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# INPUT-OUTPUT MODELING OF ECONOMIC SENSITIVITY TO ENERGY COMMODITY PRICE CHANGES, 2005-2020

Joanna HERCZAKOWSKA[1*], Ewelina WŁODARCZYK[2]

[1] Department of Safety Engineering, Faculty of Mining, Safety Engineering and Industrial Automation, Silesian University of Technology; joanna.herczakowska@polsl.pl, ORCID: 0000-0001-7579-0447
[2] Department of Safety Engineering, Faculty of Mining, Safety Engineering and Industrial Automation, Silesian University of Technology; Ewelina.wlodarczyk@polsl.pl, ORCID: 0000-0003-0836-5998
* Correspondence author

**Purpose:** This study provides a comprehensive analysis and assessment of changes in the Polish economy from 2005-2020 and its sensitivity to energy commodity price fluctuations. It focuses on resource use, import dependence, and the processes shaping economic resilience, with particular attention to crude oil and natural gas volatility given Poland's high import reliance.

**Design/methodology/approach**: The research applies input-output analysis to measure intersectoral linkages and multipliers. Using statistical data for Poland from 2005-2020, the study calculates material and import intensity, labor input, production and price multipliers, and develops a price model. The approach is quantitative and comparative, emphasizing long-term trends rather than short-term fluctuations.

**Findings:** The study reveals significant structural changes in the Polish economy from 2005-2020 and its varying sensitivity to energy price fluctuations. Coal and electricity sectors showed low, unstable price multipliers, while crude oil and gas exerted stronger impacts earlier but weakened over time. Chemical, metallurgical, and electromechanical industries displayed the highest multipliers, transmitting shocks across the economy due to high import dependence. Coal mining remained the most labor-intensive sector, while services grew increasingly sensitive to energy costs. Overall, vulnerability shifted from traditional energy commodities toward energy-intensive industries and services, highlighting broader exposure to energy price volatility.

**Research limitations/implications**: The input-output model is static, based on aggregated data, and ends in 2020, excluding recent shocks and energy transition policies. Delays in publishing input-output data by GUS reduce timeliness. Future research should extend the period, include international comparisons, and integrate micro-level data.

**Practical implications:** The results identify the sectors most sensitive to energy prices, providing a basis for risk management, strategic planning, and supporting the energy transition process.

**Social implications:** The research shows that rising energy prices can affect households through higher living costs. Labor-intensive sectors like coal mining remain vulnerable, while wage pressures in services and high-tech industries underscore the need for workforce adaptation.

**Originality/value:** This paper presents the latest study on Poland's economic sensitivity to energy commodity price changes, covering a long period. Its value lies in providing an up to date, comprehensive view, making it relevant for researchers, policymakers, and businesses.
**Keywords:** input-output analysis, energy resources prices, labor costs, systemic analysis.
**Category of the paper:** Research paper.

## 1. Introduction

The energy system is, in a broad sense, an extremely important element in the national economy, shaping economic growth of the country, human welfare and living standards, international exchange and communication, environmental quality and at the same time significantly affecting economic development, the stability of the country, its sovereignty and self-sufficiency. Energy and energy raw materials have been the most important trade commodity for many years, and subsequently source of unrest and discussions – as we have seen in recent years with regard to Russia's military actions. Prices of raw materials and energy are particularly important for proper functioning of the state, as they show strong correlation with the rate of economic growth – sharp soaring prices of raw materials and energy translate into increasing costs of production, which leads to reduction in aggregate supply ultimately affecting inflation. Moreover, noticeable climate change encourages intensified efforts to decarbonize the energy sector by increasing renewable energy share in the energy mix. Thus, on the one hand, the economic use of energy is being promoted, drawing attention to factors like energy intensity, environmental protection and promotion of 'green energy', while on the other hand, Western lifestyles and the advances of civilization are stimulating an increase in energy consumption.

Due to its globally significant solid fuel resources Poland's energy sector is mainly based on coal. Unfortunately, Poland does not have significant natural gas and oil resources – their extraction is not able to supply the current demand, which necessitates import. Figure 1 shows the structure of primary energy production in Poland in 2005-2023 and illustrates a clear and steady transition in Poland's primary energy production over nearly two decades. During the reviewed period the primary energy production in Poland decreased by 30% (from 78 Mtoe to 54 Mtoe). In 2005, the energy mix was overwhelmingly dominated by solid fossil fuels and peat, accounting for nearly 88% of total production. By 2023, this share had dropped to 65%, reflecting a significant 23 percentage point decline. Meanwhile, renewables and biofuels saw a remarkable rise – from just 5.8% in 2005 to 25.6% in 2023 – a more than fourfold increase. This shift highlights Poland's growing commitment to decarbonization and energy diversification, especially in response to EU climate targets and domestic air quality concerns. Natural gas remained relatively stable throughout the period, hovering around 5-6%, indicating limited domestic production and continued reliance on imports.

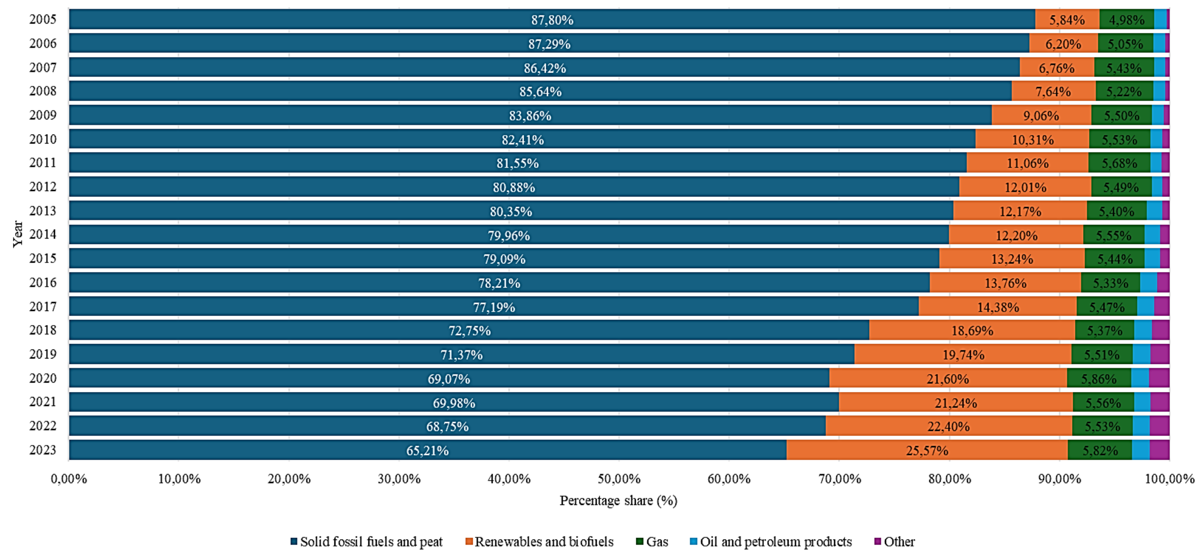

**Figure 1.** Primary energy production in Poland (2005-2023) – share by source [%].

Source: Eurostat. Database 2025. Available online: https://ec.europa.eu/eurostat/data/database (accessed on 28 October 2025)

In contrast to primary energy production, the structure of Poland's gross inland consumption in 2005-2023 shows a similar decline in the share of solid fossil fuels, accompanied by a steady rise in renewables and biofuels, though the overall level of consumption decreased less sharply than production. Figure 2 illustrates the evolution of Poland's gross inland energy consumption over this period, broken down by energy source. It reveals a gradual but significant shift in the country's energy structure.

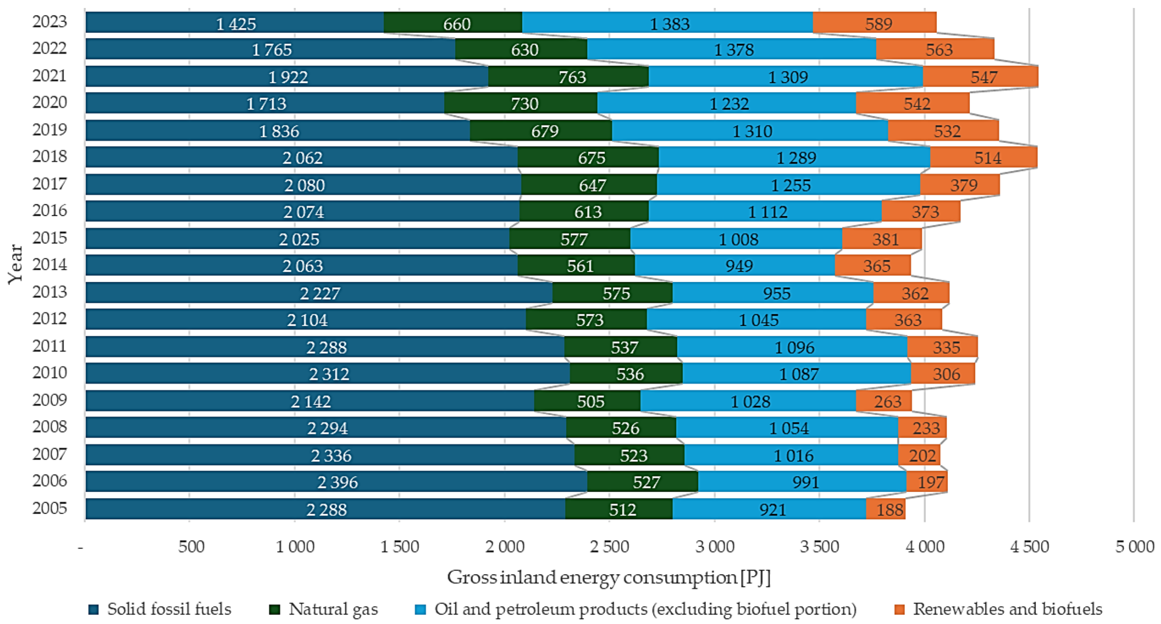

**Figure 2.** Gross inland consumption in Poland (2005–2023) [PJ].

Source: Eurostat. Database 2025. Available online: https://ec.europa.eu/eurostat/data/database (accessed on 28 October 2025)

The structure of energy consumption in Poland is different from that of highly developed European Union member states, mainly due to the preponderance of coal, the low share of hydrocarbon fuels and deficiency of nuclear power.

Gross inland consumption, defined as the total energy supplied to the domestic market in Poland between 2005 and 2023, remained relatively stable at around 4000-4600 PJ (Figure 2). The consumption of solid fuels in the reviewed period decreased by 38%, with simultaneous increase of consumption of oil (by 50%), natural gas (by 29%) and energy from renewable sources and biofuels (by 214%).

Thanks to its internationally considerable reserves of solid fuels, Poland is the largest coal producer in the European Union (Report Energy, 2022) and the tenth largest in the world (International Index of energy security risk, 2020), and its energy sector is based mainly on coal. It should be noted that despite taking a number of measures to achieve energy balance over the past decade, there are no doubts that, with significant resource reserves and existing mining infrastructure, coal will continue to play a key role in Poland's energy system (Nyga-Łukaszewska, Aruga, Stala-Szlugaj, 2020; Bórawski, Bełdycka-Bórawska, Holden, 2023; Rybak, Aurelia., Rybak, Aleksandra, Joostberens, 2023). Dominant share of domestic solid fuels both in the structure of primary energy consumption and electricity production ensures high and stable level of energy security and limits, as far as possible, the burden on the trade balance by the cost of imports of energy carriers. However, appropriate measures are needed to be taken to provide sound management of deposits and to reduce the intensity of the use of fossil fuels, in particular hard coal and lignite, in electricity generation. Reducing or even phasing out the extraction and combustion of hard coal and lignite in Poland has been recognised by experts participating in the Poland Energy Foresight project as the most important element of energy transformation of the country (Dębkowska et al., 2021). At the same time, it is essential that any modification or transformation process also considers the social dimension of such decisions, as emphasized in a study on residents of the Silesian region's perceptions of Poland's sustainable energy transition (Włodarczyk, Herczakowska, 2025).

In view of the above, a systemic study of the Polish energy market becomes indispensable. The application of the input-output model provides a valuable analytical tool that makes it possible to capture the complex interdependencies between supply, demand, and economic development.

## 2. Methods

Input-output tables, also known as input-output matrices, are an analytical tool used in economics to show the value or volume of transactions that have taken place within a given economic system over a specific period of time. These transactions are grouped according to the type of products or industries to which they relate (Przybyliński, 2012). The first such table, the socalled economic table, was constructed by François Quesnay (Quesnay, 1928), while the author of the currently used form is Wassily Leontief (Leontief, 1936), who in the 1930s developed an interindustry flow table for the United States economy based on data from 1919 and 1929 (Gruszczyński, Kuszewski, Podgórska, 2009). More on input-output methods and directions of their development can be found in the literature (e.g., Boratyński, Przybyliński, Świeczewska, 2015; Xie et al., 2018). At present, input-output methods are used to build various simulation models, to conduct research on environmental protection (Prandecki, 2016), energy intensity (Mrówczyńska-Kamińska, Mańkowski, Bajan, 2024; Szymańska, Mroczek, 2023), or labor intensity (Parteka, 2018), as well as to assess the environmental impacts of electricity generation, where they form the basis for emission footprint analyses and comparisons of energy technologies (Henriques, Sousa, 2020). Thanks to data on exports and imports, it is also possible to evaluate foreign trade and include these resources in analyses.

Input-output analysis constitutes one of the key tools for examining interdependencies within the national economy. It enables the identification of interindustry flows, the assessment of production structures, and the determination of the role of individual sectors in generating value added. In the case of Poland, whose economy over the past two decades has undergone intensive processes of transformation and integration with the European market, the application of the input-output model makes it possible to capture both changes in the structure of demand and supply as well as the consequences for the energy balance and the development of key industries.

The systemic approach offered by this method is particularly valuable in the analysis of the energy market, where the interdependencies between production, consumption, and imports have a direct impact on the country's economic stability and energy security. The use of input-output tables enables both the description of the current situation and the forecasting of energy and economic policy impacts. The Central Statistical Office (Główny Urząd Statystyczny) publishes input-output tables cyclically, at five-year intervals, though with a significant delay. The most recent compilation, covering data for the year 2020, was released only in June 2024, which continues the trend observed in earlier editions. These tables present the structure of the flow of goods and services between sectors of the Polish economy, distinguishing between resources originating from domestic production and from imports, and they also illustrate their use in production and consumption processes.

For the analysis and assessment of trends and the impact of changes occurring in the energy resources market on other branches of the economy, data from the input-output balance were used, which were presented in the input-output balance at current basic prices (the so-called table without separation of imports), in the input-output balance at current basic prices for domestic production (the so-called table with separation of imports), and in the table concerning the use of imported goods and services (the so-called import table).

### 2.1. Input-output table – general form

The number of sectors in the considered economic system is denoted by $n$, and their indices by $i, j = 1,2, \dots, n$. The individual quantities, expressed in monetary units, denote:
$x_{ij}$ – the flow from sector $i$ to $j$, i.e., the value of production generated in sector $i$, and consumed in sector $j$,
$X$ – the total (global) production of the entire economy,
$Y_i$ – the final demand of sector $i$,
$Z_i$ – the intermediate consumption of sector $i$,
$K_j$ – material costs, i.e., the sum of the value of production consumed in sector $j$,
$D_j$ – the value added of sector $j$ (net production), defined as the difference between the value of total production and material costs.

The applied sectoral division is exhaustive, which means that the sum of the production values of all sectors $X_i$ equals the total production value of the entire economy:

$$X = \sum_{i=1}^{n} X_i \tag{1}$$

The general form of the input-output table is presented in Figure 3.

| | | Branches / Directions of Use 1 | 2 | … | n | Intermediate Consumption $Z_i = \sum_{j=1}^{n} x_{ij}$ | Final Demand $Y$ | Total Output (Global Production) $X$ |
|---|---|---|---|---|---|---|---|---|
| Branches / Products | 1 | $x_{11}$ | $x_{12}$ | … | $x_{1n}$ | $Z_1$ | $Y_1$ | $X_1$ |
| | 2 | $x_{21}$ | $x_{22}$ | … | … | $Z_2$ | $Y_2$ | $X_2$ |
| | … | … | … | … | … | … | … | … |
| | n | $x_{n1}$ | $x_{n2}$ | … | $x_{nn}$ | $Z_n$ | $Y_n$ | $X_n$ |
| Material Costs $K_j = \sum_{i=1}^{n} x_{ij}$ | | $K_1$ | $K_2$ | … | $K_n$ | $Z = \sum_{i=1}^{n} Z_i = = K = \sum_{j=1}^{n} K_j$ | $Y = \sum_{i=1}^{n} Y_i$ | $X = \sum_{i=1}^{n} X_i = = Y + Z$ |
| Value Added | | $D_1$ | $D_2$ | … | $D_n$ | $D = \sum_{j=1}^{n} D_j$ | | |
| Total Output (Global Production) | | $X_1$ | $X_2$ | … | $X_n$ | $X = \sum_{j=1}^{n} X_j = = K + D$ | | |

**Figure 3.** Input-output Table: Basic Structure.

Source: author's own work.

The decomposition of total production can be expressed in the form of a system of production balance equations, also referred to as distribution equations:

$$\begin{cases} x_{11} + x_{12} + \cdots + x_{1n} + Y_1 = X_1 \\ x_{21} + x_{22} + \cdots + x_{2n} + Y_2 = X_2 \\ \vdots \\ x_{n1} + x_{n2} + \cdots + x_{nn} + Y_n = X_n \end{cases} \tag{2}$$

which is equivalent to:

$$X_i = \sum_{j=1}^{n} x_{ij} + Y_i \tag{3}$$

The above system is a multi-equation, linear, static, deterministic model, whose matrix notation is as follows:

$$\mathbf{X}\,\mathbf{i} + \mathbf{y} = \mathbf{x} \tag{4}$$

where:

**X** – the input-output flow matrix with elements $x_{ij}$,

**i** – the summation vector of matrix **X**, of dimensions $n$ x 1,

**y** – the final demand vector of dimensions $n$ x 1 with elements $Y_i$,

**x** – the total production vector of dimensions $n$ x 1 with elements $X_i$.

Analogously, the value of total production can be expressed from the perspective of its creation, in the form of the following system of equations:

$$\begin{cases} x_{11} + x_{12} + \cdots + x_{1n} + D_1 = X_1 \\ x_{21} + x_{22} + \cdots + x_{2n} + D_2 = X_2 \\ \vdots \\ x_{n1} + x_{n2} + \cdots + x_{nn} + D_n = X_n \end{cases} \tag{5}$$

where: $D_i$ – the value added in sector $i$,
or, in matrix notation:

$$\mathbf{X}^{\mathrm{T}}\, \mathbf{i} + \mathbf{d} = \mathbf{x} \tag{6}$$

where $\mathbf{d}$ is the vector of value added with elements $D_i$.

The systems of equations presented above constitute models, from which the following relationships result:

$$Z + Y = X \tag{7}$$

The sum of intermediate consumption $Z$ and final demand $Y$ equals total production $X$.

$$K + D = X \tag{8}$$

The sum of material costs $K$ and value added $D$ equals total production $X$.

$$K = Z \tag{9}$$

Material costs $K$ are equal to intermediate consumption $Z$.

$$D = Y \tag{10}$$

The inputs of production factors are transformed into final product, which means that value added $D$ is equal to final demand $Y$.

## 2.2. Input-output table without separation of imports

The input-output table without separation of imports presents the total value of both domestic and imported flows. The difference compared to the general form lies in the introduction of an additional row containing data on the volume of imports of products in a given sector, as well as in the refinement of the components of the cost equation:

$$\begin{cases} x_{11} + x_{12} + \cdots + x_{1n} + D_1 = X_1^K \\ x_{21} + x_{22} + \cdots + x_{2n} + D_2 = X_2^K \\ \vdots \\ x_{n1} + x_{n2} + \cdots + x_{nn} + D_n = X_n^K \end{cases} \tag{11}$$

where:

$x_{ij}$ – inter-industry flows of domestic and imported products,

$Y_i$ – value of final demand for domestic and imported products of sector $i$,

$X_i^K$ – total (global) production of sector $i$,

$M_i$ – imports of products of sector $i$,

$X_i$ – total supply (total use), i.e., the sum of the global production of sector $i$ ($X_i^K$) and the imports of products of that sector ($M_i$).

Balancing the table without separation of imports, which in matrix notation can be expressed as:

$$\mathbf{X\,i} + \mathbf{y} = \mathbf{x} \tag{12}$$

$$\mathbf{X}^{\mathbf{T}} + \mathbf{d} + \mathbf{m} = \mathbf{x}^{\mathbf{K}} + \mathbf{m} = \mathbf{x} \tag{13}$$

where **m** is the import vector with elements $M_i$.

Balancing the table without separation of imports consists of summing global production and imports to obtain total supply (total use), thereby ensuring consistency between sectoral outputs and the overall economic equilibrium.

## 2.3. Input-output table with separation of imports

The input-output table with separation of imports consists of reducing inter-industry flows and final demand by the value of imported products:

$$x_{ij}^{K} = x_{ij} - x_{ij}^{M} \tag{14}$$

$$Y_i^{K} = Y_i - Y_i^{M} \tag{15}$$

The index $K$ refers to domestic products, while $M$ refers to imported ones. As a result, the table describes flows exclusively of domestic goods, with the costs of imported materials included in additional rows.

The balancing variable of the domestic input-output table is total production:

$$\mathbf{X}^{\mathbf{K}}\,\mathbf{i} + \mathbf{y}^{\mathbf{K}} = \mathbf{x}^{\mathbf{K}} \tag{16}$$

$$(\mathbf{X}^{\mathbf{K}})^{\mathbf{T}}\,\mathbf{i} + (\mathbf{X}^{\mathbf{M}})^{\mathbf{T}}\,\mathbf{i} + \mathbf{d} = \mathbf{x}^{\mathbf{K}} \tag{17}$$

where: $\mathbf{X}^{\mathbf{M}}$ – the matrix of intermediate product flows originating from imports.

The macroeconomic relations take the following form:

$$Z^{K} + Y^{K} = X^{K} \tag{18}$$

$$K^{K} + K^{M} + D = X^{K} \tag{19}$$

Since:

$$Z = K \tag{20}$$

then:

$$K^{M} + D = Y^{K} \tag{21}$$

By combining the tables of domestic product flows and imported product flows, we obtain a complete and accurate picture of the economy.

## 2.4. Cost coefficients

Input-output tables make it possible to describe production processes in individual sectors using input-output relations (Gruszczyński, Kuszewski, Podgórska, 2009). The relationship between the inputs of sector j and production outputs is defined by the cost coefficients of that sector, denoted by $a_{ij}$, and defined as:

$$a_{ij} = \frac{x_{ij}}{X_j} \qquad i,j = 1,2,\dots,n \tag{22}$$

where:
$x_{ij}$ – the flow from sector i to sector j, i.e., the value of production generated in sector i and consumed in sector j,
$X_j$ – the total (global) production of sector $j$.

The cost coefficients for all sectors are recorded in the form of a matrix:

$$\mathbf{A} = [a_{ij}] \tag{23}$$

called the cost structure matrix. The elements $a_{ij}$ are non-negative, and the sum of the elements forming the j-th column equals the material intensity coefficient of that sector.

Depending on the type of table, cost coefficients may take the following forms:

– for tables with separation of imports, they express the share of domestic raw material and input costs in the production costs of goods manufactured domestically:

$$a_{ij}^K = \frac{x_{ij}^K}{X_j^K} \tag{24}$$

$$\mathbf{A^K} = [a_{ij}^K] \tag{25}$$

These are referred to as direct product intensity coefficients of domestic production.

– for tables presenting the breakdown of imported products, the import intensity of production can be determined using direct import intensity coefficients:

$$a_{ij}^M = \frac{x_{ij}^M}{X_j^K} \tag{26}$$

$$\mathbf{A^M} = [a_{ij}^M] \tag{27}$$

Cost coefficients form the basis of the mathematical model in the form of a system of linear equations or a linear matrix equation, describing the relationships between total and final production across all sectors.

## 2.5. Leontief model

The general form of the distribution equations is given by:

$$\begin{cases} x_{11} + x_{12} + \cdots + x_{1n} + Y_1 = X_1 \\ x_{21} + x_{22} + \cdots + x_{2n} + Y_2 = X_2 \\ \vdots \\ x_{n1} + x_{n2} + \cdots + x_{nn} + Y_n = X_n \end{cases} \tag{28}$$

Transforming the cost coefficient formula, we obtain the relation:

$$x_{ij} = a_{ij} X_j \tag{29}$$

which allows the distribution equations to be written as:

$$\begin{cases} a_{11}X_1 + a_{12}X_2 + \cdots + a_{1n}X_n + Y_1 = X_1 \\ a_{21}X_1 + a_{22}X_2 + \cdots + a_{2n}X_n + Y_2 = X_2 \\ \vdots \\ a_{n1}X_1 + a_{n2}X_1 + \cdots + a_{nn}X_n + Y_n = X_n \end{cases} \tag{30}$$

which is equivalent to:

$$\mathbf{Ax} + \mathbf{y} = \mathbf{x} \tag{31}$$

After rearrangement, we obtain:

$$\left(\begin{bmatrix} 1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 1 \end{bmatrix} - \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix}\right)\begin{bmatrix} X_1 \\ \vdots \\ X_n \end{bmatrix} = \begin{bmatrix} Y_1 \\ \vdots \\ Y_n \end{bmatrix} \tag{32}$$

which is:

$$(\mathbf{I} - \mathbf{A})\mathbf{x} = \mathbf{y} \tag{33}$$

This matrix equation describes the relationship between total and final production, where the matrix $(\mathbf{I} - \mathbf{A})$ is called the Leontief matrix or the production structure matrix.

It can also be written as:

$$\mathbf{Lx} = \mathbf{y} \tag{34}$$

using the following notation:

$\mathbf{x} = [X_i]$ – an $n$-dimensional column vector of total production,

$\mathbf{y} = [Y_i]$ – an $n$-dimensional column vector of final production,

$\mathbf{L} = \mathbf{I} - \mathbf{A}$ – an $n \times n$ matrix, where $\mathbf{A}$ is the cost structure matrix and $\mathbf{I}$ is the identity matrix of order $n$.

This equation constitutes the Leontief model of the considered $n$-sector economic system, describing the relationships between total and final production across all sectors. The parameters of the model are the cost coefficients given by the cost structure matrix **A**.

The parameters $\alpha_{ij}$ of the inverse Leontief matrix, i.e. $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$ express the amount of total production of sector i required to satisfy a unit of final demand for products of sector j. The elements of this matrix are called coefficients of total product intensity, showing how final demand for products of type j changes under the influence of a change in production of goods of type i by $\alpha_{ij}$:

$$\mathbf{x}^{\mathbf{K}} = (\mathbf{I} - \mathbf{A}^{\mathbf{K}})^{-1}\mathbf{y}^{\mathbf{K}} = \mathbf{L}^{\mathbf{K}}\mathbf{y}^{\mathbf{K}} \tag{35}$$

while the sums of its columns are called production multipliers or input-output multipliers:

$$\alpha_j = \sum_{i=1}^{j} \alpha_{ij} \tag{36}$$

which indicate the increase in production in the entire economic system resulting from a unit increase in final demand for products of type $j$.

Similarly, based on the direct import intensity coefficients, we can determine the coefficients of total import intensity as:

$$\mathbf{L}^{\mathbf{M}} = \mathbf{A}^{\mathbf{M}}\mathbf{L}^{\mathbf{K}} \tag{37}$$

Since multipliers are the derivative of an endogenous variable with respect to an exogenous variable, their determination in the case of linear models poses no difficulty, as they are constants. In the case of nonlinear models, however, their determination may be more complex. Therefore, in practice, multiplier analysis is reduced to conducting simulations and examining the reactions of endogenous variables to the occurrence of disturbances.

## 2.6. Coefficients describing production and imports of individual sectors

The determination of coefficients characterizing the production and imports of individual sectors requires the calculation of the appropriate cost coefficient matrices A and AK, as well as the matrix AM of direct import intensity coefficients of production. Since the cost coefficients $a_{ij}$, recorded in matrix **A** represent the share of total intermediate costs of type $i$ – both domestic and imported – in the supply of domestic and imported products of sector $j$, the interpretation of the model in the form without separation of imports may raise doubts from an economic perspective, due to the assignment of costs incurred domestically simultaneously to domestic production and imports (Przybyliński, 2012). Therefore, when determining matrix **A**, it was taken into account that the costs given in the numerator serve exclusively to generate domestic production, not imported products, and the following relation was used:

$$a_{ij} = \frac{x_{ij}}{X_j^K} \tag{38}$$

At the same time, the following condition is satisfied:

$$a_{ij} = a_{ij}^K + a_{ij}^M \tag{39}$$

The sum of the elements forming the j-th column is equal to the material intensity coefficient of that sector:

$$\sum_{i=1}^{n} a_{ij} = \frac{\sum_{i=1}^{n} x_{ij}}{X_j} = \alpha_j \tag{40}$$

This formulation ensures that the coefficients reflect the true material intensity of each sector, linking intermediate inputs directly to the scale of domestic production.

## 2.7. Labor inputs

Input-output tables also allow for the analysis of employment costs, which, together with taxes, depreciation of fixed assets, and operating surplus, constitute the gross value added of production. The relationship between the employment costs of sector $j$ and production outputs is defined by the labor intensity coefficients of that sector, denoted by $w_j$ and defined as:

$$c_j = \frac{C_j}{X_j^K} \qquad i,j = 1,2,\dots,n \tag{41}$$

where:

$C_j$ – employment costs in sector $j$,

$X_j^K$ – domestic total production of sector $j$.

The analysis of labor inputs was carried out on the basis of the input-output table with separation of imports, since employment costs relate exclusively to domestic production. The coefficients $c_j$ are defined analogously to the coefficients of direct material inputs, and the total value of factor inputs is expressed by the vector equation:

$$\mathbf{C} = \mathbf{c}^{\mathbf{T}}\mathbf{x}^{\mathbf{K}} = \hat{\mathbf{c}}\,\mathbf{x}^{\mathbf{K}} \tag{42}$$

where:
$\mathbf{C}$ – vector with elements $C_j$,
c – vector of direct factor input coefficients (production results),
$\hat{\mathbf{c}}$ – diagonal matrix derived from vector c with elements $c_j$,
$\mathbf{x}^{\mathbf{K}}$ – vector of domestic total production of sector $j$.

Substituting into the equation:

$$\mathbf{x}^{\mathbf{K}} = (\mathbf{I} - \mathbf{A}^{\mathbf{K}})^{-1}\,\mathbf{y}^{\mathbf{K}} \tag{43}$$

we obtain:

$$\mathbf{C} = [\hat{\mathbf{c}}(\mathbf{I} - \mathbf{A}^{\mathbf{K}})^{-1}\,]\mathbf{y}^{\mathbf{K}} \tag{44}$$

In the above formula, the magnitude of employment-related inputs depends on the level of final demand.

### 2.8. Price model

Input-output tables also make it possible to conduct simulations of the economy's sensitivity to changes in the prices of imported products, based on the price model (Miller, Blair, 2009), According to this model, the scale of the impact of import prices on domestic prices results from the import intensity of individual sectors and the mutual raw-material – product linkages between them. The foundation of the price model is the cost equation:

$$\hat{\mathbf{x}}\mathbf{A}^{\mathbf{T}}\mathbf{i} + \mathbf{d} = \mathbf{x} \tag{45}$$

where:
$\mathbf{x}$ – vector of total production,
$\hat{\mathbf{x}}$ – diagonal matrix derived from vector $\mathbf{x}$,
$\mathbf{A}^{\mathbf{T}}$ – transposed cost coefficient matrix,
$\mathbf{d}$ – value added of production.

Applying the transformations described in the works, (Przybyliński, 2012; Herczakowska, 2016, 2020) the final price equation for an open economy takes the form:

$$\mathbf{p}^{\mathbf{K}} = \mathbf{\Pi}^{\mathbf{M}}\mathbf{p}^{\mathbf{M}} + (\mathbf{L}^{\mathbf{K}})^{\mathbf{T}}\mathbf{v} \tag{46}$$

where:
$\mathbf{p^K}$ – vector of domestic prices,
$\mathbf{p^M}$ – vector of import prices,
$\mathbf{\Pi^M p^M} + (\mathbf{L^K})^\mathbf{T}\mathbf{v}$ – multiplier matrix expressing changes in domestic prices under the influence of changes in import prices,
$\mathbf{\Pi^M} = (\mathbf{L^K})^\mathbf{T} \cdot (\mathbf{A}^\mathrm{M})^\mathbf{T} = [\pi_{ij}^M]$ – matrix expressing the magnitude of the change in the domestic price of sector *i* resulting from a unit change in the price of imported products of sector $j$.

From the input-output tables, we can also read the initial share of imports $m$ in total supply for product group $i$:

$$S_i = \frac{m}{x^K + m} \tag{47}$$

where:
$S_i$ – share of imports in supply for product group $i$,
$m$ – volume of imports for product group $i$,
$x^K$ – domestic total production of sector $i$.

Furthermore, by including production volume in the price equation in the form of vector $\mathbf{\dot{x}^K}$:

$$\dot{x}_i^K = \frac{x_i^K}{\sum_{i=1}^n x_i^K} \tag{48}$$

we obtain the equation:

$$\boldsymbol{\pi}^\mathbf{M} = (\mathbf{\Pi^M})^\mathbf{T}\mathbf{\dot{x}^K} \tag{49}$$

which allows simulations of how an increase in the price of a given product group will affect domestic prices. Domestic price multipliers indicate which product group changes the economy is particularly sensitive to.

## 2.9. Materials

The basis for the analyses conducted in this publication were the Input-Output Balances in current basic prices published by the Central Statistical Office (GUS, 2009, 2014, 2019, 2024). In the analyzed period, covering the years 2005, 2010, 2015, and 2020, for which input-output tables were prepared, changes occurred in the PKD and PKWiU classifications. As a result, the 2009 balance presented the Polish economy divided into 55 sectors, while in subsequent balances this number increased to 77. Consequently, it was necessary to systematize the data to enable a consistent comparative analysis.

Given the scope of the research, the data were aggregated into ten sectors listed below, while retaining, in disaggregated form, those sectors of particular interest for this publication (Hard coal and lignite; peat, as well as Crude oil and natural gas, metal ores, and other mining products):

1. Agricultural and hunting products, forestry, fishing, and aquaculture.
2. Hard coal and lignite; peat.
3. Crude oil and natural gas, metal ores, other mining products.
4. Light industry.
5. Chemical industry.
6. Metallurgical industry.
7. Electromechanical and high-technology industry.
8. Electricity, gas, steam, and hot water.
9. Construction and water collection, treatment, and distribution.
10. Service activities.

The tables obtained through aggregation and calculations became the basis for further analyses, covering both the structure of the economy and the impact of changes in energy resource prices on other sectors. Due to their extensive form, a full presentation of the matrices in this work is not possible; instead, the main stages of model construction and the most important results of the conducted research are presented.

## 3. Results

Based on the conducted research and the calculations of coefficients characterizing the Polish economy, the directions of their changes in the years 2005-2020 were determined. Particular attention was devoted to assessing the impact of energy resource prices on the structure of the economy and the mechanisms of its functioning. The analysis covered material intensity coefficients, import intensity coefficients, and production multipliers, which make it possible to determine the degree of resource utilization and dependence on foreign supplies. The share of imports in the structure of inputs was also taken into account, enabling an assessment of the economy's sensitivity to external factors. Another area of research concerned labor inputs, indicating the intensity of human resource utilization in individual sectors. A key element of the study was the price multipliers, showing how changes in the prices of energy and other raw materials affect the entire economy. The analysis is complemented by the price model, which serves as a tool for evaluating inter-industry mechanisms of price formation under the influence of fluctuations in energy markets.

### 3.1. Material intensity of the Polish economy

The analysis of the material intensity of the Polish economy can be carried out using the material intensity coefficient, which in input-output analysis defines how many material resources (raw materials, energy, semi-finished products) must be consumed in order to produce one unit of output in a given sector of the economy. The higher the value of the coefficient, the greater the sector's dependence on material inputs.

Thus, material intensity is the relationship between the quantity (or value) of materials consumed and the value of production. In the input-output model, this coefficient reflects the material inputs per unit of total production and enables an assessment of resource use efficiency, while also identifying sectors that are highly dependent on raw materials and those with lower material intensity. Moreover, it highlights potential risks associated with rising raw material prices – the higher the material intensity, the greater the economy's sensitivity to changes in energy or raw material prices.

**Table 1.**
*Changes in material intensity coefficients in the Polish economy, 2005-2020*

| Industrial branch | Material intensity coefficient value | | | |
|---|---|---|---|---|
| | 2005 | 2010 | 2015 | 2020 |
| agricultural, hunting, forestry and fishing products | 0.520 | 0.540 | 0.590 | 0.585 |
| hard coal, lignite, and peat | 0.340 | 0.340 | 0.400 | 0.437 |
| crude oil, natural gas, metal ores, and other mining raw materials | 0.380 | 0.490 | 0.510 | 0.489 |
| light industry (textiles, apparel, consumer goods) | 0.750 | 0.740 | 0.730 | 0.748 |
| chemical industry | 0.750 | 0.750 | 0.730 | 0.715 |
| metallurgical industry (ferrous and non-ferrous metals) | 0.700 | 0.730 | 0.690 | 0.674 |
| electromechanical and high-technology industries | 0.750 | 0.770 | 0.720 | 0.726 |
| electricity, gas, steam, and hot water supply | 0.630 | 0.560 | 0.560 | 0.478 |
| construction, water abstraction, treatment, and distribution | 0.620 | 0.620 | 0.590 | 0.624 |
| service activities | 0.400 | 0.410 | 0.410 | 0.410 |

Source: author's own work.

Table 1 presents changes in the material intensity coefficient over the analyzed period, while Figure 4 illustrates the trends by focusing on the extreme years.

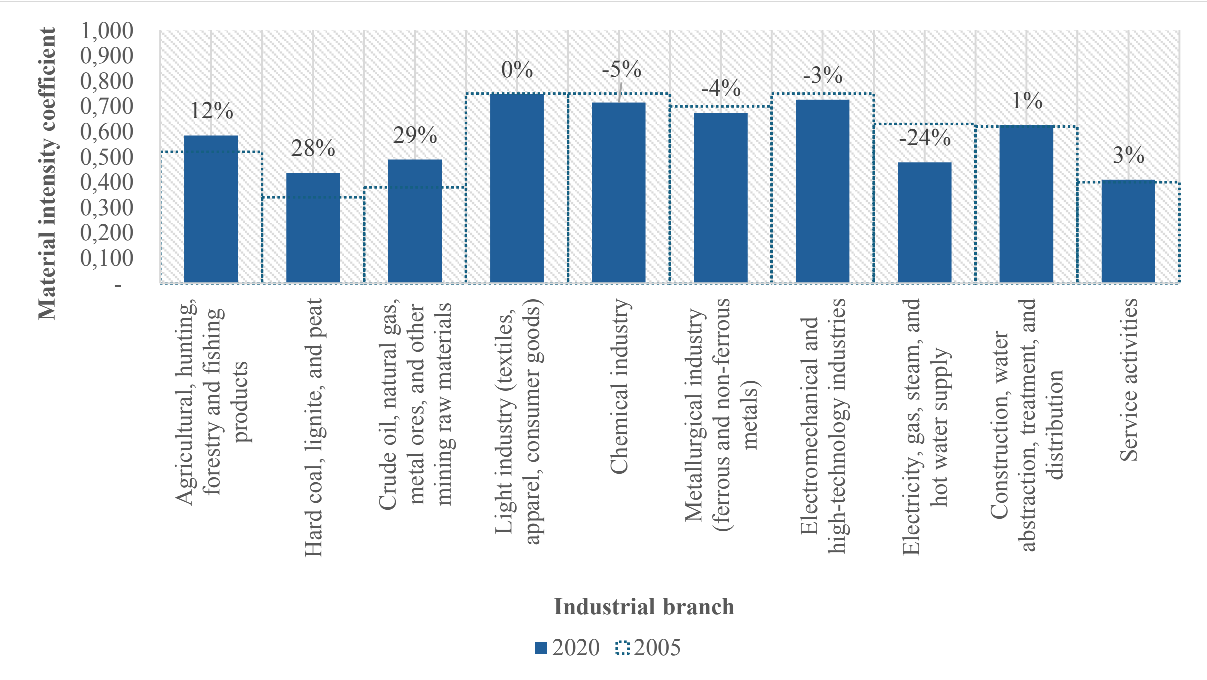


**Figure 4.** Material intensity coefficient and its changes in the Polish economy in 2005 and 2020.
Source: author's own work.

Based on the presented results, several characteristic trends can be observed across individual sectors:

- Agriculture, forestry, and fisheries – the coefficient increased from 0.520 in 2005 to 0.590 in 2015, then slightly declined to 0.585 in 2020. This indicates a gradual rise in resource use intensity, with slight stabilization in recent years.
- Hard coal, lignite, and peat – values increased systematically (from 0.340 to 0.437), pointing to higher material intensity in the mining sector.
- Crude oil, natural gas, and metal ores – the coefficient rose to 0.510 in 2015, then fell to 0.489 in 2020, suggesting improved efficiency or changes in production structure.
- Light industry – values remained stable (around 0.74-0.75), reflecting a consistent level of material use.
- Chemical industry – a slight decrease of about 5%, indicating improved material efficiency.
- Metallurgical industry – minor fluctuations with a downward trend (from 0.700 to 0.674), possibly reflecting modernization of production processes.
- Electromechanical and high technology industry – values oscillated between 0.72-0.77, with no clear trend, suggesting stable material intensity.
- Energy sector (power plants, gas, steam, hot water) – a marked decline from 0.630 in 2005 to 0.478 in 2020, indicating improved efficiency and technological changes in the sector.
- Construction and water management – values remained stable, with a slight increase in 2020 (0.624), reflecting rising material inputs in infrastructure.
- Services – the coefficient remained virtually unchanged (0.400-0.410), confirming the low material intensity of this sector.

In summary, the most material intensive sectors remain the chemical, electromechanical, and light industries, though signs of stabilization or decline are visible. The energy sector stands out for its significant efficiency improvements, while services maintain a low level of material intensity. In contrast, the coal mining sector shows increasing material burdens, which is particularly important in the context of the economy's sensitivity to changes in energy resource prices.

### 3.2. Import intensity of the Polish economy

The import intensity coefficient is a measure showing the extent to which production in a given sector of the economy, or in the economy as a whole, relies on goods and services originating from imports. A high value of the coefficient indicates strong dependence on foreign supplies, while a low value points to greater self-sufficiency and reliance on domestic resources.

In the input-output model, import intensity is defined as the share of imported goods and services in the total production inputs of a sector. This indicator makes it possible to determine the degree of the economy's dependence on external sources of supply and to identify the sectors most vulnerable to external shocks, such as increases in raw material prices on global markets or disruptions in supply chains.

It is of particular importance in studies on energy and resource security, as it highlights the branches of the economy that cannot function without imports. The interpretation of the coefficient is relatively straightforward: high import intensity means that a significant share of production inputs comes from abroad, while low import intensity indicates the dominance of domestic resources.

**Table 2.**
*Changes in import intensity coefficients in the Polish economy, 2005-2020*

| Industrial branch | Import intensity coefficient value | | | |
|---|---|---|---|---|
| | 2005 | 2010 | 2015 | 2020 |
| Agricultural, hunting, forestry and fishing products | 4% | 6% | 9% | 9% |
| Hard coal, lignite, and peat | 3% | 5% | 7% | 5% |
| Crude oil, natural gas, metal ores, and other mining raw materials | 3% | 9% | 13% | 8% |
| Light industry (textiles, apparel, consumer goods) | 15% | 17% | 17% | 17% |
| Chemical industry | 34% | 38% | 34% | 32% |
| Metallurgical industry (ferrous and non-ferrous metals) | 22% | 23% | 23% | 24% |
| Electromechanical and high-technology industries | 33% | 31% | 29% | 31% |
| Electricity, gas, steam, and hot water supply | 12% | 13% | 12% | 12% |
| Construction, water abstraction, treatment, and distribution | 9% | 8% | 10% | 10% |
| Service activities | 4% | 6% | 6% | 7% |

Source: author's own work.

As before, changes in the import intensity coefficient throughout the entire analyzed period are presented in Table 2, while the graphical presentation of the data (Figure 5) illustrates the trends between 2005 and 2020.

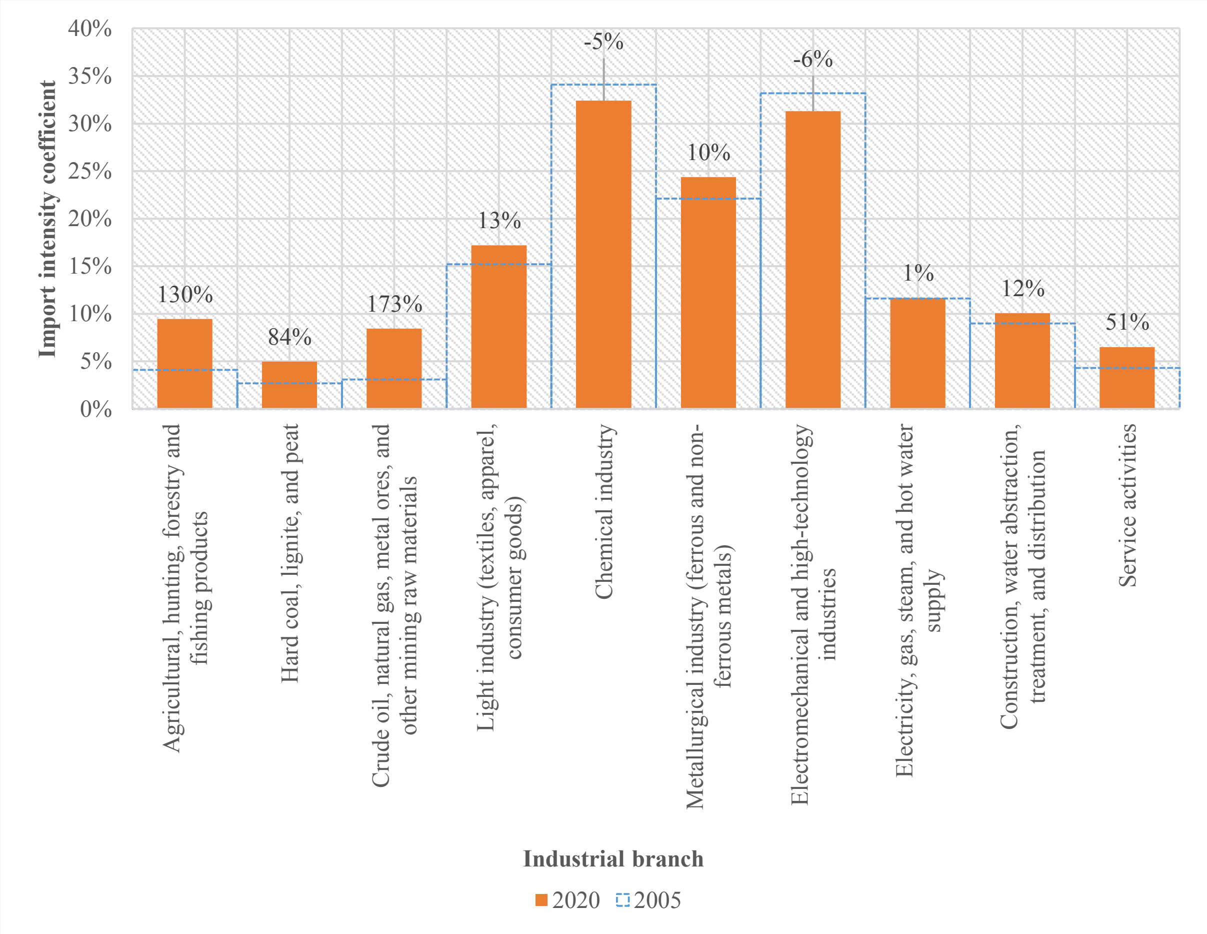


**Figure 5.** Import intensity coefficient and its changes in the Polish economy in 2005 and 2020.

Source: author's own work.

The analysis of changes in import intensity in the Polish economy between 2005 and 2020 reveals several key tendencies across individual sectors:

- Agriculture, forestry, and fisheries – the coefficient rose from 4% in 2005 to 9% in 2015, and then remained at this level. This indicates the growing importance of imported inputs in a sector traditionally based on domestic resources.
- Hard coal, lignite, and peat – values increased until 2015 (7%), then declined to 5% in 2020, which may suggest reduced imports and greater reliance on domestic resources.
- Crude oil, natural gas, and metal ores – the coefficient reached its peak in 2015 (13%), then fell to 8% in 2020. This trend reflects the variable dependence on imported energy and metallic raw materials.
- Light industry – values remained stable (15-17%), indicating a persistent reliance on imported materials and semi finished products.
- Chemical industry – the highest coefficients in the entire economy (32-38%), confirming strong dependence on imported petroleum based raw materials and chemicals.

- Metallurgical industry – stable values (22-24%) at a high level, indicating lasting dependence on imported ores and metals.
- Electromechanical and high technology industry – a slight decline from 33% in 2005 to 29% in 2015, followed by a return to 31% in 2020. This shows a consistently high, though somewhat variable, reliance on imported components.
- Energy sector (power plants, gas, steam, hot water) – stable values (12-13%), pointing to a moderate but steady dependence on imports.
- Construction and water management – minor fluctuations (8-10%), suggesting a limited role of imports in this sector.
- Services – the coefficient increased from 4% to 7%, but remained at a low level, confirming the dominance of domestic resources and limited exposure to imports.

In summary, the most import intensive sectors remain the chemical, electromechanical, and metallurgical industries, which rely heavily on foreign raw materials and components. Agriculture and services, despite traditionally low dependence on imports, show a gradual increase in the coefficient, which may indicate growing integration with international markets. Meanwhile, the energy and construction sectors maintain a moderate, stable dependence on imports.

### 3.3. Production multipliers – the impact of individual sectors on the economy

The total output multiplier is an indicator that shows how much total production in the economy will increase in response to a unit increase in final demand in a given sector. In other words, it measures the strength of one sector's impact on other branches of the economy through inter‑industry linkages.

The mechanism of the multiplier effect is based on indirect and induced effects. An increase in demand in one sector leads to higher production in that sector, which in turn requires the purchase of additional goods and services from other sectors. These sectors also raise their production levels to supply the necessary inputs, triggering further rounds of the multiplier effect. As a result, the initial impulse in one sector spreads throughout the economy, generating a total increase in production greater than the original stimulus (Miller, Blair, 2009). The interpretation of the multiplier's value is as follows: if its value equals 1, this indicates no indirect effects – production increases only in the analyzed sector. Values greater than 1 show that the sector generates additional impulses in other branches of the economy. The higher the multiplier, the stronger the inter-industry linkages and the greater the importance of the given sector for the development of the entire economy.

Total output multipliers make it possible to identify key sectors with the greatest impact on the economy, highlight areas where investments or support may yield the largest multiplier effects, and enable analysis of the economy's sensitivity to changes in final demand – whether stemming from exports, consumption, or investment.

**Table 3.**
*Changes in total output multipliers in the Polish economy, 2005–2020*

| Industrial branch | Total output multiplier value | | | |
|---|---|---|---|---|
| | 2005 | 2010 | 2015 | 2020 |
| Agricultural, hunting, forestry and fishing products | 2.240 | 2.300 | 2.460 | 2.417 |
| Hard coal, lignite, and peat | 1.810 | 1.820 | 1.920 | 1.967 |
| Crude oil, natural gas, metal ores, and other mining raw materials | 1.850 | 2.120 | 2.120 | 2.068 |
| Light industry (textiles, apparel, consumer goods) | 2.780 | 2.770 | 2.770 | 2.802 |
| Chemical industry | 2.690 | 2.760 | 2.720 | 2.656 |
| Metallurgical industry (ferrous and non-ferrous metals) | 2.750 | 2.900 | 2.700 | 2.638 |
| Electromechanical and high-technology industries | 2.940 | 3.070 | 2.840 | 2.838 |
| Electricity, gas, steam, and hot water supply | 2.290 | 2.200 | 2.230 | 2.043 |
| Construction, water abstraction, treatment, and distribution | 2.520 | 2.540 | 2.450 | 2.530 |
| Service activities | 1.870 | 1.900 | 1.870 | 1.862 |

Source: author's own work.

Changes in production multipliers during 2005-2020 are shown in Table 3, with Figure 6 highlighting the trends between 2005 and 2020.

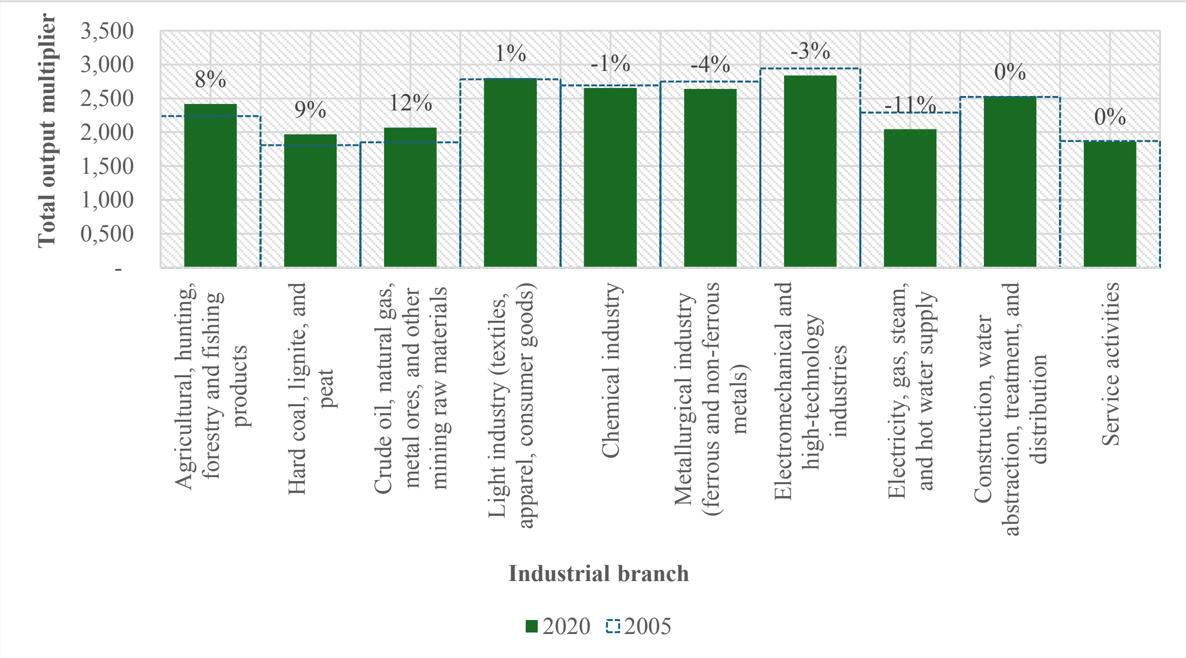


**Figure 6.** Total output multiplier and its changes in the Polish economy in 2005 and 2020.

Source: author's own work

Based on the calculated production multipliers, the following tendencies can be observed in the analyzed sectors of the economy:

– Agriculture, forestry, and fisheries – the multiplier increased from 2.240 in 2005 to 2.460 in 2015, then slightly declined to 2.417 in 2020. This indicates growing but stabilizing inter industry linkages.
– Hard coal, lignite, and peat – values rose systematically (from 1.810 to 1.967), pointing to a gradual strengthening of multiplier effects in this sector.

- Crude oil, natural gas, and metal ores – a clear increase until 2010 (2.120), maintained in subsequent years, reflecting the strong influence of the resource sector on other branches of the economy.
- Light industry – values remained stable (around 2.77-2.80), suggesting durable and relatively high linkages with other sectors.
- Chemical industry – minor fluctuations with a downward tendency in 2020 (2.656), which may indicate partial efficiency improvements or structural changes in inputs.
- Metallurgical industry – the highest values in 2010 (2.900), followed by a decline to 2.638 in 2020, suggesting a weakening of multiplier effects in this sector.
- Electromechanical and high technology industry – the highest multipliers in the entire economy (3.070 in 2010), consistently remaining at a high level, confirming the strategic importance of this sector for economic development.
- Energy sector (power plants, gas, steam, hot water) – values declined from 2.290 in 2005 to 2.043 in 2020, reflecting technological modernization and the gradual reduction of this sector's linkages with others, resulting from improved energy efficiency and increasing diversification of energy sources.
- Construction and water management – stable values (around 2.45-2.53), indicating the lasting importance of the infrastructure sector in multiplier effects.
- Services – multipliers remained at a low level (around 1.87-1.90), confirming weaker linkages with other branches of the economy.

The electromechanical and high technology industry achieves the highest total output multipliers, showing its particularly significant role in driving overall economic development – its growth strongly stimulates other sectors. High multipliers are also observed in the chemical, metallurgical, and light industries, though a gradual decline has been noted in recent years. In contrast, the energy sector and services exhibit relatively low multipliers, meaning their influence on other branches of the economy is limited. In the context of this article, this implies that changes in energy resource prices do not remain confined to the energy sector but spread throughout the economy, affecting production, prices, and employment in other industries.

### 3.4. Labor inputs in the Polish economy

Labor inputs constitute one of the fundamental elements of economic analysis in the input-output framework. They refer to the total amount of human labor engaged in production processes within a given sector or across the entire economy. This indicator makes it possible to determine how intensively individual branches utilize labor resources and what their interconnections with other sectors are.

The analysis of labor inputs enables the assessment of employment structure, productivity, and the impact of changes in final demand on the labor market.

**Table 4.**
*Changes in labor input coefficients in the Polish economy, 2005-2020*

| Industrial branch | Labor input coefficient value | | | |
|---|---|---|---|---|
| | 2005 | 2010 | 2015 | 2020 |
| Agricultural, hunting, forestry and fishing products | 0.090 | 0.070 | 0.100 | 0.076 |
| Hard coal, lignite, and peat | 0.450 | 0.450 | 0.440 | 0.534 |
| Crude oil, natural gas, metal ores, and other mining raw materials | 0.240 | 0.230 | 0.270 | 0.243 |
| Light industry (textiles, apparel, consumer goods) | 0.130 | 0.120 | 0.120 | 0.129 |
| Chemical industry | 0.100 | 0.090 | 0.100 | 0.124 |
| Metallurgical industry (ferrous and non-ferrous metals) | 0.140 | 0.140 | 0.140 | 0.167 |
| Electromechanical and high-technology industries | 0.130 | 0.130 | 0.130 | 0.150 |
| Electricity, gas, steam, and hot water supply | 0.130 | 0.140 | 0.110 | 0.123 |
| Construction, water abstraction, treatment, and distribution | 0.140 | 0.140 | 0.140 | 0.134 |
| Service activities | 0.230 | 0.240 | 0.250 | 0.272 |

Source: author’s own work.

Table 4 presents the values of the labor input coefficient for individual sectors of the economy, while their graphical representation is shown in Figure 7. In most sectors, we observe moderate stability of labor input coefficients, with only slight fluctuations over time. Clear increases occurred in coal mining, services, and in the chemical and metallurgical industries, whereas sectors such as agriculture or light industry show fluctuations without a lasting upward trend.

Since this indicator shows what share of production in a given sector relies on human labor, the following tendencies were observed in the analyzed area:

- Agriculture, forestry, and fisheries – values are variable: a decline from 0.090 in 2005 to 0.070 in 2010, then an increase to 0.100 in 2015, followed by another decline to 0.076 in 2020. This reflects fluctuations in labor intensity, likely linked to mechanization and modernization processes that reduced labor demand, but also temporarily increased it due to EU subsidies and transitional structural changes.
- Hard coal, lignite, and peat – the coefficient remained at a high level (around 0.45), rising to 0.534 in 2020. This reflects difficulties in the sector—declining productivity, the need to maintain employment, and social and political pressure to preserve jobs.
- Crude oil, natural gas, and metal ores – values oscillated around 0.23–0.27, with a slight increase in 2015 and a decline in 2020. The sector remains moderately labor‑intensive, with fluctuations linked to global raw material price volatility and Poland’s limited role as a producer of these resources.
- Light industry – stable values (around 0.12-0.13), suggesting a consistent level of employment relative to production.
- Chemical industry – a slight decline to 0.090 in 2010, followed by an increase to 0.124 in 2020, which may indicate greater importance of labor in production processes in recent years.

- Metallurgical industry – stable values until 2015 (0.140), then rising to 0.167 in 2020, suggesting growing labor intensity in the sector, resulting from the increasing importance of these branches in the economy, the development of chemical and pharmaceutical production, and modernization of metallurgy requiring additional technological support.
- Electromechanical and high-technology industry – stable values (0.130), with a clear increase to 0.150 in 2020, possibly reflecting greater importance of specialized labor.
- Energy sector (power plants, gas, steam, hot water) – minor fluctuations, with a decline to 0.110 in 2015 and a rise to 0.123 in 2020, possibly reflecting modernization processes and the development of new energy sources.
- Construction and water management – stable values (0.134-0.140), indicating a lasting employment structure in this sector.
- Services – systematic growth from 0.230 in 2005 to 0.272 in 2020, confirming the growing importance of the service sector in job creation and the natural effect of a market economy, in which services gradually assume a dominant role.

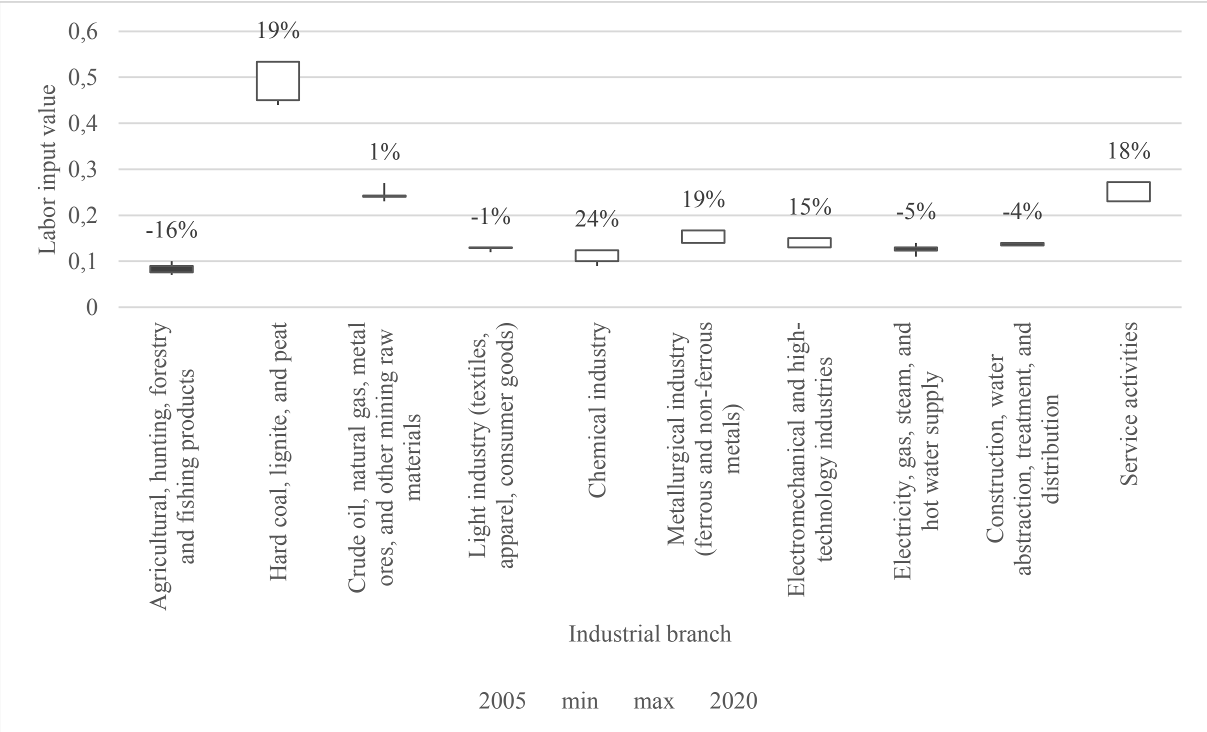


**Figure 7.** Labor input coefficients and its changes in the Polish economy, 2005-2020.

Source: author's own work.

The analysis of labor input coefficients indicates significant differentiation between individual sectors of the economy as well as clear changes over time. The average level for the entire economy remained relatively stable during the analyzed period, at around 0.18-0.20, which corresponds to labor costs of approximately 180-200 thousand PLN per 1 million PLN of production.

The highest values were consistently recorded in mining (hard coal, lignite, and peat), where the labor input coefficient was around 0.45 in 2005-2015 and rose to 0.534 in 2020. This means that labor costs accounted for more than half of the production value in this sector, making mining the most labor-intensive branch of the economy. Such a high share of employment costs results both from occupational risk and from organizational specifics as well as historical wage conditions.

In summary, between 2005 and 2020 the structure of labor inputs in the Polish economy showed relative stability, but with clear sectoral differences. Mining remains the most labor-intensive sector, while services and high-technology industries gradually increase their share of labor costs. Agriculture and energy, on the other hand, benefit from modernization effects, which reduce the intensity of labor inputs.

### 3.5. Price model in the Polish economy

Price analysis within the input-output methodology is based on Leontief's concept, which assumes that the economy is a system of mutually interconnected production sectors. Each sector produces goods and services while simultaneously using the products of other sectors as inputs. In this framework, prices are not treated solely as the outcome of supply and demand, but rather as the result of the technological structure of the economy and the cost relations between individual branches.

The input-output price model makes it possible to trace how changes in the costs of production factors – such as labor, capital, or raw materials – spread throughout the entire economic system and affect final prices. In particular, it enables:

- determining the share of individual inputs in shaping production prices,
- analyzing indirect effects, i.e., the impact of costs in one sector on prices in others,
- studying the consequences of technological and structural changes for price levels,
- assessing the impact of economic policy (e.g., taxes, subsidies, energy regulations) on costs and prices across different industries.

Introducing the price model into input-output analysis is crucial for understanding inflationary mechanisms and for assessing the competitiveness of the economy. This tool captures not only the direct effects of cost increases in a given sector but also their diffusion throughout the entire economic system (Miller, Blair, 2009).

The analysis of import shares in the input-output model allows us to capture the degree of dependence of individual sectors of the economy on foreign supplies. Data from 2005-2020 (Table 5) show clear differences between industries – from sectors almost entirely reliant on imports to those based mainly on domestic resources. Among the sectors with a growing importance of imports, we can distinguish:

- Agriculture and agricultural products, where the share of imports rose from 8.7% in 2005 to 17.4% in 2020. This indicates the increasing presence of foreign agricultural products on the Polish market, resulting from EU integration, trade liberalization, and rising demand for goods unavailable in domestic production.
- Light industry (clothing, textiles, consumer goods), where a systematic increase in import share to 27.5% in 2020 reflects the relocation of production to countries with lower labor costs and the dominance of imported consumer goods.
- Chemical and metallurgical industries, both showing a stable but high import share (around 33-39%), due to the need to import raw materials and semi‑finished products not sufficiently available domestically.
- Electromechanical and high‑technology industry, where the import share rose to over 46% in 2020, showing strong dependence on foreign components and technologies, particularly in electronics and IT.

Among the sectors highly dependent on imported raw materials are:

- Crude oil, gas, and metal ores, where the import share remained very high (around 78%), dropping only in 2020 to 69%. Poland is largely dependent on foreign supplies here, and the decline in the last year may reflect diversification of sources,
- Hard coal and lignite, with an initially low import share (3.4% in 2005), but a sharp increase to over 18% in 2010 and 2020. This points to the growing importance of imported coal despite large domestic reserves, linked to extraction costs and the price competitiveness of foreign coal.

In the remaining sectors – Energy (electricity, gas, heat), Construction and water management, and Services – the share of imports remains very low.

**Table 5.**
*Changes in import share in the Polish economy, 2005-2020*

| Industrial branch | Import share value | | | |
|---|---|---|---|---|
| | 2005 | 2010 | 2015 | 2020 |
| Agricultural, hunting, forestry and fishing products | 8.70% | 12.20% | 16.45% | 17.38% |
| Hard coal, lignite, and peat | 3.40% | 18.50% | 12.24% | 18.38% |
| Crude oil, natural gas, metal ores, and other mining raw materials | 78.80% | 79.10% | 78.01% | 69.03% |
| Light industry (textiles, apparel, consumer goods) | 18.30% | 22.80% | 25.51% | 27.48% |
| Chemical industry | 35.60% | 34.30% | 36.51% | 39.13% |
| Metallurgical industry (ferrous and non-ferrous metals) | 30.90% | 32.20% | 31.93% | 33.28% |
| Electromechanical and high-technology industries | 43.60% | 43.10% | 43.93% | 46.25% |
| Electricity, gas, steam, and hot water supply | 0.50% | 1.10% | 2.07% | 2.96% |
| Construction, water abstraction, treatment, and distribution | 1.20% | 1.40% | 2.27% | 1.57% |
| Service activities | 2.60% | 3.80% | 4.53% | 4.88% |

Source: author’s own work.

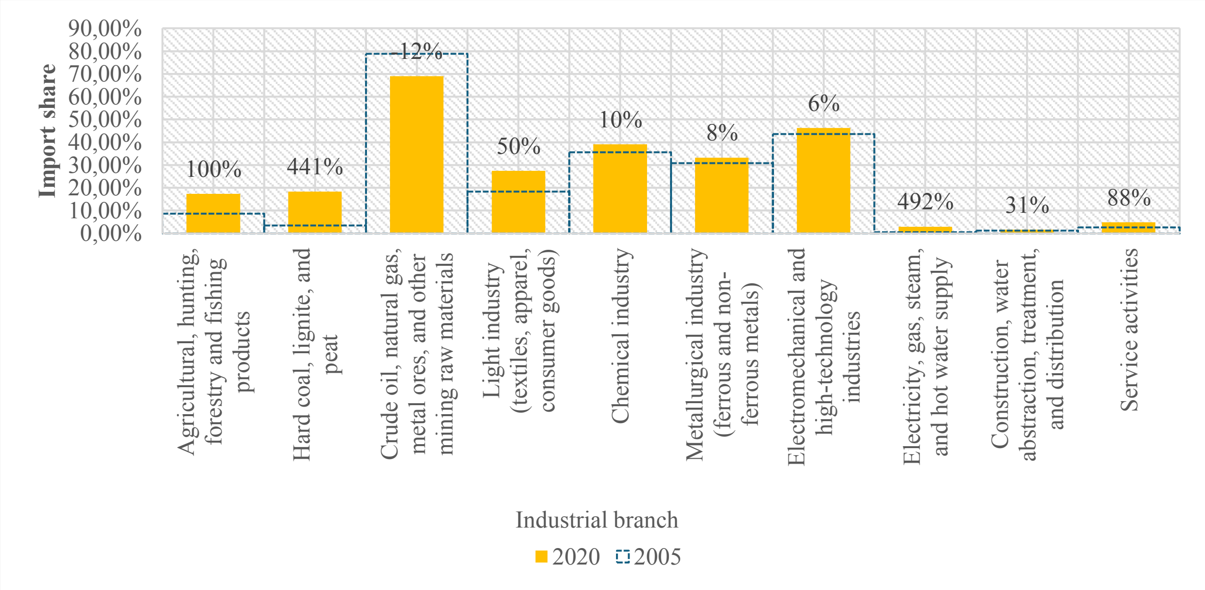


**Figure 8.** Import share and its changes in the Polish economy in 2005 and 2020.

Source: author's own work.

Figure 8 illustrates that between 2005 and 2020 the Polish economy strengthened its integration with global markets. Industrial and consumer sectors became increasingly import-dependent, while resource-based and high-technology industries show the highest vulnerability to external supply shocks. In contrast, construction, energy, and services continue to rely predominantly on domestic inputs, underscoring their relative resilience.

**Table 6.**
*The impact of rising oil and natural gas prices on domestic product prices, 2005-2020*

| **Reaction – sectoral price changes** | **Impulse - an increase in oil and natural gas prices by one unit (100%)** | | | |
|---|---|---|---|---|
| | **2005** | **2010** | **2015** | **2020** |
| Agricultural, hunting, forestry and fishing products | 1.70% | 1.96% | 1.58% | 1.01% |
| Hard coal, lignite, and peat | 1.40% | 1.63% | 1.71% | 1.31% |
| Crude oil, natural gas, metal ores, and other mining raw materials | 1.90% | 5.62% | 8.44% | 2.60% |
| Light industry (textiles, apparel, consumer goods) | 1.70% | 1.61% | 1.09% | 0.90% |
| Chemical industry | 18.00% | 21.42% | 16.79% | 12.96% |
| Metallurgical industry (ferrous and non-ferrous metals) | 4.30% | 4.37% | 3.51% | 3.12% |
| Electromechanical and high-technology industries | 1.30% | 1.95% | 1.33% | 0.97% |
| Electricity, gas, steam, and hot water supply | 10.00% | 10.56% | 7.83% | 8.92% |
| Construction, water abstraction, treatment, and distribution | 3.30% | 3.69% | 2.51% | 1.95% |
| Service activities | 1.10% | 1.26% | 0.80% | 0.58% |

Source: author's own work.

Since crude oil, natural gas, and related raw materials account for the largest share of imports, it was assumed that the Polish economy is most sensitive to price changes in this group of resources. Therefore, simulations were conducted to examine how changes in the prices of these products would affect the Polish economy if their price increased by one unit. Detailed results are presented in Table 6. In addition, a graphical illustration of the sensitivity of domestic production sector prices to changes in the prices of imported crude oil and natural gas for the year 2020 is shown in Figure 8.

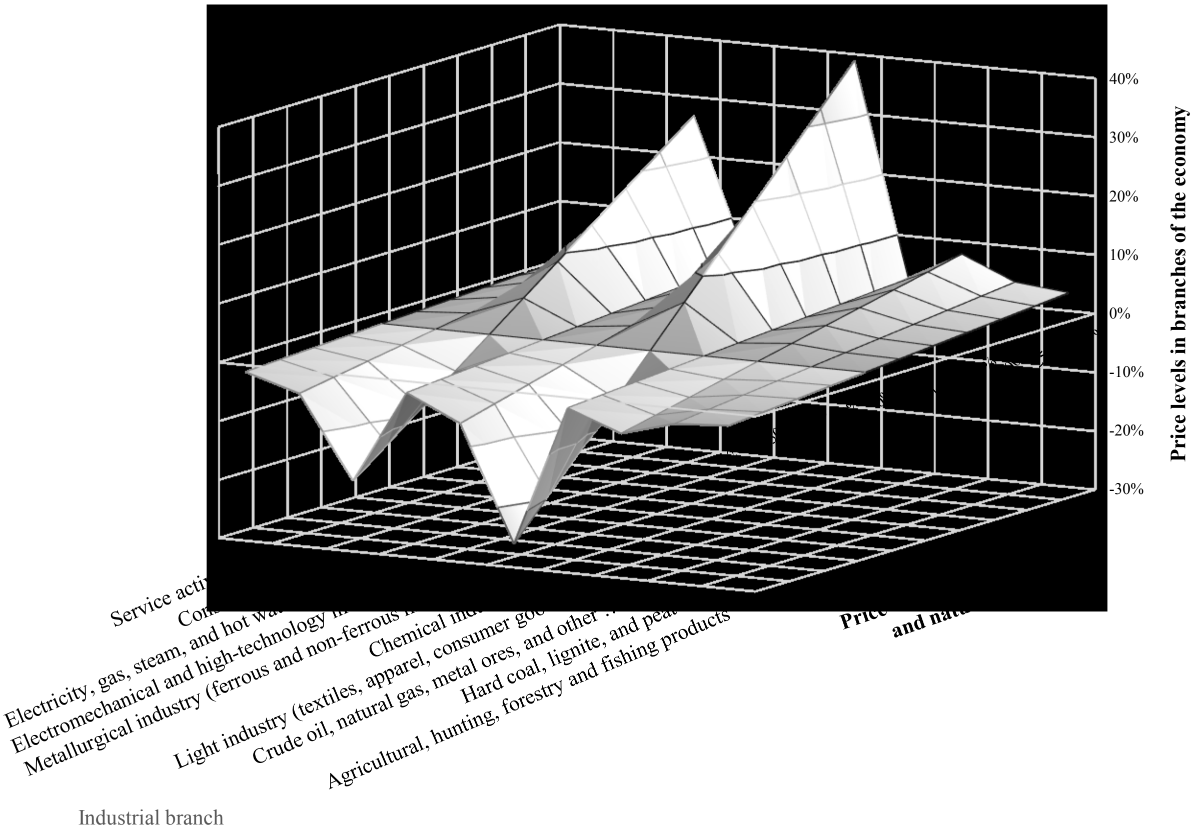


**Figure 9.** Price sensitivity of domestic production sectors to changes in imported crude oil and natural gas prices.

Source: author's own work.

Figure 9 presents a three-dimensional simulation of the impact of price changes in two key energy resources – crude oil and natural gas (Z-axis) – on price levels in different branches of the economy (Y-axis), broken down by sectors (X-axis). The analysis makes it possible to assess which sectors are most vulnerable to fluctuations in the prices of these resources and how the intensity of this impact changes depending on the scale of the price impulse.

The greatest price sensitivity is observed in industrial sectors with high energy intensity and strong linkages to raw material markets: the chemical, metallurgical, and electromechanical industries. In these sectors, even a moderate increase in oil and gas prices (e.g., by 50-100%) translates into a significant rise in production costs – reaching several percentage points. In the case of sharp price changes, the effect in these branches may be even more pronounced, confirming their systemic vulnerability to such shocks. By contrast, service sectors and construction show lower direct price sensitivity, although with large changes in resource prices the effect becomes noticeable. This results from the indirect impact of energy costs on service prices, especially in transport, logistics, and operating costs.

Resource sectors such as coal mining, oil and gas extraction, and agriculture exhibit varied reactions. Coal mining and agriculture are relatively less sensitive to oil and gas price changes, which may stem from their local character and limited dependence on imported energy carriers.

The oil and gas extraction sector, however, reacts strongly, reflecting its direct linkage to market prices of these resources.

It is worth noting the non-linearity of price reactions – in many sectors the impact of changes in energy resource prices does not grow proportionally, but shows a threshold effect once certain levels are exceeded (e.g., a 100% price increase). This may result from transfer pricing mechanisms, long-term contracts, and technological constraints in adapting to new cost conditions.

For a complete picture of the phenomenon under study, it is also important to consider changes in price multipliers during the analyzed period (Table 7).

**Table 7.**
*Changes in price multipliers in the Polish economy, 2005-2020*

| Industrial branch | Price multipliers | | | |
|---|---|---|---|---|
| | 2005 | 2010 | 2015 | 2020 |
| Agricultural, hunting, forestry and fishing products | 0.466 | 0.534 | 0.604 | 0.624 |
| Hard coal, lignite, and peat | 0.074 | 0.232 | 0.097 | 0.118 |
| Crude oil, natural gas, metal ores, and other mining raw materials | 3.009 | 3.686 | 2.651 | 1.996 |
| Light industry (textiles, apparel, consumer goods) | 2.448 | 2.265 | 2.414 | 2.325 |
| Chemical industry | 5.180 | 5.330 | 5.519 | 5.318 |
| Metallurgical industry (ferrous and non-ferrous metals) | 2.913 | 2.894 | 2.965 | 3.036 |
| Electromechanical and high-technology industries | 4.102 | 4.762 | 4.742 | 4.812 |
| Electricity, gas, steam, and hot water supply | 0.027 | 0.001 | 0.075 | 0.085 |
| Construction, water abstraction, treatment, and distribution | 0.112 | 0.147 | 0.267 | 0.256 |
| Service activities | 1.666 | 2.619 | 2.786 | 3.372 |

Source: author's own work.

Table 7 and figure 10 shows the changes in price multipliers across different sectors of the Polish economy between 2005 and 2020. This indicator reflects how strongly price changes in a given sector affect prices throughout the economy via inter-industry linkages. The analysis of price multipliers reveals clear differences between sectors. The highest values are consistently observed in the chemical industry, the electromechanical and high-technology industries, and the metallurgical industry, highlighting their strategic importance in shaping prices across the entire economy. Agriculture and services show systematic growth, indicating their increasing influence on price formation. The largest decline in 2020 compared to the base year 2005 is observed in the sector crude oil, natural gas, metal ores, and other mining raw materials, while the most pronounced drop is in electricity, gas, steam, and hot water supply.

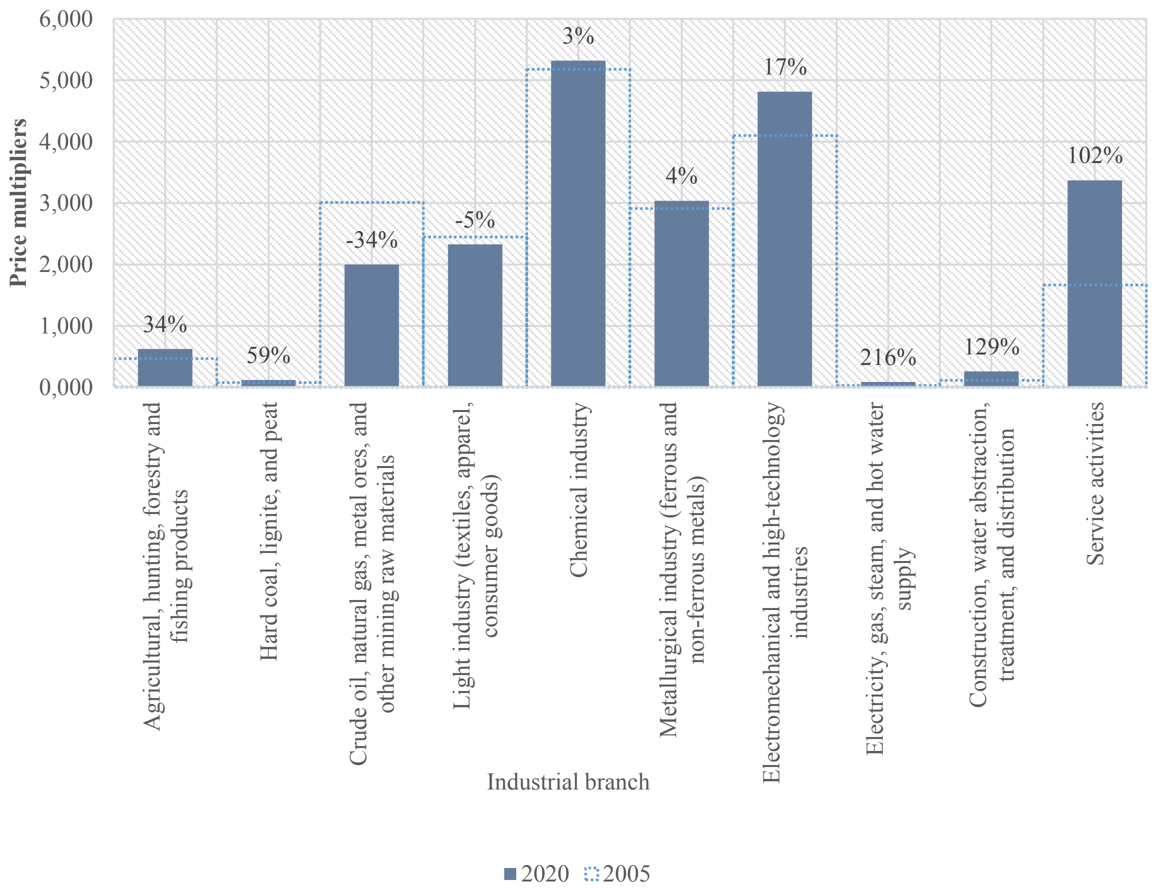


**Figure 10.** Price multipliers and its changes in the Polish economy in 2005 and 2020.

Source: author's own work.

Overall, the analysis indicates that the role of traditional raw materials in shaping price dynamics has diminished, while sectors such as chemicals, high technology, and services have become the primary drivers of cost transmission across the economy. This structural shift underscores the growing importance of knowledge-intensive and service-oriented industries in determining Poland's economic resilience to price shocks.

## 4. Discussion

The conducted analysis made it possible to capture the complex mechanisms of the Polish economy's sensitivity to changes in energy resource prices in the years 2005-2020. The results indicate that individual sectors differ in the intensity of multiplier effects, reflecting their position in the economic structure and the degree of inter-industry linkages. High multiplier values in the chemical, metallurgical, and electromechanical industries confirm that these sectors are particularly vulnerable to energy price fluctuations, and their strong connections with other branches cause price shocks to spread widely throughout the economy. In contrast, stable, low values in services point to limited material intensity and lower direct exposure to raw material prices, although the growing role of services in the economy means that energy costs are gradually permeating this sector as well.

An important trend is the decline in multiplier values in the energy sector, which can be interpreted as the result of technological modernization, improved efficiency, and diversification of energy sources – also visible in statistical data on primary production and gross inland consumption. The reduction of energy sector linkages with other industries does not imply a loss of importance, but rather a change in the nature of its impact – from a traditional, material-intensive structure toward more efficient and sustainable solutions. These findings are consistent with broader observations pointing to the growing importance of energy transition and climate policy as factors shaping the economic structure.

The analysis of import intensity reveals an additional dimension of economic vulnerability. Sectors such as the chemical, electromechanical, and metallurgical industries remain heavily dependent on foreign raw materials and components, increasing the risk of transmitting price shocks from international markets. Agriculture and services, despite traditionally low import dependence, show a gradual increase in indicators, reflecting growing integration with global supply chains.

The results have important implications for economic policy. First, they highlight the need to strengthen the resilience of sectors most sensitive to energy price changes through diversification of sources, investment in energy efficiency, and the development of low-emission technologies. Second, they emphasize the importance of monitoring import intensity, especially in strategic sectors, to limit the risk of excessive dependence on foreign supplies. Third, the growing role of services in the economy requires incorporating energy costs into policies supporting the competitiveness of this sector.

At the same time, the limitations of the analysis must be underlined. The input-output model is static and based on aggregated data, which may conceal significant differences within individual sectors, as noted in other studies (Bunsen, Finkbeiner, 2023). Moreover, ending the analysis in 2020 does not account for subsequent shocks such as the COVID-19 pandemic or the energy crisis linked to the war in Ukraine, which significantly affected cost structures and economic linkages. An additional limitation is the delay in the publication of input-output tables by Statistics Poland (GUS), which reduces the timeliness of the results.

Future research should be expanded to include dynamic models and comparative analyses with other countries to better understand the specificity of the Polish economy in an international context. Incorporating microeconomic data would make it possible to capture distributional effects and assess how energy price changes affect different groups of enterprises and households.

## 5. Summary

The aim of the research presented in this publication was to analyze and assess the changes occurring in the Polish economy between 2005 and 2020, as well as to evaluate its sensitivity to energy resource price fluctuations using input-output tables. Based on these tables, changes and trends in material intensity, labor costs, and import dependence were identified. In view of the persistently high level of crude oil and natural gas imports, the study also examined how price fluctuations in these resources could affect the Polish economy.

The results show that sectors reacted differently to energy price fluctuations. Coal and electricity-related sectors had relatively low and unstable price multipliers, indicating a limited direct impact on the overall price level. However, it should be noted that the analyzed period does not cover the most recent years, marked by significant price volatility due to the COVID-19 pandemic and the war in Ukraine.

The study covering 2005-2020 reveals a clear structural shift in the Polish economy. The strongest production linkages and the highest price multipliers are found in the chemical, metallurgical, and electromechanical industries, which play a key role in transmitting price impulses throughout the economy. The high import intensity of these branches makes them particularly vulnerable to fluctuations in energy resource and component prices. Coal mining remains the most labor‑intensive sector, with labor costs accounting for more than half of production value. Services, on the other hand, show growing sensitivity to energy costs, indicating that price effects are gradually permeating wider areas of the economy.

Simulations demonstrate that increases in oil and gas prices hit hardest in the chemical industry, energy, and metallurgy. Sectors such as agriculture, light industry, and services respond more weakly, but their rising price multipliers indicate growing vulnerability to such shocks.

In summary, the Polish economy during the analyzed period remained strongly dependent on energy resource prices, with the greatest risk to price stability concentrated in energy-intensive and import‑dependent industries. At the same time, the growing role of services shows that the impact of energy on the economy is becoming increasingly widespread, extending beyond industry to the service sector.

Overall, the findings highlight a structural shift: the sensitivity of the Polish economy has moved away from traditional energy resources toward complex, energy‑intensive industrial sectors, while the rising importance of services demonstrates that energy price changes now affect a much broader spectrum of economic activity than in the past.

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