated by tariffs on the import of products that do not meet circular economy standards, differentiated taxes on products depending on the environmental footprint of production, and tariffs on the import of technologies that contradict the principles of sustainable development. These

challenges are related to the need of developing complicated methodologies, achieving international agreement on standards, and establishing effective control systems.

Table 5

Potential impact level and implementation complexity of economic instruments within the "Extended Producer Responsibility and Social Welfare" model

Instrument	Potential Impact Level	Implementation Complexity	Brief Comments
Targeted taxes to finance waste collection and recycling infrastructure within the framework of EPR	High	Medium	Provides the financial foundation for implementing extended producer responsibility (EPR). It is important to ensure transparency in the use of funds and the effectiveness of the EPR system.
Tariffs on the import of products from manufacturers who do not comply with EPR principles	Medium	High	Stimulates manufacturers to adopt EPR principles. It may be challenging to implement and monitor compliance with EPR principles by foreign manufacturers.
Tax incentives for manufacturers participating in EPR schemes and achieving high recycling rates	High	Low	Encourages manufacturers to actively participate in EPR schemes and improve recycling efficiency. It is important to clearly define criteria for receiving incentives and monitor the achievement of targets.
Subsidies for organizations involved in the social adaptation and employment of vulnerable groups in the waste management sector	Medium	Medium	Has a positive social impact and can contribute to the development of the waste management sector. It is important to ensure the effective use of subsidies and the quality of social services.

Source: created by the authors

Regarding the potential impact, the highest level is shown by tariffs on the import of products that do not meet circular economy standards, differentiated taxes based on environmental footprint, and targeted taxes to finance EPR infrastructure. These instruments have a significant potential to stimulate systemic changes in production and consumption. The lowest potential impact is shown by tariffs on the import of primary raw materials that are difficult to recycle, and the tax on technologically outdated waste disposal equipment. This is due to their limited scope or dependency on other influencing factors.

The synergistic effect of applying all three proposed models in an integrated manner is the key for achieving maximum efficiency in the transition to circular economy and optimization of waste management. The different focus of each model – waste minimization, stimulation of green innovations, and extended producer responsibility – ensures a complex influence on various aspects of economic activity, mutually strengthening the results and supporting more deep and sustainable transformations

Conclusions

The conducted research confirms the important role of environmental taxes, tariffs, and tax incentives as key instruments of environmental policy aimed at promoting sustainable development and effective waste management. The analysis of the dynamics of revenues from environmental taxes in Ukraine for the period 2019–2024 revealed a general trend of increasing fiscal importance of these payments, particularly due to the carbon dioxide emissions tax, which indicates a strengthened regulatory impact on greenhouse gas emissions. At the same time, there is a decrease in revenues from taxes on emissions of pollutants from stationary sources and waste disposal, which may reflect both positive shifts in the environmental behavior of enterprises and the need to revise tax rates and administration mechanisms.

Environmental tariffs are considered an important tool of international trade regulation with the aim to protect the environment and encourage environmentally responsible production, especially in the sphere of transboundary waste flow management. Tax incentives, in turn, act as an effective mechanism to encourage enterprises and consumers to adopt environmentally friendly technologies and practices, including the use of

secondary raw materials and investments into nature protection measures. The effectiveness of all three instruments highly depends on their synergic interaction, as well as their adaptation to specific regional conditions and enterprise characteristics.

To achieve the maximum positive impact on the environmental situation and promote sustainable development in Ukraine, a comprehensive and balanced application of environmental taxes, tariffs, and tax incentives is necessary. It is important to continue analyzing the dynamics of revenues and the effectiveness of existing instruments, as well as to develop and implement new, more targeted and efficient mechanisms that consider international experience and the specifics of the national economy. This will contribute to the internalization of external environmental costs, encourage environmentally responsible behavior, and support the implementation of clean technologies across different sectors of the economy.

The conducted research highlights the crucial role of economic mechanisms, especially environmental taxes, tariffs, and tax incentives, in forming effective waste management systems and encouraging the transition to circular economy. Environmental taxes act as a powerful tool that internalizes external environmental costs, pushing the industry toward the adoption of cleaner production processes, development of more sustainable products, and treating waste as a potential resource. The successful experience of European countries demonstrates the significant impact of taxes on landfilling and separate waste streams on the reduction of landfilling volumes and increase of recycling rates.

The interaction between environmental tariffs and taxes provides a flexible approach to waste management in the context of international trade, allowing to balance environmental goals and market openness. A strategic combination of tariffs, which may protect domestic industries transitioning to cleaner production, and environmental taxes, which directly affect waste generation, is important for addressing pollution problems related to both imports and domestic production. Tax incentives, especially in the context of extended producer responsibility, play a key role in encouraging producers to take responsibility for the waste generated by their products, stimulating eco-innovation and wider implementation of sustainable practices.

The effectiveness of landfill taxes is critically important for improving waste management, but their level must be carefully calibrated and supported

by investments into alternative recycling infrastructure and awareness campaigns. The experience of countries that gradually increased landfill taxes along with the development of recycling infrastructure confirms the importance of a comprehensive approach. In general, achieving significant improvements in the field of waste management and the transition to a circular economy requires integrated and thoughtful application of economic instruments, adapted to specific national conditions and industrial features.

In the presented work, the features of three complementary models of effective waste management based on the synergic interaction of environmental taxes, tariffs, and tax incentives were deepened and detailed. Conceptual frameworks for each model were created and described, namely: "Circular Economy and Waste Minimization," "Green Innovation and Technological Development," and "Extended Producer Responsibility and Social Welfare," with emphasis on their key objectives and functioning mechanisms.

For each of the developed models, specific financial instruments were purposefully selected to best match its strategic objectives. In particular, for the circular economy model, the focus was made on instruments that stimulate waste reduction and the use of secondary raw materials; for the green innovation model – on instruments that encourage technological development in the field of waste management; and for the extended producer responsibility model – on instruments that place responsibility on producers and promote social justice.

The next step of the research was to determine the approximate levels of potential impact of each proposed economic instrument on the waste management system and to assess the level of complexity of its practical implementation. Conducting such analysis is a necessary stage to evaluate the realism and potential effectiveness of each model, as well as to identify possible obstacles and develop strategies for their overcoming during the stage of practical realization.

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