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Study of the influence of commercial activities on waste formation in Ukraine in the context of sustainable development

Keywords: sustainable development, environmental safety, waste formation, utilization and recycling, information support, multiple regression econometric model

Introduction

The issue of waste accumulation and management in Ukraine is a pressing concern and takes precedence among other environmental problems. The concentration of solid waste, household waste, and hazardous waste substances is a factor contributing to ecological instability and the occurrence of emergencies.

Flammini et al. (2022) emphasize the quantitative assessment of greenhouse gas emissions resulting from the combustion of fossil fuels for energy use in agriculture, forestry, and fisheries. Samojlik (2014) also emphasized the regional aspects of the necessity for waste utilization. At the same time, the author underlined the need for

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a comprehensive assessment of the waste management efficiency in the region based on balancing the economic, environmental, social, and technological criteria in this field. Within the framework of the topic, Kryvenko (2015) proves that waste management in regions is characterized by a significant impact on the environment due to waste utilization processes, lack of available land for waste disposal, and low efficiency of the waste management system overall. Viedienina et al. (2020) also assert that the disposal of solid household waste is a necessary foundation for sustainable economic development.

Pryshliak et al. (2021) justified the prerequisites and organizational-economic mechanism for the formation and implementation of waste management strategies in agricultural enterprises.

Electronic waste is of particular significance in modern times, being just as harmful as waste from agrarian activities. It contains not only hazardous substances but also precious metals such as gold, silver, copper, and platinum. For example, in 2016, approximately 0.44 million t of mobile phones were discarded worldwide, with a raw material value of 9.4 billion EUR (Honcharenko, 2021). Skorik (2017) summarized issues related to electronic waste and proposed an economic mechanism for managing electronic waste in Ukraine.

Kovalenko et al. (2022) focused on the problems of Ukraine's municipal solid waste and ways to address them.

Flammini (2022) also conducted research on key waste generation trends at global, regional, and national levels. Expanding on this research, Brohi et al. (2023) studied waste at the regional level, specifically solid municipal waste in Dadu, Sindh, Pakistan.

The state of waste management in countries is a significant concern and poses a threat to the ecological safety of a nation, necessitating the immediate implementation of a comprehensive set of legislative, organizational, and research measures aimed at the practical realization of the concept of sustainable development. UN member countries have identified waste management as one of the important requirements for achieving sustainable development goals (Government Portal of Ukraine, 2023) by incorporating Goal 12 (Responsible Consumption and Production), which emphasizes the need to reduce ecological impact by changing production and consumption patterns, and Goal 13 (Climate Action), which focuses on reducing greenhouse gas emissions, saving lives and helping communities (Government Portal of Ukraine, 2023). It is worth noting that the concept of sustainable development takes into consideration not only the environment, but also the economic and social dimensions (Kalemkerian et al., 2023). Adhering to sustainable development requirements is advocated by Škrinjarić (2020).

The information about the state of the environment, allowing for the identification of threats to nature and species and the development of strategies for their preservation, is the basis for deciding on a waste management mechanism. In addition, Dovga (2011) points out the necessity of implementing modern recycling technologies for solid household waste. Simultaneously, such an approach will ensure improvements in the quality of the environment and the quality of life for the population in the context of sustainable development goals (Masyk et al., 2023).The state of environment has a direct impact on human health. Air, water, and soil pollution can lead to illnesses, and information about these risks helps take preventive measures. Moreover, the quantity of waste and its management are crucial for agriculture and the level of food security, as demonstrated by Dziurakh et al. (2022). Furthermore, the increase in waste disposal expenses stimulates overall eco-expenditures within the region (Shpak et al., 2021b). Additionally, it is essential not to overlook the presence of qualified personnel capable of conducting such disposal effectively, as the COVID-19 pandemic and the war in Ukraine have led to a decrease in the population and resulted in a problem with the quality of personnel in Ukraine (Podolchak et al., 2021). Thus, the state of the environment is determined by a combination of information regarding its pollution and waste management (Lotrecchiano et al., 2022).

Martynovych et al. (2023) have prepared recommendations for the development of territories subject to restoration. They proposed a concept of territory conversion and justified the need to distribute territories based on the added value and the quality of life of the population.

However, currently there is insufficient research related to the influence of various factors on waste generation within specific territories. In particular, this study proposes to investigate the influence of agricultural, forestry, and fishery activities, mining and processing industries, construction, electricity, gas, steam, and conditioned air supply, and other economic activities in Ukraine on waste generation. This research will build upon previous waste management issues in European countries (Papagiannis et al., 2021) and in Ukraine. The increase in the volume of waste in Ukraine is facilitated by the increased use of packaged goods. Therefore, Krykavskyi et al. (2018) emphasize the importance of promoting ecological awareness and behavior among Ukrainians in this direction, promoting this idea at the state level, and engaging manufacturers and intermediaries in its implementation. Ishchenko et al. (2021) have also continued research in this direction. Research in this direction was also conducted by Shults et al. (2021), revealing the level of influence of stimulating and destimulating factors on consumer capacity. Simultaneously, Shpak et al. (2021a) indicate the need to formulate a development strategy for each industry, taking into account the influence of various factors on its development. Bochko et al. (2022), on the other hand, point out the level of competitiveness of the development of each industry separately and the country as a whole, considering the necessity to apply the digital economy. However, the studies of these authors are relatively general and present the problem in a generalized manner.

Significant volumes of waste in Ukraine pose a substantial obstacle to its sustainable development. They require further processing and disposal, necessitating the provision of dedicated facilities for these purposes and the allocation of land for their accumulation. Simultaneously, waste has a negative impact on the state of the environment, the occurrence of emergencies, and people's health. Therefore, every country faces the issue of waste accumulation and the analysis of sources of their formation. In the pre-war period, various sectors of the economy primarily generated a significant portion of Ukraine's waste. In the conditions of the post-war state, their functioning will also negatively affect Ukraine's environment. Therefore, the aim of this article is to analyze the impact of various economic sectors in Ukraine on the formation of the total amount of waste in Ukraine based on statistical data.

Research into the impact of economic activity on waste generation in Ukraine in the context of sustainable development entails studying the influence of economic activities on the quantity and composition of waste generated in Ukraine. This research aims to develop strategies and practices for reducing the negative impact of various economic sectors on the environment. It is worth noting that an increase in the production and consumption of goods and services often leads to an increase in waste. There is a strong correlation between the increase in waste and an increase in energy consumption. The overall impact of economic activity on waste levels depends on various factors, including the industry, region, technologies, and stakeholders' awareness in the process. Effective waste management and the development of a sustainable economy can contribute to reducing the negative impact of economic activities on the environment.

In the current circumstances, during the wartime situation in Ukraine, the waste problem has taken unprecedented proportions, especially after the explosion of the Kakhovska Hydroelectric Station (Kyiv School of Economics, 2023). In general, waste volumes in Ukraine will continue to increase with the ongoing war initiated by the Russians (Kolesnichenko, 2023). The state can influence waste reduction through the regulation of various economic sectors that pollute the environment and the formation of ecological behavior among the population.

Material and methods

To determine the quantitative assessment of the impact of various sectors of the economy on waste generation in Ukraine, it is advisable to use a multiple regression econometric model that allows for a quantitative evaluation of the influence of various factors on a specific economic process or phenomenon. In general, such a model takes the form of (Nakonechnyi et al., 2004):

$$y = a_0 + a_1 x_1 + a_2 x_2 + \ldots + a_m x_m + u. \tag{1}$$

To determine the structure of a multifactor linear model, a correlation matrix $\boldsymbol{R_y}$ is utilized, which includes both the factors and the indicator.

$$\boldsymbol{R}_y = \begin{pmatrix} r_{x_1x_1} & r_{x_1x_2} & \ldots & r_{x_1x_m} & r_{x_1y} \\ r_{x_2x_1} & r_{x_2x_2} & \ldots & r_{x_1x_1} & r_{x_2y} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ r_{x_mx_1} & r_{x_mx_2} & \ldots & r_{x_mx_m} & r_{x_my} \\ r_{yx_1} & r_{yx_2} & \ldots & r_{yx_m} & r_{yy} \end{pmatrix}, \tag{2}$$

where: $$r_{x_ix_j} = \frac{\frac{1}{n}\sum_{k=1}^{n}\left(x_{ik} - \bar{x}_i\right)\left(x_{jk} - \bar{x}_j\right)}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x}_i)^2 \sum_{j=1}^{n}(x_j - \bar{x}_j)^2}}. \tag{3}$$

The model should include factors that correlate with the indicator and not correlate with each other.

For multiple regression econometric models, it is important to investigate whether there are interrelationships between the factors, which is referred to as multicollinearity, as it negatively affects the quantitative characteristics of the econometric model.

Investigating multicollinearity can be done using the Farrar–Glaube’s algorithm, which employs three types of statistical criteria (Nakonechnyi et al., 2004) to check for multicollinearity: multicollinearity in the entire array of factors (χ^2); multicollinearity of each factor with all other factors (F-criterion); multicollinearity between each pair of factors (t-criterion):

$$\chi_p^2 = -\left(n - 1 - \frac{2m+5}{6}\right)\ln\left(\det R\right), \quad (4)$$

where n is the number of observed data; m is the number of factors; $\det R$ is the determinant of the correlation matrix:

$$\boldsymbol{R} = \begin{pmatrix} r_{x_1x_1} & r_{x_1x_2} & \cdots & r_{x_1x_n} \\ r_{x_2x_1} & r_{x_2x_2} & \cdots & r_{x_2x_n} \\ \cdots & \cdots & \cdots & \cdots \\ r_{x_mx_1} & r_{x_mx_2} & \cdots & r_{x_mx_n} \end{pmatrix}, \quad (5)$$

$$F_j = \left(z_{jj} - 1\right)\frac{n-m-1}{m}, \quad (6)$$

in which z_{jj} represents the elements of the matrix inverted from the correlation matrix.

To determine the structure of a multifactor linear model, a correlation matrix $\boldsymbol{R_y}$ is utilized, which includes both the factors and the indicator:

$$t_{ij} = \frac{r_{ij,1,2,\ldots,m}\sqrt{n-m-1}}{\sqrt{1-r^2_{ij,1,2,\ldots,m}}}, \quad (7)$$

where $r_{ij,1,2,\ldots,m}$ represents the partial correlation coefficients determined by following formula:

$$r_{ij,1,2,\ldots,m} = \frac{z_{ij}}{\sqrt{z_{ii}z_{jj}}}. \quad (8)$$

In the case of detecting multicollinearity, it is necessary to eliminate the factors that cause it. To determine the model parameters a_0, a_1, a_2, a_3, …, a_m, the method of least squares can be used (Nakonechnyi et al., 2004):

$$\vec{A} = \left(X^T X\right)^{-1} \left(X^T \vec{Y}\right), \tag{9}$$

where $\vec{Y}$ is the data vector of the indicator; X represents the data matrix of factors; $\vec{A}$ is the vector of model parameters.

To check the adequacy of the constructed multiple regression model, coefficients of determination (R^2), the F-statistic (F), the Neyman's criterion (Q), and the Student's t-test (t) can be used.

Coefficient of determination is calculated as follows:

$$R^2 = \frac{\sum (\hat{y}_i - \overline{y})^2}{\sum (y_i - \overline{y})^2}, \tag{10}$$

where $\hat{y}_i$ is the theoretical values; $\overline{y}$ is the mean value; y_i is the actual values.

The F value is calculated as follows:

$$F = \frac{\dfrac{R^2}{m}}{\dfrac{\left(1 - R^2\right)}{\left(n - m - 1\right)}} \tag{11}$$

The Q value is calculated as follows:

$$Q = \frac{\dfrac{\sum_{i=2}^{n} (u_i - u_{i-1})^2}{n-1}}{\dfrac{\sum_{i=1}^{n} u_i^2}{n}}, \tag{12}$$

where u_i represents the random deviations (residuals).

To determine the structure of a multifactor linear model, a correlation matrix $\boldsymbol{R_y}$ is utilized, which includes both the factors and the indicator.

$$t_{a_i} = \frac{|a_i|}{\sigma_{a_i}}, \tag{13}$$

where σ_{a_i} is the standard error of the parameter estimate.

The partial coefficient of elasticity for x_i factor is calculated using following formula:

$$E_{x_i} = \frac{\partial y}{\partial x_i} \frac{x_i}{y}. \tag{14}$$

The partial coefficient of elasticity indicates how the indicator *y* changes if the factor changes by 1% while keeping the values of other factors constant. To determine the quantitative assessment of the impact of various factors on waste generation in Ukraine across different directions, the authors proposed utilizing a multifactor econometric linear model.

To determine the quantitative assessment of the impact of various factors on waste generation in Ukraine across different directions, the authors proposed utilizing a multifactor econometric linear model:

$$\hat{y} = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + a_5x_5 + a_6x_6, \tag{15}$$

where $\hat{y}$ – total waste generated; x_1 – agriculture, forestry, and fisheries; x_2 – extractive industry and quarrying; x_3 – extractive industry and quarrying processing industry; x_4 – supply of electricity, gas, steam, and conditioned air; x_5 – construction; x_6 – other types of economic activities.

The indices of waste generation dynamics were determined as individual chain indices:

$$I_{w_{i,j}} = \frac{x_{i,j}}{x_{i,j-1}}, y = a_0 = a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + a_5x_5 + a_6x_6, \tag{16}$$

where the value of the *i*-th type of waste in the *j*-th time period.

The research is based on statistical data regarding the dynamics of waste generation in Ukraine by sources for the years 2010–2022.

Results and discussion

Analysis of existing waste in Ukraine

The question of reforming the waste management system and reducing waste is a crucial component of Ukraine's national environmental security. Even before the full-scale invasion by Russia, Ukraine had accumulated approximately 54 million m^3 of waste. However, only 6% of the total municipal waste was subject to recycling, with the rest ending up in landfills, many of which have long exceeded their capacity. Over the past 10 years, solid municipal waste in our country has increased by nearly 50% per capita, averaging to 300–400 kg per capita annually (Rokhova, 2019). The increasing volume of waste poses a significant problem for the environment and society as a whole. Among the key factors contributing to the growth of waste during the pre-war period were population growth, rising consumer incomes, increased use of disposable goods and excessive packaging, technological development, the shift from production to a consumption-based economy, inefficient resource utilization, the need for recycling, and consumerism.

If these factors are not addressed, they will remain relevant for Ukraine in the post-war period. A graphical representation of the causes and consequences of waste generation in Ukraine is presented in Figure 1.

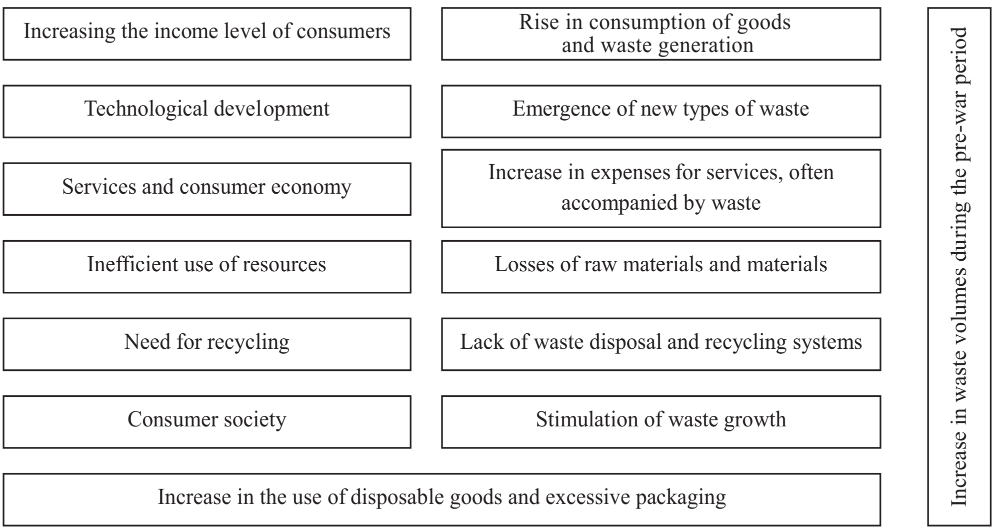

FIGURE 1. Main factors and consequences of waste generation in the pre-war period
Source: own elaboration.

Kolodiichuk (2022) identifies other factors influencing the level of waste generation in Ukraine. Notably, organizational and economic factors that determine the volume and structure of waste generation and disposal are mentioned. These factors encompass the country's macroeconomic situation, business activities of enterprises, waste logistics, economic and environmental incentives, and production constraints. The author also highlights a group of innovation and technological factors that affect the formation of waste management systems. These factors include the technological level of production and disposal facilities, investment activity, and access to credit resources.

To quantitatively assess the impact of various factors on waste generation in Ukraine from different sources, data from Table 1 were used. Figure 2 shows the dynamics of waste generation indices by sources for the years 2011–2020.

Analyzing Figure 2, we can observe that there are no clear trends in waste generation by sources. Therefore, to determine the impact of individual factors on the level of waste generation in Ukraine, it is advisable to use econometric modeling.

TABLE 1. Dynamics of waste generation by sources in 2010–2020

Year	Agriculture, forestry, and fisheries [kt]	Extractive industry and quarrying [kt]	Extractive Industry and quarrying processing industry [kt]	Supply of electricity, gas, steam, and conditioned air [kt]	Construction [kt]	Other types of economic activities [kt]	Total waste generate [kt]
	x_1	x_2	x_3	x_4	x_5	x_6	y
2010	8 304.5	347 442.3	47 676.5	8 636.4	326.7	3 795.8	422 549.9
2011	12 201.2	357 863.6	48 920.4	9 895.6	677.9	9 524.4	443 795.5
2012	10 030.4	364 964.1	48 709.9	9 805.5	609.4	5 059.7	446 716.9
2013	10 080.6	373 042.6	40 738.5	9 339.2	737.3	2 914.3	445 262.1
2014	8 451.4	297 290.0	34 796.7	5 972.7	306.4	1 868.9	355 000.4
2015	8 736.8	257 861.9	31 000.5	6 597.5	376.2	1 641.4	312 267.6
2016	8 715.5	237 461.4	34 093.0	7 511.5	300.2	1 442.0	295 870.1
2017	6 188.2	313 738.2	32 176.7	6 191.7	493.8	1 407.4	366 054.0
2018	5 968.1	301 448.9	31 523.2	6 322.7	378.8	1 148.7	352 333.9
2019	6 750.5	390 563.8	30 751.8	5 959.2	188.7	1 405.8	441 516.5
2020	5 315.4	391 077.9	52 311.0	5 333.7	14.5	2 371.3	462 373.5

Source: State Statistics Service of Ukraine (2021).

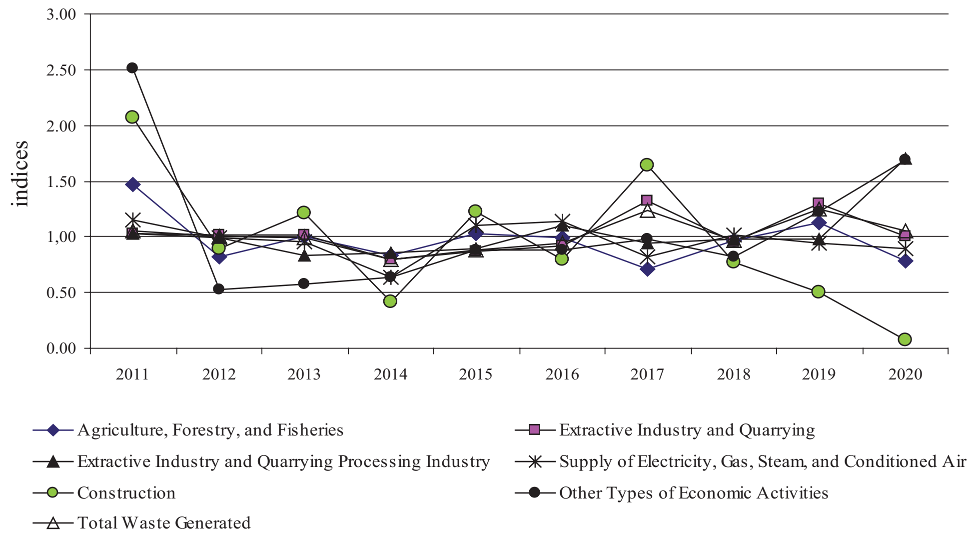

FIGURE 2. Dynamics of waste generation index by sources for the years 2011–2020

Source: compiled based on data from State Statistics Service of Ukraine (2021).

Studying the impact of individual factors on waste generation in Ukraine

To determine the significance of the influence of individual factors (different sectors of the economy) on the level of waste generation in Ukraine, a correlation matrix $\boldsymbol{R_y}$ was used:

$$\boldsymbol{R_y} = \begin{pmatrix} 1.000 & -0.004 & 0.327 & 0.859 & 0.743 & 0.765 & 0.140 \\ -0.004 & 1.000 & 0.594 & 0.213 & 0.045 & 0.374 & 0.982 \\ 0.327 & 0.594 & 1.000 & 0.516 & 0.106 & 0.682 & 0.717 \\ 0.859 & 0.213 & 0.516 & 1.000 & 0.796 & 0.758 & 0.357 \\ 0.743 & 0.045 & 0.106 & 0.796 & 1.000 & 0.546 & 0.134 \\ 0.765 & 0.374 & 0.682 & 0.758 & 0.546 & 1.000 & 0.511 \\ 0.140 & 0.982 & 0.717 & 0.357 & 0.134 & 0.511 & 1.000 \end{pmatrix}.$$

According to the matrix $\boldsymbol{R_y}$, waste generation in Ukraine is significantly influenced by the extractive industry and quarrying (x_2), the processing industry (x_3), and other types of economic activities (x_6).

In the construction of a multifactor econometric model, it's essential to ascertain whether the condition of independence between the selected factors is met, in other words, to verify the absence of multicollinearity. The Farrar–Glauber's method was employed to investigate the phenomenon of multicollinearity.

To perform further calculations, it is necessary to determine the correlation matrix (***R***):

$$\boldsymbol{R} = \begin{pmatrix} 1.000 & 0.594 & 0.374 \\ 0.594 & 1.000 & 0.682 \\ 0.374 & 0.682 & 1.000 \end{pmatrix}.$$

To determine multicollinearity in the entire set of factors, the criterion $\chi^2_p = 6.745$ was calculated, which needs to be compared with $\chi^2_k = 7.8$ with a reliability of 0.95 and degrees of freedom 3. The obtained value indicates the absence of general multicollinearity:

$$\boldsymbol{X} = \begin{pmatrix} 1.0 & 347{,}442.3 & 47{,}676.5 & 3{,}795.8 \\ 1.0 & 357{,}863.6 & 48{,}920.4 & 9{,}524.4 \\ 1.0 & 364{,}964.1 & 48{,}709.9 & 5{,}059.7 \\ 1.0 & 373{,}042.6 & 40{,}738.5 & 2{,}914.3 \\ 1.0 & 297{,}290.0 & 34{,}796.7 & 1{,}868.9 \\ 1.0 & 257{,}861.9 & 31{,}000.5 & 1{,}641.4 \\ 1.0 & 237{,}461.4 & 34{,}093.0 & 1{,}442.0 \\ 1.0 & 313{,}738.2 & 32{,}176.7 & 1{,}407.4 \\ 1.0 & 301{,}448.9 & 31{,}523.2 & 1{,}148.7 \\ 1.0 & 390{,}563.8 & 30{,}751.8 & 1{,}405.8 \\ 1.0 & 391{,}077.9 & 52{,}311.0 & 2{,}371.3 \end{pmatrix}, \quad \boldsymbol{Y} = \begin{pmatrix} 422{,}549.9 \\ 443{,}795.5 \\ 446{,}716.9 \\ 445{,}262.1 \\ 355{,}000.4 \\ 312{,}267.6 \\ 295{,}870.1 \\ 366{,}054.0 \\ 352{,}333.9 \\ 441{,}516.5 \\ 462{,}373.5 \end{pmatrix}.$$

To apply the least squares method, a matrix of factor values X and a vector of indicator values Y were formed.

As a result of the calculations, the parameters of the multifactor model were obtained:

$$\vec{A} = \begin{pmatrix} 22{,}587.404 \\ 0.989 \\ 0.995 \\ 2.227 \end{pmatrix}.$$

Therefore, the model will have the form of $\hat{y} = 22,587 + 0.989x_2 + 0.995x_3 + 2.227x_6$.

The obtained model was checked for adequacy with a reliability of 0.95 (Table 2).

TABLE 2. Results of the adequacy study of the multifactor model for the impact of identified factors on waste generation in Ukraine

Indicator	Value	Critical value	Result
Coefficient of determination	0.997	–	There is a strong correlation between the identified factors and the generation of waste in Ukraine.
F-criterion	883.522	4.35	The model is adequate to the general population data.
Neuman's criterion	1.390	1.18 3.61	No autocorrelation of residuals is present.
Student's criterion (ta_1)	44.548	2.365	The parameter a_1 is statistically significant.
Student's criterion (ta_2)	7.270		The parameter a_2 is statistically significant.
Student's criterion (ta_3)	4.762		The parameter a_3 is statistically significant.

Source: own elaboration.

Considering that the constructed multifactor econometric model is adequate to the static data of the general population, it can be used for further analysis of the waste generation process in Ukraine.

Assessing the significance of the impact of changes in waste generation in the researched economic sectors on waste generation in Ukraine

To determine the influence of the identified factors on waste generation in Ukraine, partial elasticity coefficients play a crucial role. They indicate the percentage change in the indicator when one of the factors changes by one percent while keeping the values of other factors constant. Partial elasticity coefficients are presented in Table 3.

TABLE 3. Impact of changes in the identified factors on waste generation in Ukraine

Elasticity coefficients	Value	Result
Ex_2	0.829	When waste from mining and quarrying industries increases by 1%, waste generation in Ukraine will increase by 0.829%, assuming that waste from the processing industry and other economic activities remains unchanged.
Ex_3	0.112	When waste from the processing industry increases by 1%, waste generation in Ukraine will increase by 0.112%, assuming that waste from mining and quarrying industries and other economic activities remains unchanged.
Ex_6	0.011	When waste from other economic activities increases by 1%, waste generation in Ukraine will increase by 0.011%, assuming that waste from mining and quarrying industries, as well as the processing industry, remains unchanged

Source: own elaboration.

Therefore, the key factors influencing waste generation in Ukraine are waste from mining and quarrying industries and the processing industry. A 1% increase in these factors can result in a 0.829% and 0.112% increase, respectively, in waste generation in Ukraine. Polyanska et al. (2022) pointed out that given the low rate of waste utilization and the increasing industrial production index, developing waste management skills within industries is crucial.

Conclusions

To quantify the impact of various factors on waste generation in Ukraine, statistical data was used to build a multi-factor econometric linear model. Information on waste generation from 2010 to 2020 was collected and analyzed, considering various economic sectors, such as agriculture, forestry, and fisheries, mining and quarrying industries, the processing industry, energy supply, construction, and other economic activities. The multi-factor econometric linear model and calculated partial elasticity coefficients indicated that the key factors influencing waste generation in Ukraine during the pre-war period were waste from mining and the quarrying industries, as well as the processing industry. A 1% increase in these factors could result in a 0.829% and 0.112% increase in waste generation in Ukraine, respectively. Therefore, it is essential to organize waste reduction and utilization in these economic sectors.

The war in Ukraine has had a negative impact on all aspects of people's lives, the economy, and the environment. From February 24, 2022 to May 2023, nearly 1.2 million t of pollutants were released into the atmosphere due to combat activities. This included 0.43 million t of carbon oxide, 0.7 million t of dust, and 0.04 million t of non-methane volatile organic compounds. The levels of heavy metals and other harmful substances in the atmosphere have also increased significantly due to the fighting. Forest and grassland fires were the primary sources of these emissions. Additionally, hundreds of thousands of tons of waste were generated as a result of the conflict, including significant construction waste due to the destruction and ruin of numerous buildings and structures, some of which contain toxic substances, polluting the environment. Currently, there are three main methods of handling construction waste: burial, disposal, and recycling. In the current Ukrainian context, the first two methods are primarily used. According to secondary marketing information provided by the Ministry of Ecology, the approximate environmental damage in Ukraine from land pollution amounts to over 900 billion UAH. However, significantly reducing the negative impact on the environment of waste generated in conditions of war is impossible. Today, due to the danger of hostilities, it is even difficult to determine the quantity of such waste. A significant amount of waste is formed by metallic fragments from shells containing sulfur and copper. These substances, as a result of migration to groundwater, can enter food products and adversely affect the health of humans and animals. A crucial task for the post-war period is to develop an effective environmental monitoring system in Ukraine, including monitoring the quantity and analyzing the structure of waste, and developing measures for their disposal. This requires involvement not only of the legislative body, the Verkhovna Rada, and the Ministry of Environmental Protection and Natural Resources of Ukraine but also of the broader public.

Our research focuses on identifying the level of influence of key determinants on waste generation in Ukraine during the pre-war period and forming directions for their reduction, both at the state level and at the enterprise level.

To reduce waste generation, the following recommendations are proposed at the national level:

- Analyze and identify the types of waste generated in the mining and processing industries and study how they should be utilized or processed.
- Improve existing environmental standards and legislation, ensure their enforcement, and make waste disposal mandatory.
- Investigate the possibilities of reducing the impact of mining and processing industries on waste generation and based on this, develop measures for their disposal and processing.
- Develop conditions for and implement cooperation between the government and the public, as this can lead to the development and implementation of effective waste utilization and recycling strategies.
- Introduce environmental taxes and high environmental standards to incentivize companies to reduce emissions and waste.

To reduce waste generation, the following recommendations are proposed at the enterprise level:

- Enable on-site waste disposal, for example, by using technologies to reduce the amount of waste sent to landfills.
- Seek partners for joint waste disposal, as other companies or organizations may use this waste as raw materials in their production processes.
- Enable the secondary processing of waste to obtain new products or materials, as secondary processing can be economically advantageous and reduce waste.
- Implement innovative technologies that promote waste reduction and improved waste disposal.

– Involve staff and employees of enterprises as much as possible in addressing waste utilization and recycling, which can promote a more responsible approach in this area.

Promoting recycling and material reuse can help reduce waste and minimize the environmental impact of economic activities. Waste management will only develop if there is access to high-quality secondary raw materials on the domestic market. Currently, there is a deficit of secondary raw materials on Ukraine's internal market, accounting for about 30% of the industry's total needs due to poor quality sorting (Matveichuk, 2021). Ensuring waste disposal and recycling in mining and processing industries requires a comprehensive approach and collaboration from all parties. To achieve this goal, it is important to combine technological innovations, enhance environmental awareness among employees, and implement relevant legislative initiatives.

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Summary

Study of the influence of commercial activities on waste formation in Ukraine in the context of sustainable development. It has been determined that resolving waste reduction and disposal issues plays a crucial role in implementing the concept of sustainable development in individual countries. However, developing a waste management mechanism requires adequate information. The influence of various types of economic activities in Ukraine on waste formation is investigated in the pre-war period. It is assumed that these factors will remain relevant for Ukraine in the post-war period. To quantify the impact of various factors on waste generation in Ukraine, statistical data were used, and a multiple regression econometric model with partial elasticity coefficients was constructed. The calculations helped us establish that the determining factors influencing waste generation in Ukraine in the pre-war period were waste from the mining industry and quarry development and the processing industry. Ensuring waste reduction, disposal, and recycling in these sectors requires a comprehensive approach and cooperation from all parties. To achieve this goal, it is essential to combine technological innovations, environmental awareness among workers, and appropriate legislative initiatives. Recommended measures have been developed to reduce waste levels in various sectors of the economy at both the national and enterprise levels.