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Industrial Waste in Poland (2010–2020): A Sectoral View Using Input-Output Models and Structural Decomposition Analysis

Abstract: This study examines the evolution of industrial waste generation within the Polish economy over the decade of 2010–2020. Rapid economic growth, structural shifts among sectors, and growing environmental awareness have influenced waste production patterns. While numerous studies have addressed related topics in other contexts, a gap remains in assessing how technological changes and shifts in final demand jointly shape industrial waste generation in Poland.

The article aims to investigate how changes in technology and final demand affected the volume and composition of waste in the Polish economy, thereby providing insights for policymakers and stakeholders seeking to enhance sustainability and resource efficiency.

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The research uses Environmental Extended Input-Output (EEIO) models combined with Structural Decomposition Analysis (SDA). Using Input-Output tables for Poland from 2010 and 2020 along with waste generation data aggregated into 17 sectoral clusters, the study decomposes changes in waste output into waste intensity, technological shifts, and final demand components. Further disaggregation captures the effects of product-mix adjustments, changes in demand composition, and sector-specific technological innovations.

Results show that final demand is the dominant driver of increased waste generation. Technological changes produced mixed effects across sectors: the Electricity, Gas, Steam and Air Conditioning Supply sector recorded the largest reduction in waste generation, while the Waste Collection, Treatment and Disposal Activities; Materials Recovery sector experienced a significant increase. Additionally, Mining and Quarrying along with Construction played key roles, with the former undergoing notable technology-driven shifts, and the latter influenced by adjustments in both technology and final demand. These insights provide policymakers with a valuable reference for targeted waste reduction strategies while enhancing the understanding of how economic dynamics and technological progress shape environmental sustainability.

Keywords: Input-Output models, waste generation, Leontief models, structural decomposition analysis

JEL: C67, O44, Q53

1. Introduction

Economic growth is driven by the activities of various sectors within the economy which lead to an increase in the value of goods and services produced. Over time, economic development, driven by both external factors (such as scientific and technological advancements) and internal factors (such as economic transformation and demographic changes), results in changes in the dynamics of different sectors. This leads to qualitative and quantitative shifts within the economy. One of the consequences is the generation of industrial waste, which might take various forms depending on the sector. Industrial waste can be categorised into two types: non-hazardous and hazardous. Non-hazardous waste, such as cardboard or organic waste, does not endanger public health or the environment. In contrast, hazardous waste can have a negative impact, with examples including toxic materials (Millati et al., 2019). For instance, in mining and quarrying, typical waste includes solid rock, slag, and tailings. The energy sector generates waste such as fly ash, bottom ash, and used oils. The manufacturing sector's activities produce a range of waste, from reactive waste and acid to plastic and cardboard, and even heavy metals.

In 2022, the amount of industrial waste in Poland reached 115 million tons, with the primary sources being mining and quarrying, manufacturing, as well as the production and supply of electricity, gas, steam, and air conditioning. Using the most recent data from Eurostat, non-hazardous waste accounted for 98.4% of all industrial waste in 2020. This trend has not changed significantly over the years, as it remained at the level of 98.7% in 2010 (Eurostat, 2024a). In addition to domestically generated waste by sectors, there is waste shipment, including both imports and exports. In the case of imports, 332 thousand tons of waste were brought into Poland in 2022, of which 98.5% came from the European Union, and hazardous waste accounted for 40% of all imported waste. In the case of exports, 351 tons of waste were shipped out, with hazardous waste constituting 52% of the total (Statistics Poland, 2023). This vast amount of industrial waste generated highlights the critical importance of adopting sustainable waste management strategies that not only address domestic waste production but also consider cross-border waste flows and their environmental implications.

The management of waste has shifted from methods like landfills and incineration to more sustainable approaches in response to growing environmental concerns. Strategies such as the 3Rs (reduce, reuse, recycle) and industrial symbiosis are now seen as ways to address the issue (Huang et al., 2018). Companies are focusing on reuse, establishing partnerships with other industries and minimising waste generation. Cleaner production technologies that target the root cause of waste production are emerging as solutions for waste management (Mostaghimi, Behnamian, 2023). Despite this progress, significant challenges persist, largely due to uncertainties in market demand, regulatory licensing complexities, and logistical expenses associated with implementing new waste management practices. These barriers highlight the need for ongoing innovation and collaboration across sectors to fully realise the potential of sustainable waste management strategies (El-Haggar, 2007). This ongoing transition has been driven by increasing awareness of the long-term environmental impacts associated with conventional waste disposal methods, such as groundwater contamination (Santucci, Carol, Tanjal, 2018) and air pollution (Liu et al., 2024).

Building on these insights, this paper aims to answer the following questions using EEIO models regarding changes in the Polish economy between 2010 and 2020:

- How did the amount of waste generated by individual sectors change?
- How were the above changes associated with changes in technology (as reflected in changes in the Leontief inverse) and with changes in final demand?
- Using the possibility of further disaggregation of technology changes, what part is attributable to changes in technology within each sector and what part is associated with changes in the product mix within each sector?
- By further breaking down the components of final demand, what part reflects changes in the overall level of final demand and what part captures changes in the composition of final demand?

The article is structured as follows: the next section reviews the existing literature and situates this study within the broader research context. Following this, the methodology and data sources are described, detailing the construction of Environmental Extended Input-Output

(EEIO) models and the application of Structural Decomposition Analysis (SDA). The subsequent section presents the empirical findings, focusing on sectoral differences, technological changes, and shifts in final demand. Finally, the concluding section summarises key insights, addresses policy implications, and suggests directions for future research.

2. Literature Review

The literature on industrial waste in the context of the Polish economy addresses broad issues, including hazardous waste, waste management, process improvements, and threats associated with industrial waste. In an article examining the situation of hazardous waste in the United States and Poland, the authors highlight the scope of chemical exposure and identify priority chemicals. Additionally, the study focuses on exposure to metals and their health hazards (Pohl et al., 2008).

Drivers of waste generation may include various factors, depending on the sector and product type. Therefore, only selected aspects of waste in the respective sectors will be presented. In agriculture, forestry and fishing, waste generation is driven by overproduction and post-harvest losses. Farmers often produce a surplus and lack adequate storage, leading to discarded crops and residues (World Wide Fund for Nature, 2021). Mining and quarrying waste comes from moving huge volumes of rock for little yield, low grade ores and high demand result in vast tailings and spoil piles (Nkuna et al., 2022). Manufacturing, utilities and construction generate waste primarily through process by products, inefficiencies, and material end of life. Manufacturing produces process residues (e.g., paper sludge, metal slag, and chemical solvent waste) and scrap (fabric off cuts, plastic trimmings, and rejected units) because conversions are inherently imperfect (Bajpai, 2015; World Steel Association, 2021). High tech and chemical processes often sacrifice yield for quality, making waste an inevitable by-product. Construction and demolition generate mainly structural waste – about 90% of waste comes from tearing down old structures, while up to 30% of new building materials can be wasted on-site (U.S. Environmental Protection Agency, 2020). Utility sectors (energy, water) generate waste from service provision: power plants create coal ash and nuclear waste, and water treatment plants produce sludge when removing contaminants (Domini et al., 2022; Fernández-Arias, Vergara, Antón-Sancho, 2023; Zhang et al., 2023). The key waste generation drivers here are technical limitations (incomplete conversion, required pollution control) and the sheer scale of operations. Services largely contribute to post consumer and operational waste. Though they do not extract or fabricate at the same scale, they handle products and people, leading to waste in the form of unsold goods, packaging, and food. For example, retail and wholesale services often discard unsold inventory and generate heaps of packaging waste from distribution. Food services drive significant food waste, as restaurants and hotels throw away large portions of prepared food due to over preparation and customer plate waste (Lins et al., 2021). Offices and institutions produce paper waste and e-waste from electronics upgrades. Essentially, the service sector's waste is consumer driven: it reflects end use patterns. Behavioural factors such as convenience (single use disposables), customer expectations (always fresh goods), and poor inventory management (expired or unsold items) dominate (Filimonau, De Coteau, 2020; Riesenegger, Hübner, 2022).

Regarding waste management, increasing urbanisation, higher consumption, changing patterns of social behaviour, and waste composition, combined with inefficient management systems, will impact the environment. The steps that must be taken to improve the entire process include alternative methods of waste disposal, increasing funding for waste management projects, encouraging local authorities to apply sustainable waste management principles, and promoting the principles of rational waste management in society (Grodzińska-Jurczak, 2001). Some authors focus on specific sectors. For instance, in the following article, the issue of mining waste, which constitutes the largest group in the waste balance in Poland, is addressed. It is highlighted that the problem concerns not only the local situation in Poland but the entire industry, making the application of Circular Economy principles, known as the 3R (Reduce, Reuse, Recycle), crucial. Furthermore, a case study is presented, demonstrating strategies for the Sudety Mountains area for dumps under economic and technical conditions (Pactwa, Woźniak, Dudek, 2020). In the spirit of pursuing the Sustainable Development Goals, the next work provides a case study where a simplified SWOT analysis based on interviews with employees is used to evaluate the product groups and efficiency in the use of raw materials and waste management for the steel manufacturing sector in Poland (Depczyński, 2022). The application of EEIO models in combination with the problem of waste generation has been studied in areas related to analyses of waste management (Nakamura, Kondo, 2002; Towa, Zeller, Achten, 2020), general analyses of waste generation (Ruiz-Peñalver, Rodríguez, Camacho, 2019; Meyer, Li, Ingwersen, 2020; Lee, Kim, Park, 2022), or studies on the potentials of wastes (Song et al., 2016). However, no study has been applied to the Polish economy, except for the work concerning the drivers of waste generation (Gacek, 2024).

To the best of the author's knowledge, EEIO models that integrate waste generation data from individual sectors of the Polish economy, particularly for a detailed examination of the structure of final demand and sector-specific technological changes, have not yet been applied in any study. The research presented in this article fills a significant empirical gap and allows for drawing detailed conclusions about changes in the Polish economy between 2010 and 2020 in the context of the analysed environmental variable. The results will enhance the understanding of economic dynamics and the changes that have occurred within sectors, thereby laying the groundwork for future research in this area.

3. Methodology

3.1. Model Construction

To derive the EEIO model, it is necessary to introduce the notations that will be used in the subsequent sections of the article and are widely use in the IO literature. For clarity, the notations are as follows: bold capital letters will indicate matrices, bold lowercase letters will signify vectors, and italicised capital and lowercase letters will be used for scalars. Transposition will be represented by a capital T, and diagonal matrices will be marked with a circumflex. Let us assume that the economy consists of *n* sectors, where *t* represents the time period under analysis, *i* refers to the respective sector, and $\mathrm{x}_\mathrm{t} = \left[x_i^t, i = 1, \ldots, n \right]$ is the vector of sector outputs, $\mathrm{f}_t = \left[f_i^t, i = 1, \ldots, n \right]$ denotes the vector of sectoral final demand, and $\mathrm{A}_t = \left[a_{ij}^t, i, j = 1, \ldots, n \right]$ is the input matrix. Assuming that the matrix $\left(\mathrm{I} - \mathrm{A}_\mathrm{t}\right)^{-1}$ exists, the output from each of the sectors that is necessary to meet a given final demand can be written as:

$$\mathrm{x}_\mathrm{t} = \left(\mathrm{I} - \mathrm{A}_\mathrm{t}\right)^{-1} \mathrm{f}_\mathrm{t} = \mathrm{L}_\mathrm{t}\mathrm{f}_\mathrm{t}, \qquad (1)$$

where the matrix $\mathrm{L}_\mathrm{t} = \left(\mathrm{I} - \mathrm{A}_\mathrm{t}\right)^{-1}$ is called the Leontief inverse in the demand-driven approach model. The classical Leontief model, as expressed in equation (1), has undergone a series of modifications that have allowed for further expansion of the model. This latter extension is possible due to the introduction of a vector that can represent any policy variable (e.g., the number of jobs created, the amount of green gas house emissions, etc.). However, for the purposes of this article, let us assume that the vector $\mathrm{e}_\mathrm{t} = \left[e_i^t, i = 1, \ldots, n \right]$ indicates the amount of waste generated by the respective sectors in the chosen unit. After introducing the waste input coefficient vector as $\pi_\mathrm{t} = \mathrm{e}_\mathrm{t}\hat{\mathrm{x}}^{-1} = \left[\pi_i^t, i = 1, \ldots, n \right]$, representing the amount of waste generated per unit of output in the sector, the amount of waste generated by the sectors can be expressed as:

$$\mathrm{e}_\mathrm{t} = \hat{\pi}_\mathrm{t}\mathrm{L}_\mathrm{t}\mathrm{f}_\mathrm{t}. \qquad (2)$$

The derived model (2), due to the application of the policy variable as the amount of waste generated, will be referred to as the Environmental Extended Input-Output model (EEIO), which is widely used (Yang et al., 2017; Read et al., 2020; Lach, 2022).

3.2. Structural Decomposition Analysis

Taking into consideration two time periods, *t* and *t* + 1, changes in waste generation $(\Delta \mathrm{e})$ in each sector can be calculated as:

$$\Delta \mathrm{e} = \mathrm{e}_{\mathrm{t}+1} - \mathrm{e}_\mathrm{t} = \hat{\pi}_{\mathrm{t}+1}\mathrm{L}_{\mathrm{t}+1}\mathrm{f}_{\mathrm{t}+1} - \hat{\pi}_\mathrm{t}\mathrm{L}_\mathrm{t}\mathrm{f}_\mathrm{t}. \qquad (3)$$

From the above-presented equation, it follows that the factors contributing to changes in waste generation patterns include variations in the vectors representing the waste generation coefficient π, changes in technology, which are captured in the matrix **L**, and shifts in final demand **f**. Therefore, the next step is to decompose equation (3) using the SDA method as outlined in Chapter 8.2 of Miller and Blair (2022) and taking the average of two polar decompositions (Dietzenbacher, Los, 1998), resulting in:

$$\Delta e = \underbrace{\frac{1}{2}(\Delta\hat{\pi}_t)(L_t f_t + L_{t+1} f_{t+1})}_{\text{Waste coefficient change}} + \underbrace{\frac{1}{2}(\hat{\pi}_t(\Delta L_t) f_{t+1} + \hat{\pi}_{t+1}(\Delta L_t) f_t)}_{\text{Technology change}} + \underbrace{\frac{1}{2}(\hat{\pi}_t L_t + \hat{\pi}_{t+1} L_{t+1})(\Delta f_t)}_{\text{Final demand change}}, \tag{4}$$

where $\hat{\pi}_{t+1} = \hat{\pi}_t + \Delta\hat{\pi}_t$, $L_{t+1} = L_{t+1} + \Delta L_t$ and $f_{t+1} = f_t + \Delta f_t$. The decomposed change in waste generation provides a general overview of the contributions made by the individual components in the analysed sectors. To gain a deeper understanding of the ongoing changes, it is essential to further break down the last two components: technology change and final demand change.

In the Input Output table, final demand is composed of several categories such as household consumption, government spending and export. Depending on the available data, the breakdown may include additional categories. Changes in final demand (Δf) can be further divided into the total amount of spending for final demands (level), allocation among categories (distribution) and the product-mix within each final demand category. Let us assume that there are p categories of final demand and define f_t as the total amount (level) of final-demand spending across all sectors, with y_p^t representing the expenditure for the category p in the year *t*. Since f_t is a scalar, the distribution of f_t across the p categories can be calculated as:

$$d_t = \left(\frac{1}{f_t}\right) y_t, \tag{5}$$

where $y_t = [y_1^t, \ldots, y_p^t]$. To capture the share of total expenditures by the final demand category p that was allocated to the output of sector *i*, referred to as the product mix, let us define the $n \times p$ bridge matrix B_t in the form:

$$B_t = F_t(\hat{y}_t)^{-1}, \tag{6}$$

where $F_t = [f_1^t, \ldots, f_p^t]$. From the above, it directly follows that $f_t = f_t B_t d_t = B_t y_t$. Using the reasoning from SDA and taking the average of two polar decompositions, the following is obtained:

$$\Delta f_t = \underbrace{\frac{1}{2}(\Delta f)(B_t d_t + B_{t+1} d_{t+1})}_{\text{Level effect}} + \underbrace{\frac{1}{2}(f_t(\Delta B_t) d_{t+1} + f_{t+1}(\Delta B_t) d_t)}_{\text{Mix effect}} + \underbrace{\frac{1}{2}(f_t B_t + f_{t+1} d_{t+1})(\Delta d)}_{\text{Distribution effect}} \tag{7}$$

To disaggregate technology change (ΔL) into shifts between individual sectors, one may start with the decomposition of the Leontief inverse $L = (I - A)^{-1}$, and then move to the input matrix A, since both matrices are interdependent. Building further on Miller and Blair (2022), using basic matrix calculations, pre- and post-multiplication of matrices, rearranging and subtracting, one can derive the result as follows:

$$\Delta L_t = L_{t+1} - L_t = L_{t+1}A_{t+1}L_t - L_{t+1}A_tL_t = L_{t+1}(\Delta A)L_t. \tag{8}$$

One approach to capturing the effect of input changes in each sector is to examine the changes on a column-by-column basic. Changes in the *j*-th sector between two perdios can be expressed as:

$$\Delta A^{(j)} = \begin{bmatrix} 0 & \dots & \Delta a_{1j} & \cdots & 0 \\ \vdots & 0 & \vdots & 0 & \vdots \\ 0 & \cdots & \Delta a_{nj} & \cdots & 0 \end{bmatrix}. \tag{9}$$

Changes in the input matrix (ΔA) can be shown as the sum of matrices representing changes in individual sectors, namely:

$$\Delta A = \Delta A^{(1)} + \dots + \Delta A^{(j)} + \dots + \Delta A^{(n)} = \sum_{j=1}^{n} \Delta A^{(j)}. \tag{10}$$

Using equations (9) and (10), one can show changes in technology as:

$$\begin{aligned} \Delta L_t &= L_{t+1}(\Delta A)L_t = L_{t+1}\left(\Delta A^{(1)} + \dots + \Delta A^{(j)} + \dots + \Delta A^{(n)}\right)L_t = \\ &= \underbrace{L_{t+1}\left(\Delta A^{(1)}\right)L_t}_{\text{Technology change in sector 1}} + \dots + \underbrace{L_{t+1}\left(\Delta A^{(n)}\right)L_t}_{\text{Technology change in sector } n}. \end{aligned} \tag{11}$$

The final step is to substitute equations (7) and (11) into (4), resulting in:

$$\begin{aligned} \Delta e &= \frac{1}{2}\underbrace{\left(\Delta\hat{\pi}_t\right)\left(L_t f_t + L_{t+1} f_{t+1}\right)}_{\text{Waste coefficient change}} + \\ &+ \frac{1}{2}\underbrace{\left(\hat{\pi}_t\left(\Delta L_{t+1}\left(\Delta A^{(1)}\right)L_t\right)f_{t+1} + \hat{\pi}_{t+1}\left(L_{t+1}\left(\Delta A^{(1)}\right)L_t\right)f_t\right)}_{\text{Technology change in sector 1}} + \dots + \\ &+ \frac{1}{2}\underbrace{\left(\hat{\pi}_t\left(\Delta L_{t+1}\left(\Delta A^{(n)}\right)L_t\right)f_{t+1} + \hat{\pi}_{t+1}\left(L_{t+1}\left(\Delta A^{(n)}\right)L_t\right)f_t\right)}_{\text{Technology change in sector } n} + \\ &+ \frac{1}{4}\underbrace{\left(\hat{\pi}_t L_t + \hat{\pi}_{t+1} L_{t+1}\right)\left(\Delta f\right)\left(B_t d_t + B_{t+1} d_{t+1}\right)}_{\text{Final demand Level effect}} + \\ &+ \frac{1}{4}\underbrace{\left(\hat{\pi}_t L_t + \hat{\pi}_{t+1} L_{t+1}\right)\left(f_t\left(\Delta B_t\right)d_{t+1} + f_{t+1}\left(\Delta B_t\right)d_t\right)}_{\text{Final demand Mix effect}} + \\ &+ \frac{1}{4}\underbrace{\left(\hat{\pi}_t L_t + \hat{\pi}_{t+1} L_{t+1}\right)\left(f_t B_t + f_{t+1} d_{t+1}\right)\left(\Delta d\right)}_{\text{Final demand Distribution effect}}. \end{aligned} \tag{12}$$

4. Data Sets and Sectoral Classification

This paper uses Input Output tables from the years 2010 and 2020, sourced from the Central Statistics Office, covering 77 sectors of the Polish economy (Statistics Poland, 2015; 2024). The data cover goods and services from both local production and imports, originally shown in current prices and expressed in the local currency – millions of PLN. To compare both analysed periods, the cumulative inflation over the period was calculated, amounting to 17.96%, and the 2010 Input-Output tables were adjusted to reflect 2020 prices. Information on the amount of waste generated for the analysed periods is available for 17 sector clusters. The data were obtained from the Eurostat database and are expressed in thousands of tons (Eurostat, 2024a). Given that the data on waste generation are available for fewer sectors than those represented in the Input-Output tables, it was necessary to aggregate the data into 17 groups of sectors using an aggregation matrix, as described in Chapter 4.9 of Miller and Blair (2022). In Table 1, the names of the available sector categories are listed, along with their statistical classification of economic activities (NACE Rev. 2) and the labels that will be used throughout the rest of the article. Following the aggregation of sectors, the analysis of final demand is structured around five distinct categories presented in Table 2.

5. Results

Figures 1, 2, and 3 present the results of equation (12), illustrating respectively: sector-specific decomposition of waste generation, detailed changes in final demand, and technological changes. Using the sector labels from Table 1, the difference in the amount of waste generated between 2010 and 2020 (Δ), as well as the corresponding percentage change (%), is shown for each sector and the entire economy. Due to the rounding of numbers and percentages, there may be discrepancies where the sum of the rows does not exactly match the value shown in the ‘Waste Generation Change’ column in Figure 1, or the ‘Total’ columns in Figures 2 and 3. Given that the presented research results contain a great deal of detailed information, selected sectors with the largest and smallest shares in the respective category will be discussed. Since the sector names are long, the abbreviations provided in Table 1 will be used for clarity and conciseness.

Between 2010 and 2020, significant changes in the amount of waste generated were observed, ranging from –9078.3 to 9110.4 thousand tons. Notably, S13 achieved the largest reduction in waste generation, a decrease of 9,078.3 thousand tons. Similarly, S3 and S5 reduced their waste by 3,058.9 units and 1,399.6 thousand tons, respectively. In contrast, S15 experienced the most significant rise in waste generation, an increase of 9,110.4 thousand tons. S17 saw a considerable increase of 6,678.4 thousand tons, while in S9 waste generation increased by 1,924.9 thousand tons.

Across most sectors (13 out of 17), the waste coefficient change is negative, reflecting how waste efficiency influenced total waste generation during the analysed period. The largest decrease was observed in S13, amounting to –8386.1 thousand tons. In contrast, the S2 sector, despite showing a relatively small change in total waste generation compared to other sectors over the analysed period, recorded a waste coefficient change of 15,679.8 thousand tons – the highest among all sectors studied. To reduce the impact of sector size (both waste and output generated) on changes in the considered policy variable, from the perspective of percentage changes – calculated as the ratio of waste coefficient change to waste generation change – S8 achieved the largest percentage change of –2735.6, while S11 recorded a change of 3644.9%. The amount of waste generated is also affected by two key factors: changes in technology and in final demand.

Starting with technological changes, the largest shifts occurred in S2 and S13, with reductions of –25,803.6 and –4512.2 thousand tons, respectively. For S2, these changes could have been driven by factors such as the implementation of climate policy goals, including the aim of achieving climate neutrality by 2050, which has led to the modernisation of mining from an industrial-era model to a knowledge-based economy (Marszowski, Iwaszenko, 2021). Additionally, the adoption of innovations in the mining industry, including management as well as product and process innovations, was implemented as part of the European Union's 'Europe 2020' strategy (Midor, Michalski, 2015; Brodny, Tutak, 2022). In turn, for S13, the reasons for these changes may have included improvements in grid energy storage, a shift from carbon-based manufacturing technologies, and breakthroughs in hydrocarbon exploration and production technologies (Gawlik, Mokrzycki, 2019). Furthermore, an increase in the share of energy from renewable sources in gross final energy consumption, which rose from 9.28% in 2010 to 16.13% in 2020, could have contributed to these changes (Statistics Poland, 2021a). The largest increases of waste generated due to technological changes were observed in S15 and S16, resulting in 3354.9 and 2466.6 thousand tons, respectively. The growth in the first group of sectors was driven, among other factors, by investments in new waste processing facilities, including thermal waste treatment plants in cities such as Konin, Kraków, Białystok, Poznań, Szczecin, Rzeszów, and Olsztyn, which opened progressively between 2015 and 2020 (Olejnik, Krupa, 2023). The by-products of the incineration processes are gases, fly ash, and bottom ash, while pyrolysis produces pyrolysis gas, oil, and coke (Kęps, Jaszczura, 2020). Changes in S16 may have been driven by energy-efficient retrofitting initiatives promoted by the EU Energy Policy, which involved, among others, upgrading windows and insulation. Such retrofits can contribute to waste due to the removal of older materials and the challenges associated with the recycling or disposing of outdated components, with the next step involving measures such as implementing low-emission technologies in the building sector (Marszał et al., 2020).

The presented results summarised the contribution of sectors to the amount of waste generated from both technological and final demand perspectives. A detailed analysis of technological changes across 17 sectors is shown in Figure 3, which illustrates the interconnections among all sectors in the economy, resulting in a total of 17 × 17 = 289 values. The distribution of these values is as follows: 12 sectors recorded no changes or values that are negligible, 103 values are positive, indicating that technological changes were responsible for an increase in waste generation, while 174 values are negative, meaning that technological changes positively impacted the analysed variable by reducing the amount of waste generated during the analysed period. Figure 3 presents an extensive amount of information; therefore, we will focus on selected sections. The largest differences in values between the smallest and the highest figures occur in rows in S2, S13 and S15, amounting to 10,717, 2,961, and 2,531 thousand tons, respectively. For each of the mentioned sectors, the minimum value, i.e., the smallest (negative) value in the row, representing the reduction in the amount of waste generated, was associated with S17. Considering that this is an aggregated category consisting of 43 sectors, statistics will be presented for the next three sectors with the largest differences between the minimum and maximum values in the rows, excluding the impact of the Services. Taking the above into account, one can obtain the following information from the data:

– In S8, the minimum value is –150.3 for the S11, while the maximum value is 117.9 for the S16.
– In S10, the minimum value is –271.9 for the sector itself, and the maximum value is 330.8 for S16.
– In S16, the minimum value is –51.9 for S11, while the maximum value is 1433.1 for the sector itself.

Additionally, the diagonal elements illustrate the impact of technological changes within sectors on themselves. Ten out of seventeen sectors recorded the most significant technological changes in the analysed variable as an internal effect. In summary, S5, S10, S12, and S13 experienced the largest reduction in waste generation as a self-impact, while S2, S4, S11, S13, S16, and S17 recorded the largest increase in waste generation, considering the distribution across all sectors of the economy.

Analysing the data on the contribution of final demand to the amount of waste generated, all sectors exhibit the same pattern: in every sector, the impact of final demand was positive, meaning it contributed to an increase in the amount of waste generated. Among all sectors, S2 and S15 stood out the most in terms of waste generation, producing 10,915.4 thousand tons and 8,261.3 thousand tons, respectively. Several factors may have contributed to the significant increase in waste generation within the S2 sector. Firstly, a notable rise in the production of copper and silver, as reported by KGHM Polska Miedź S.A. in their 2011 and 2021 reports, led to an escalation in mining activities, and consequently a higher volume of waste materials being extracted and processed. Secondly, the analysed period saw increased demand for construction and infrastructure raw materials (Statistics Poland, 2021b), which intensified mining operations to meet the growing needs of the construction industry. Moreover, changes in geological and mining legislation introduced new definitions and classifications of waste, resulting in improved reporting and registration practices that led to more accurate and comprehensive documentation of waste generation. The enhanced regulatory framework increased transparency and highlighted the actual scale of waste produced in the sector. Collectively, the surge in production, heightened demand for raw materials, and stricter reporting standards contributed to the significant rise in waste generation within the S2 sector.

The increase in the amount of waste generated in S15 could have been caused by several factors. These include the growth in industrial sectors between 2010 and 2020, leading to more waste requiring collection and treatment. This growth is reflected in several key indicators, including a 32% increase in GDP during the analysed period and a 5.6 percentage point drop in the unemployment rate. Additionally, the adoption of the Circular Economy (CE) strategy by the EU in 2014 prompted Poland in 2016 to initiate the development of the CE Roadmap. The main goal of this roadmap was the preparation of an action plan for increasing resource efficiency and waste reduction in Poland. This plan included, among others, sustainable industrial production and sustainable consumption, which involved measures such as recycling (Bisello et al., 2021). Consequently, the rate of materials and organic recycling increased (Ciuła et al., 2023), and it is expected that the percentage share of reuse and recycling will continue to grow over time, aiming for 55% by 2025, 60% by 2030, and 65% by 2035 (European Environment Agency, 2022). Additionally, there was a significant rise in waste electrical and electronic equipment (WEEE) between 2010 and 2020. The amount of WEEE increased from 172 thousand tons in 2013 to 424 thousand tons in 2020, driven by the heightened consumption of technological goods (Eurostat, 2024b). This surge underscores the growing demand for electronic devices and highlights the need for effective waste management strategies in this sector.

A detailed analysis of final demand, as presented in Figure 2, allows for a further breakdown into three categories: level, mix, and distribution. As previously mentioned, final demand contributed to an increase in the amount of waste generated across all sectors. This effect is also reflected in the values shown in the first column of Figure 2. level, which corresponds to the total amount of all expenditures for final demand. Among all sectors, S2 significantly stands out. It shows a value of 23,781.3 thousand tons, accounting for 41% of the level changes across all sectors. This indicates a substantial contribution of this sector to the overall increase in waste generation, highlighting its impact on the economy. Another component of final demand is the product mix within each final demand category as proportions of total final demand expenditure. In this context, the sector with the most significant impact is sector S15, recording a value of 2,082.7 thousand tons. Conversely, S2 shows the lowest value of –12,595.6 thousand tons, suggesting a major decrease in its contribution in this category. The final category is the distribution of total expenditures across final demand categories. Here, the sector with the highest value is S10, with a value of 670.9 thousand tons. On the other hand, S16 has the lowest value of –2,162.3 thousand tons. This contrast underscores the varying impacts different sectors have on expenditure distribution within the economy. This comprehensive breakdown enhances our understanding of how individual sectors contribute to changes in waste generation and economic dynamics, emphasising the significant roles specific industries play in the overall economic landscape.

In order to present the aforementioned analysis as actionable insights, policy recommendations are proposed for selected sectors. These strategies aim to support further waste reduction by addressing the key drivers identified in the SDA conducted. It should be noted that some recommendations may have an impact on more than one sector. In the case of S2, the recommendation is to intensify modernisation efforts and reduce the impact of final demand through more efficient resource use and the development of secondary raw material extraction (urban mining). S3 should strengthen policies aimed at reducing production losses, support the processing of surpluses, and implement digital forecasting and logistics systems. For S5, the recommendation is to promote the use of wood waste for bioenergy and composite materials, as well as to implement eco-design principles. In S8, binding targets for process efficiency should be established, along with support for clean chemical synthesis technologies and industrial symbiosis. S9 would benefit from promoting the use of recycled aggregates and developing standards that allow for the inclusion of secondary materials. In S10, it is important to support circular economy practices in metal processing and introduce digital material passports. S11 should be subject to extended producer responsibility regulations that encourage the design of repairable and recyclable products (right-to-repair, EPR). S13 is encouraged to continue and expand the energy transition towards renewable sources and energy storage, while also modernising energy infrastructure. Regarding S15, introducing quality standards for incineration plants, supporting technologies that minimise secondary waste, and developing high-quality recycling infrastructure are key. For S16, mandatory pre-demolition audits, incentives for selective demolition, and minimum recycled content requirements in public construction projects should be implemented. Finally, S17 would benefit from regulations aimed at reducing waste in retail and food services, as well as from promoting zero-waste strategies in the public sector.

6. Conclusions

In this paper, the relationship between Input-Output models and waste generation was established to assess the drivers of waste generation in the Polish economy between 2010 and 2020. This study represents the application of Structural Decomposition Analysis (SDA) for Polish waste management, effectively capturing interdependencies between sectors in the context of the analysed environmental variable. The SDA conducted allowed to decompose the overall change in waste generation between two periods not only into general drivers such as waste intensity, technological change, and final demand change but also into detailed components within these general drivers. The research shows that, even in their static form, EEIO models can be valuable tools, providing detailed environmental analyses that can be further used by researchers and policymakers. The findings underscore the critical role of final demand, which emerged as the main driver in waste generation across sectors. This highlights the necessity for actions aimed at increasing awareness among society and producers, representing one of the biggest challenges for environmental activists and government agencies.

Taking into account the high granularity of the data and the comprehensive scope of the analysis, the summary of answers to the research questions is narrowed to the sectors with the greatest and smallest changes in waste. *The Electricity, Gas, Steam and Air Conditioning Supply* sector (S13) achieved the largest reduction in waste generation, a decrease of 9,078.3 thousand tons, whereas the *Waste Collection, Treatment and Disposal Activities; Materials Recover*y sector (S15) experienced the most significant rise, an increase of 9,110.4 thousand tons. When analysing changes in technology and final demand, it should be noted that the percentages do not sum to 100 percent because there is a third component: the change in waste coefficients. In sector S13, the technology contribution led to a 49.7 percent reduction in waste generation, while final demand changes accounted for a 42.1 percent increase. Conversely, in sector S15, both the technology change and the final demand change contributions resulted in increases of 36.8 percent and 90.7 percent, respectively. Examining the decomposition of the technology change into a 17 × 17 matrix of sector-by-sector contributions, S13's largest decrease originated from the *Services* sector, and its largest increase was attributable to the sector itself. In S15, the most substantial upward contribution stemmed from the *Water Collection, Treatment and Supply; Sewerage; Remediation Activities and Other Waste Management Services* sector, while the greatest downward contribution came from the *Services* sector. A similar decomposition was performed for final demand: among the three components: Level, Mix, and Distribution, in S13, Level made the largest contribution to the reduction in waste generation, whereas Mix drove the increase. In S15, Level was the primary contributor to the rise in waste generation, followed by Mix.

Conversely, when assessing absolute waste volumes rather than relative changes, the sectors with the highest impact during the analysed period were *Mining and Quarrying, Waste Collection, Treatment and Disposal Activities; Materials Recovery*, and *Construction*. These sectors reflect the main pillars and evolving trends of the Polish economy, such as the longstanding importance of the mining sector, the responsive and mitigating role of the waste management sector during a period of intensive economic development, and the demand-driven growth in housing development. Understanding these sectoral impacts provides valuable insights for developing targeted strategies to manage and reduce waste generation effectively. A careful examination of the results offers useful knowledge and information for policymakers, enabling them to create strategies to mitigate further environmental damage.

Additionally, the presented results include the most recent environmental analyses utilising published Input-Output tables, thereby filling an empirical gap for the Polish economy. This contributes significantly to the body of knowledge in environmental economics and offers a foundation for future research. Despite the niche nature of this research, the application of SDA in the context of waste generation allows for comparisons with results from other countries, such as the study conducted for Australia between 2007 and 2014 (He et al., 2019). Such comparisons can help assess the effectiveness of waste management strategies and identify best practices on an international scale. However, limitations of the study include data availability. Specifically, Input-Output data for the Polish economy are published every five years, and data regarding the amount of waste generated by individual sectors are published every two years with a high level of aggregation. Access to more detailed waste data would allow for even more precise analyses and the identification of individual units within sectors that are the largest drivers concerning the analysed environmental variable.

In conclusion, this study lays the groundwork for future research and provides a valuable resource for other researchers and specialists working in the specific analysed sectors. By highlighting the key drivers of waste generation and the sectors with the most significant impact, the findings contribute to a better understanding of environmental challenges in Poland. This understanding is crucial for developing effective policies and strategies aimed at promoting sustainability and mitigating environmental damage. Future research should focus on obtaining more granular data to enhance the precision of analyses and extend the applicability of SDA models in environmental studies.

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Annex

Table 1. Classification of sectoral categories

Sector label	Category name	NACE Rev. 2
S1	Agriculture, forestry and fishing	A
S2	Mining and quarrying	B
S3	Manufacture of food products; beverages and tobacco products	C10-C12
S4	Manufacture of textiles, wearing apparel, leather and related products	C13-C15
S5	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	C16
S6	Manufacture of paper and paper products; printing and reproduction of recorded media	C17-C18
S7	Manufacture of coke and refined petroleum products	C19
S8	Manufacture of chemical, pharmaceutical, rubber and plastic products	C20-C22
S9	Manufacture of other non-metallic mineral products	C23
S10	Manufacture of basic metals and fabricated metal products, except machinery and equipment	C24-C25

Sector label	Category name	NACE Rev. 2
S11	Manufacture of computer, electronic and optical products, electrical equipment, motor vehicles and other transport equipment	C26-C30
S12	Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	C31-C33
S13	Electricity, gas, steam and air conditioning supply	D
S14	Water collection, treatment and supply; sewerage; remediation activities and other waste management services	E36-E37, E39
S15	Waste collection, treatment and disposal activities; materials recovery	E-38
S16	Construction	F
S17	Services	G-U

Source: own elaboration based on Statistics Poland (2015; 2024)

Table 2. Classification of final demand categories

Category label	Category name
C1	Final demand expenditure by households and non-profit institutions serving households
C2	Final demand expenditure by general government
C3	Gross capital formation (gross fixed capital formation, changes in inventories and changes in valuables)
C4	Exports Free on Board (fob) within the European Union
C5	Exports Free on Board (fob) outside the European Union

Source: own elaboration based on Statistics Poland (2015; 2024)

Table 3. Sector-specific decomposition results of waste generation between 2010 and 2020

	Waste Generation Change		Waste Coefficient Change	Technology Change Contribution	Final Demand Change Contribution
S1	– 322,4	Δ	– 413,1	– 30,3	121,0
		%	128,2	9,4	– 37,5
S2	791,6	Δ	15 679,8	– 25 803,6	10 915,4
		%	1 980,9	– 3 259,9	1 379
S3	– 3058,9	Δ	– 5 146,1	– 151,2	2 238,3
		%	168,2	4,9	– 73,2
S4	– 34,5	Δ	– 88,2	– 5,1	58,9
		%	255,9	14,8	– 170,9
S5	– 1399,6	Δ	– 2 073,4	60,4	613,4
		%	148,1	– 4,3	– 43,8

	Waste Generation Change		Waste Coefficient Change	Technology Change Contribution	Final Demand Change Contribution
S6	– 70,0	Δ	– 612,4	– 71,9	614,2
		%	874,7	102,7	– 877,3
S7	42,5	Δ	58,9	– 32,0	15,6
		%	138,6	– 75,3	36,7
S8	87,2	Δ	– 2 385,1	– 306,5	2 778,7
		%	– 2 735,6	– 351,5	3 187,1
S9	1924,9	Δ	1 240	– 192,0	876,8
		%	64,4	– 10	45,6
S10	1018,4	Δ	– 2 547,6	– 364,1	3 930,0
		%	– 250,2	– 35,8	385,9
S11	– 22,1	Δ	– 806,0	– 93,7	877,6
		%	3 644,9	423,7	– 3 968,7
S12	221,8	Δ	– 323,3	3,4	541,7
		%	– 145,8	1,5	244,3
S13	– 9078,3	Δ	– 8 386,1	– 4 512,2	3 820,0
		%	92,4	49,7	– 42,1
S14	109,3	Δ	– 564,2	– 173,5	847,0
		%	– 516,0	– 158,7	774,7
S15	9110,4	Δ	– 2 505,8	3 354,9	8 261,3
		%	– 27,5	36,8	90,7
S16	1233,0	Δ	– 5 117,6	2 466,6	3 884,0
		%	– 415,1	200	315
S17	6678,4	Δ	4 087,9	34,1	2 556,4
		%	61,2	0,5	38,3

Source: own elaboration based on Statistics Poland (2015; 2024) and Eurostat (2024a)

Table 4. Sector-specific decomposition results of waste generation between 2010 and 2020 with three-factor final demand decomposition detail

		Final Demand Change Contribution			
		Level	Mix	Distribution	Total
S1	Δ	175,4	– 41,8	– 12,6	121,0
	%	– 54,4	13	3,9	– 37,5
S2	Δ	23 781,3	– 12 595,6	– 270,3	10 915,4
	%	3 004,4	– 1 591,3	– 34,1	1 379
S3	Δ	1 861	434,7	– 57,5	2 238,3
	%	– 60,8	– 14,2	1,9	– 73,2
S4	Δ	39,2	17,1	2,5	58,9
	%	– 113,7	– 49,6	– 7,3	– 170,9

		Final Demand Change Contribution			
		Level	Mix	Distribution	Total
S5	Δ	571,3	– 33,3	75,4	613,4
	%	– 40,8	2,4	– 5,4	– 43,8
S6	Δ	548	– 11,6	77,8	614,2
	%	– 782,7	16,6	– 111,1	– 877,3
S7	Δ	30,7	– 14,8	– 0,4	15,6
	%	72,3	– 34,8	– 0,9	36,7
S8	Δ	2 277,6	185	316,1	2 778,7
	%	2 612,3	212,2	362,6	3 187,1
S9	Δ	799,4	90	– 12,5	876,8
	%	41,5	4,7	– 0,6	45,6
S10	Δ	3 613	– 353,8	670,9	3 930
	%	354,8	– 34,7	65,9	385,9
S11	Δ	709,9	40,8	126,8	877,6
	%	– 3 210,3	– 184,5	– 573,4	– 3 968,7
S12	Δ	347,2	175,5	19	541,7
	%	156,6	79,1	8,6	244,3
S13	Δ	6 211,9	– 1 724,2	– 667,7	3 820
	%	– 68,4	19	7,4	– 42,1
S14	Δ	809,8	115,9	– 78,6	847
	%	740,7	106	– 71,9	774,7
S15	Δ	5 840,9	2 082,7	337,7	8 261,3
	%	64,1	22,9	3,7	90,7
S16	Δ	8 064,1	– 2 017,8	– 2 162,3	3 884
	%	654	– 163,6	– 175,4	315
S17	Δ	2 676,5	36,9	– 157	2 556,4
	%	40,1	0,6	– 2,4	38,3

Source: own elaboration based on Statistics Poland (2015; 2024) and Eurostat (2024a)

Table 5. Sector-specific decomposition results of waste generation between 2010 and 2020 with technology decomposition detail

		Technology Change Contribution																	
		S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**	**S15**	**S16**	**S17**	**Total**
S1	Δ	−6,5	0,2	−11,4	−0,3	−7,5	−0,5	0,1	−2,6	−0,3	−0,3	−0,8	1,7	3,5	0,1	0	−0,3	−5,4	−30,3
	%	2	−0,1	3,5	0,1	2,3	0,2	0	0,8	0,1	0,1	0,2	−0,5	−1,1	0	0	0,1	1,7	9,4
S2	Δ	−1013,7	3193,6	−528,8	−115,2	−107,9	−137,4	−3810,9	−2167,4	−912,6	−3549,6	−790,6	−264,2	−4981,1	−28	−149,1	−2917,2	−7 523,5	−25 803,6
	%	−128,1	403,5	−66,8	−14,6	−13,6	−17,4	−481,4	−273,8	−115,3	−448,4	−99,9	−33,4	−629,3	−3,5	−18,8	−368,5	−950,5	−3 259,9
S3	Δ	77,2	0,7	−96	−5,2	−5,9	−1,1	2,4	−5,7	−0,3	−1,6	−4,6	−4,1	−0,4	−0,1	−0,3	−4,2	−102	−151,2
	%	−2,5	0	3,1	0,2	0,2	0	−0,1	0,2	0	0,1	0,2	0,1	0	0	0	0,1	3,3	4,9
S4	Δ	0	0	0	−2,7	0	0,2	0	−0,6	0	0	−0,8	−0,8	−0,1	0	0	0,1	−0,4	−5,1
	%	0	0	0	7,8	0	−0,6	0	1,7	0	0	2,3	2,3	0,3	0	0	−0,3	1,2	14,8
S5	Δ	3,2	0,9	5,6	2,8	52,4	29,7	1,6	8,4	−4,9	−2	−27,7	−2,8	2,8	−0,5	−0,1	−12,6	3,5	60,4
	%	−0,2	−0,1	−0,4	−0,2	−3,7	−2,1	−0,1	−0,6	0,4	0,1	2	0,2	−0,2	0	0	0,9	−0,3	−4,3
S6	Δ	3	1	21,3	−3,4	19,7	19,5	−0,5	−1,2	−9,3	−1,8	−3,5	−14,9	−3,8	−1,8	−0,3	−6,3	−89,5	−71,9
	%	−4,3	−1,4	−30,4	4,9	−28,1	−27,9	0,7	1,7	13,3	2,6	5	21,3	5,4	2,6	0,4	9	127,8	102,7
S7	Δ	−2,3	−0,2	−0,1	−0,1	−0,1	0	−0,4	−0,7	−0,2	−3,3	−0,4	−0,3	−0,6	0,1	−0,2	−6,6	−16,5	−32
	%	−5,4	−0,5	−0,2	−0,2	−0,2	0	−0,9	−1,6	−0,5	−7,8	−0,9	−0,7	−1,4	0,2	−0,5	−15,5	−38,8	−75,3
S8	Δ	32,2	0,3	−17,3	−20,8	−1,4	−0,9	13,1	−82,7	−30,2	−10,3	−150,3	−42,9	−5	3,6	−5,1	117,9	−106,9	−306,5
	%	36,9	0,3	−19,8	−23,9	−1,6	−1	15	−94,9	−34,6	−11,8	−172,4	−49,2	−5,7	4,1	−5,8	135,2	−122,6	−351,5
S9	Δ	1,2	2,9	−13,4	−1,4	−2,6	2,5	2	−9,8	−36,3	−8,6	−9,4	−7,6	−1,5	7,1	−0,4	−74,8	−41,7	−192
	%	0,1	0,2	−0,7	−0,1	−0,1	0,1	0,1	−0,5	−1,9	−0,4	−0,5	−0,4	−0,1	0,4	0	−3,9	−2,2	−10
S10	Δ	1,5	1	−41,3	−6,5	1,4	−1,7	10,9	14,3	6	−271,9	−57,2	−107,6	−31,4	−22,2	−3,7	330,8	−186,6	−364,1
	%	0,1	0,1	−4,1	−0,6	0,1	−0,2	1,1	1,4	0,6	−26,7	−5,6	−10,6	−3,1	−2,2	−0,4	32,5	−18,3	−35,8
S11	Δ	1,7	0,8	0,5	−1,4	0,1	0,1	1,4	0	3	1,3	−54,2	−10,7	−8,2	0,7	−0,5	−2,5	−25,9	−93,7
	%	−7,7	−3,6	−2,3	6,3	−0,5	−0,5	−6,3	0	−13,6	−5,9	245,1	48,4	37,1	−3,2	2,3	11,3	117,1	423,7
S12	Δ	0,3	4,9	1,4	−0,7	−0,1	−0,3	4,8	−1,6	−0,7	−0,6	−4,7	−18,9	−2,5	0,7	−0,1	4,1	17,5	3,4
	%	0,1	2,2	0,6	−0,3	0	−0,1	2,2	−0,7	−0,3	−0,3	−2,1	−8,5	−1,1	0,3	0	1,8	7,9	1,5
S13	Δ	−70,6	67,6	−248,4	−87,9	−39	−73	62,4	−527,8	−214,4	−300,6	−266,1	−89,9	199,9	3,8	−67,4	−100,1		−4 512,2
	%	0,8	−0,7	2,7	1	0,4	0,8	−0,7	5,8	2,4	3,3	2,9	1	−2,2	0	0,7	1,1	30,4	49,7
S14	Δ	11,3	18,5	7,9	−0,7	1,7	3,9	10,4	−8,9	−7,5	−4,1	−8,9	0,5	−41,8	70,3	−17,9	8,5	−216,7	−173,5
	%	10,3	16,9	7,2	−0,6	1,6	3,6	9,5	−8,1	−6,9	−3,7	−8,1	0,5	−38,2	64,3	−16,4	7,8	−198,2	−158,7

		Technology Change Contribution																	
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	Total
S15	Δ	41,4	55,5	88,8	– 42,6	9,8	18,4	42,1	90,3	77,2	520,4	13,6	5,2	11,8	2 450,2	– 7,4	60,7	– 80,6	3 354,9
	%	0,5	0,6	1	– 0,5	0,1	0,2	0,5	1	0,8	5,7	0,1	0,1	0,1	26,9	– 0,1	0,7	– 0,9	36,8
S16	Δ	8,9	18	1,4	– 11,8	– 14,6	– 19,3	29,2	– 18,2	– 7,6	– 20,5	– 51,9	1,8	237,1	15,3	– 3,1	1 433,1	868,9	2 466,6
	%	0,7	1,5	0,1	– 1	– 1,2	– 1,6	2,4	– 1,5	– 0,6	– 1,7	– 4,2	0,1	19,2	1,2	– 0,3	116,2	70,5	200
S17	Δ	8,7	4,7	3,6	– 7,6	– 1,5	– 2,9	1,2	– 6,3	0,6	– 11,1	– 49,7	– 13,9	– 30,2	4,4	– 2,1	– 30,1	166,1	34,1
	%	0,1	0,1	0,1	– 0,1	0	0	0	– 0,1	0	– 0,2	– 0,7	– 0,2	– 0,5	0,1	0	– 0,5	2,5	0,5

Source: own elaboration based on Statistics Poland (2015; 2024) and Eurostat (2024a)

Odpady przemysłowe w Polsce w latach 2010–2020: ujęcie sektorowe z wykorzystaniem modeli przepływów międzygałęziowych i dekompozycji strukturalnej

Streszczenie: Celem artykułu jest zbadanie, w jaki sposób zmiany technologiczne oraz zmiany w popycie finalnym wpłynęły na wielkość i strukturę odpadów przemysłowych w Polsce w latach 2010–2020. Zastosowane zostały rozszerzone modele przepływów międzygałęziowych w połączeniu z analizą dekompozycji strukturalnej. Z wykorzystaniem tablic przepływów międzygałęziowych dla lat 2010 i 2020 oraz danych o wytwarzaniu odpadów, zagregowanych w 17 klastrów sektorowych, rozłożono zmiany w ilości generowanych odpadów na składniki intensywności odpadowej, postęp techniczny i ewolucję popytu finalnego wraz z ich dalszym podziałem. Wyniki wskazują, że głównym czynnikiem wzrostu wytwarzania odpadów był rosnący popyt finalny, natomiast wpływ zmian technologicznych był zróżnicowany – sektor wytwarzania i zaopatrzenia w energię elektryczną, gaz, parę i klimatyzację odnotował największy spadek odpadów, podczas gdy sektor gospodarki odpadami wyraźnie je zwiększył. Górnictwo i wydobywanie oraz budownictwo odegrały kluczową rolę: pierwsze dzięki zmianom technologicznym, drugie poprzez połączone efekty technologii i popytu. Otrzymane wnioski dostarczają podstaw do projektowania ukierunkowanych strategii redukcji odpadów i pogłębiają zrozumienie zależności między dynamiką gospodarczą, postępem technologicznym a zrównoważonym rozwojem.

Słowa kluczowe: odpady przemysłowe, modele przepływów międzygałęziowych, modele Leontiefa, dekompozycja strukturalna

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