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AN ECONOMIC EVALUATION OF THE FUNCTIONING OF HARD COAL MINING IN POLAND IN THE YEARS 2016-2018

This work is a continuation and extension of previous socio-economic analyses of hard coal mines, which were conducted at the Central Mining Institute in the years 2013-2015. The paper presents the results of the economic evaluation of the hard coal mining sector in the years 2016-2018 using the Cost-Benefit Analysis (CBA) methodology. Used for the socio-economic assessment of hard coal mining, the CBA methodology enables the comprehensive evaluation of the functioning of this sector of the economy in Poland. In addition to financial aspects, which are important from the point of view of coal companies, it also included the social and environmental influence resulting from the impact of mines on the environment. Direct data of operating costs and payments (including public-law payments), incurred by the hard coal mining industry in Poland, was used. This data is obtained by Industrial Development Agency JSC, Branch Office Katowice as part of the "Program of statistical surveys of official statistics" – statistical survey "Hard coal and lignite mining industry". They were supplemented with data coming from commonly available public statistics. For the analysed period the presented results indicate that the financial and social benefits resulting from the hard coal mining activity in Poland outweighed the financial, social and environmental costs generated by this industry. This confirms the desirability of further functioning of the hard coal mining industry in Poland, however, assuming effective restructuring activities that will result in lower costs of coal production.

Keywords: cost-benefit analysis, hard coal mine, economic efficiency, social and environmental impacts

1. Introduction

Mining operations in hard coal mines are a process that directly or indirectly affects the environment. The effects of this impact can be negative and take the form of losses (e.g. environmental) or positive, for example in the form of social benefits for mine employees and business entities directly and indirectly associated with it. Traditional financial analysis of the operation

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of mining enterprises is insufficient, because these impacts are not taken into consideration. Such analysis covers only the financial aspects directly related to the economic efficiency of the coal production and sale. The results of the financial analysis enable the assessment of only the financial sustainability and efficiency of the enterprise, i.e. the mine. A full picture of operation of the mine including the impact on the environment is given by the economic evaluation carried out using the cost-benefit analysis (CBA) methodology. CBA uses the economic values that reflect the cost of the alternative use of the mine's resources or the price which the society is ready to pay for a particular good or service. CBA takes into account and evaluates all factors according to their alternative cost to society (Ligus, 2010). It is performed from the point of view of the interests of the entire population (region or country), as opposed to financial analysis, which is from the investor's point of view (Florio et al., 2001). The purpose of the CBA is to evaluate the contribution of the project to the economic well-being of the given region or country.

The CBA extends the financial assessment to consider external factors, such as the benefits for society resulting from the operation of the mine, as well as losses resulting from the negative impact on the surrounding environment. The valuation of environmental costs, as well as human life and health, poses many difficulties because the externalities (costs and social benefits, and ecological costs) are not of a monetary nature. If the benefits and costs cannot be measured in a monetary form, then the principle of the indirect valuation of these factors is applied.

This paper presents the adopted methodology for performing the CBA and the results of calculations of the economic evaluation of the hard coal mining sector in Poland. The adopted methodology has already been used in previous studies conducted at the Central Mining Institute. These studies were limited to the analyses of only two selected hard coal mines in Poland (Krawczyk et al., 2016). The performed CBA of the entire hard coal mining sector was conducted based on real operational and financial data from the years 2016-2018. This data came from Polish mines as well as from official statistics. The data concerning Polish mines is obtained by Industrial Development Agency JSC, Branch Office Katowice (IDA JSC), as part of the "Hard coal and lignite mining industry" statistical survey which was part of "Program of statistical surveys of official statistics". They were supplemented with data available from the official statistics in Poland, published by Statistics Poland (GUS).

Since the scope of analysis concerns the activity of the hard coal mining sector in Poland, it did not include social and environmental costs resulting from the use of coal as fuel in the energy industry. This approach results from the specificity of the energy sector in Poland, which is currently based mainly on coal. It is not possible for the Polish energy industry to quickly switch from coal to other fuels. Thus, the results of the CBA should be considered when deciding on the sources of supply of hard coal to the Polish energy sector, and not with regard to stopping the transformation of this energy sector into a less emissive one.

2. State of knowledge regarding the application of the cost-benefit analysis methodology for the assessment of mines in Poland

The evaluation of the mining industry and mines often leads to controversial results, due to the fact that the mining industry combines private interests and public benefits. At the same time, it contributes to the environmental impact associated with mining operations and production

of mining wastes. Therefore, mining assessment requires a complex approach and cost-benefit analysis (CBA) is considered to be a good evaluation method because it considers economic, social and environmental factors in the assessment. The first studies on determining the ecological losses and socio-economic benefits resulting from mining activities were carried out in Poland in the 1980s. The estimation of losses caused by the degradation of the land's surface in the Katowice voivodship was performed by Piontek (1989), who also calculated the socio-economic costs of coal extraction (Piontek, 1992). However, these pieces of work did not concern the whole of Poland, but presented in detail the estimated balance of ecological losses and social benefits performed for the mines located in the former Katowice Voivodeship. The work of Mokrzycki et al. (1992) presents the impact of air, water and soil pollution on the natural environment, as well as various methods for estimating losses in the environment, human health and building structures. The work of Famielec (1999) describes the methodology for assessing economic losses caused by environmental pollution in the national economy. On the other hand, society's perception of mine operations, the consequences of mining activities, and the need to take into account the costs and benefits generated by mines in economic analyzes were presented by Martyka et al. (2001). In the work of Kulczycka et al. (2014), the cost-benefit analysis method was used to assess the profitability of aggregate production from the mining wastes. In turn, the paper of Kulczycka et al. (2012a) presents the economic and non-economic benefits resulting from the use of accompanying minerals and mining waste in lignite mining. In addition, ways of assessing the profitability of the management of the minerals accompanying the mining exploitation were indicated. In the publication of Kulczycka et al. (2012b) the use of cost-benefit analysis to evaluate the management of waste resulting from hard coal mining was proposed. The MinNovation project analysed the possibilities of the management of waste resulting from mining operations in the Baltic Sea region and presented the economic and non-economic benefits from their processing (Cała, 2013).

Numerous papers widely present works on the use of cost-benefit analysis to assess mining waste management. For example, Abelson (2015) presented issues related to the use of the CBA method for mining projects and he discussed the problems and restrictions related to data availability, the difficulty in valuing non-market goods, the scope of analysis and uncertainty. The report prepared by Deloitte (2014) assessed the operation of one of the deepest in the world, Mount Owen located in New South Wales, Australia, 20 km from the town of Singleton. The assessment of the net benefits for the community of the region and the town of Singleton was carried out using the CBA method. The CBA together with the NPV and greenhouse gas (GHG) emissions were used to select the best mining waste management option, showing that the simultaneous improvement of technology combined with the use of renewable energy is most beneficial (Adiansyah et al., 2017). In turn, Johansson (2017) presented the application of the CBA method to assess the operation of a nickel mine in Sweden. The CBA assessment was used to evaluate the variant, assuming increased use of methane from the methane drainage of the Mahui and Pingshang mines in Shanxi Province in China (US EPA, 2015).

In addition to the CBA, the environmental assessment method LCA (Life Cycle Assessment) is also used to assess mining processes, often in combination with the LCC (Life Cycle Costing) analysis (Czaplicka-Kolarz, 2002; Kulczycka, 2011). The results of the LCA analysis and the LCC assessment can be used in the cost-benefit analyses, as presented by Kulczycka et al. (2003). Śliwińska and Burchart-Korol (2014) used the LCA method to assess the environmental impact associated with the operation of a hard coal mine. The assessment, in addition to factors such as waste storage, underground water discharges, and methane emissions, included the indirect

impact associated with the mine – the environmental impact attributed to the production of raw materials, materials, and the energy consumed in the mine. Segeth-Boniecka (2017) presented cost analysis in the life cycle of a mining excavation as a method which enables the support of the cost planning process, estimating the profitability of exploitation, as well as ongoing monitoring and control of costs. Batrancea et al. (2019) analysed the econometric indicators related to coal mining in Romania. They analyzed the influence of the relationship between variables: quantity of production, direct, indirect, variable and fixed costs and profit, on the the data for 1993-2016.

The cost estimation of the accidents at work and occupational diseases, the activities carried out by the European Agency for Safety and Health at Work are important. The methodology for estimating this type of cost in Poland was developed at the Central Institute for Labour Protection – National Research Institute (CIOP-PIB) and the Nofer Institute of Occupational Medicine in Łódź. The problem concerning the value of ecological and social effects when valuing degraded areas in terms of the multi-criteria method is presented in the paper of Janik (2012). He pointed out that the methods used for valuing land property located in degraded areas, do not take into account the value of environmental losses and social costs. Also, the negative impact of mines on the surface is associated not only with the occurrence of mining damage but also with a decrease in the aesthetic value of the area. Estimating this type of cost of mining operations involves the risk of underestimating or overestimating their value. However, good practice and a reference point for further work in this area may be an extensive approach to the valuation of the external costs of infrastructure projects – HEATCO, IMPACT projects, or guidelines created for the needs of EU-DG Mobility and Transport.

Despite the visible increase in the importance and scope of the CBA, this methodology is not commonly used for the comprehensive assessment of the entire hard coal mining sector in Poland.

3. Description of the adopted methodology for the economic assessment of the hard coal mining sector using CBA

As the period covered by the analysis is quite short (3 years: 2016, 2017 and 2018) discount methods were abandoned. The change of the discount coefficient value over a period of 3 years is too insignificant to affect the calculation results. Therefore, the calculations were made for each year separately, determining the difference between the sum of revenues and social benefits and the sum of operating, environmental and social costs. The calculated difference was referred to the amount of coal extracted in a given year. The equation used for the calculations takes the form:

$$EV_n = \frac{\sum B_n - \sum C_n}{P_n} \tag{1}$$

where:

- EV_n — unit economic benefit / loss of the hard coal production in the year "n" [PLN/Mg],
- ΣB_n — sum of the revenues and social benefits generated by the hard coal mining industry in Poland in the year "n" [PLN],
- ΣC_n — sum of the operating, environmental and social costs generated by the hard coal mining industry in Poland in the year "n" [PLN],
- P_n — hard coal production in Poland in the year "n" [Mg].

The CBA took into account the costs and social benefits, as well as ecological losses related to the operation of hard coal mines in Poland, which were possible to quantify and value in monetary units. These consist of:

- external social benefits from cooperation,
- benefits from direct tax receipts to the budgets of communes/districts,
- benefits of employment – jobs created (maintained),
- costs of accidents at work – light,
- costs of occupational diseases – pneumoconiosis,
- ecological losses in the aquatic environment,
- non-operational ecological losses of hard coal,
- ecological losses resulting from soil degradation,
- ecological losses on the earth's surface.

The adopted formula for valuation of the external social benefits of cooperation with other entities takes the form (own study based on Bartik, 2011; Fujiwara, 2010; Rzepecki, 2005):

$$KO_{SKOP} = (LMP \cdot (PWP - ZB)) + \\ + ((LMP \cdot SZB) + (LMP \cdot ((PD \cdot PWP) - PB))) \quad (2)$$

where:

LMP — estimated number of jobs in cooperating companies [full time],
PWP — average salary in the industry [PLN],
ZB — the amount of unemployment benefit (100% allowance) [PLN],
SZB — the amount of contributions from the unemployment benefit (100% allowance) [PLN],
PB — the amount of tax on unemployment benefit (100% allowance) [PLN],
PD — an indicator of the level of personal income tax [%].

The formula for the valuation of the external social benefits of tax receipts to the budget of a commune/powiat takes the form (own study based on European Commission, 2014; Kasztelewicz and Zajączkowski 2010):

$$KO_{SWP} = (POE \cdot (OE \cdot W_K)) \quad (3)$$

where:

POE — coefficient of the amount of exploitation fees directed to communes/districts [%],
OE — the rate of exploitation fee for hard coal [PLN / Mg],
W_K — hard coal extraction quantity, gross – total [Mg].

The value of external social benefits resulting from maintained jobs was assumed as equal to the salaries of the mine employees adjusted by the factor of dual wages. This ratio was calculated from the formula (European Commission, 2014):

$$WPD = (1 - u) \cdot (1 - t) \quad (4)$$

where:

u — the unemployment rate in the region [%],
t — the amount of social security contributions and applicable taxes [%].

The formula for the valuation of the external social costs of a light accident at work takes the form (own study based on Rzepecki 2005):

$$K_{SWL} = L_{WL} \cdot (ISK_L + K_{NFZL}) \tag{5}$$

where:

L_{WL} — the number of light accidents [number of people],
ISK_L — other components of the cost of a light accident for the victim and the family (among others: costs of treatment, purchase of medicines, transport, purchase of indispensable things) [PLN],
K_{NFZL} — costs of a light accident covered by the National Health Fund [PLN].

The formula for the valuation of the external social costs of occupational disease – the pneumoconiosis of former mine employees takes the form (own study based on Rydlewska-Liszkowska, 2006).

$$K_{SCHZPNE} = (L_{CHZPNE} \cdot (PUNZ_{CHZP} \cdot SJO_{CHZ})) + \\ + ((L_{CHZPNE} \cdot WPŚR_P) \cdot (WŚZ \cdot PRNP \cdot POPE)) \tag{6}$$

where:

L_{CHZPNE} — the incidence of pneumoconiosis (former employees) [number of people],
$PUNZ_{CHZP}$ — an indicator of the average share of disability benefits granted in the event of occupational disease – pneumoconiosis [%],
SJO_{CHZ} — the rate of one-off compensation from the Social Insurance Institution (ZUS) for an accident at work and occupational diseases for 1% of impairment of health [PLN],
$WPŚR_P$ — an indicator of the average share of disability benefits awarded in the event of occupational disease – pneumoconiosis [%],
WŚZ — the rate of treatment benefits,
PRNP — the average amount of pension due to incapacity for work (miners) [PLN],
POPE — the average period of receiving pensions (miners) [number of months].

Ecological losses caused in the aquatic environment were calculated according to the relationship (own study based on Mokrzycki et al., 1992; Famielec, 1999; Piontek (ed.), 1989):

$$S_w = 0,96 \cdot P_w \cdot (Z_{zs} + Z_{ku}) + 0,00166 \cdot P_r \cdot P_{TG} \cdot U_{ur} \cdot L_{mc} \tag{7}$$

where:

P_w — industrial water intake from the surface and underground intakes [m^3],
Z_{zs} — reduction of self-purification water capacity [PLN/m^3],
Z_{ku} — increased costs of treating excessively polluted water [PLN/m^3],
P_r — the volume of global agricultural production of the voivodship [PLN/ha],
P_{TG} — mining area [ha],
U_{ur} — the share of agricultural area (arable land) in the total area of the voivodship [%],
L_{mc} — the number of months covered by the analysis.

The following formula was used to calculate the non-operational hard coal losses (own study based on Mokrzycki, 1992; Famielec, 1999; Piontek (ed.), 1989):

$$S_e = 0,207 \cdot W_c \cdot \frac{P_{sw}}{S_w} \tag{8}$$

where:

W_c — hard coal extraction, gross [Mg],
P_{sw} — revenues from hard coal sales [PLN],
S_w — hard coal sales [Mg].

The losses resulting from soil degradation were calculated as the following (own study based on Mokrzycki et al., 1992; Famielec, 1999, Piontek (ed.), 1989):

$$S_g = 0,0208 \cdot D_{kl} \cdot P_{TG} \cdot U_{ur} \cdot L_{mc} \tag{9}$$

where:

D_{kl} — additional costs of eliminating the negative effects of chemical compounds [PLN/ha],
P_{TG} — mining area [ha],
U_{ur} — the share of arable land in the voivodship's total area [%],
L_{mc} — the number of months covered by the analysis.

The losses on the surface of the earth were calculated using the formula (own study based on Mokrzycki et al., 1992; Piontek (ed.), 1989):

$$S_p = W_{trl} \cdot P_{trl} + R + K_{lsg} + 0,083 \cdot \left(K_d \cdot P_{TG} \cdot U_l \cdot V_d \cdot B_d \cdot L_{mc} \right) \tag{10}$$

where:

W_{trl} — the losses due to the transfer of agricultural and forestry land for other purposes [PLN/ha],
P_{trl} — the area of arable and forest land used for non-agricultural and non-forest purposes [ha],
R — the cost of reclamation [PLN],
K_{lsg} — the cost of the settlement of mining damage (including those financed by the budget subsidy) [PLN],
K_d — the cost of 1 m^3 of sawmill raw material [PLN/m^3],
P_{TG} — mining area [ha],
U_l — the share of forest land area in Poland [%],
V_d — annual growth of wood with a layer of shrubs [m^3/ha*year],
B_d — wood growth decline indicator,
L_{mc} — number of months covered by the analysis.

4. List of data used in the CBA of the mine

In order to assess the economic operation of the hard coal mining sector, the calculations were carried out based on the data from the years 2016-2018 regarding the entire hard coal min-

ing sector in Poland. This data includes the following coal mining companies:

- Polska Grupa Górnicza S.A.,
- Jastrzębska Spółka Węglowa S.A.,
- Węglokoks S.A.,
- TAURON Wydobycie S.A.,
- Lubelski Węgiel „BOGDANKA" S.A.,
- Przedsiębiorstwo Górnicze „SILESIA" Sp. z o.o.,
- Zakład Górniczy EKO-PLUS Sp. z o.o.,
- Spółka Restrukturyzacji Kopalń S.A.

The data obtained by Industrial Development Agency JSC (IDA JSC) was used as part of the "Program for statistical surveys of official statistics" in its "Mining of hard coal and lignite" statistical study (IDA JSC, 2019). It includes the following areas:

- revenues, costs and the financial result of mining enterprises,
- quantity of hard coal mining, gross
- quantity of hard coal sales,
- operational costs by type,
- current production costs, delivery and account receipts,
- operational costs by type – expenditure settled for coal production,
- public-law payments effected by the hard coal mining industry,
- investment outlays in the hard coal mining industry,
- employment status,
- employee age structure,
- number of employees of the hard coal mining industry with retirement entitlements,
- material and financial data characterizing the environmental effects of the hard coal mining industry operations.

The following offices and institutions published the statistical data which was also used for the calculations:

- Statistics Poland (GUS),
- Narodowy Bank Polski (NBP) (https://www.nbp.pl),
- Ministry of Family, Labour and Social Policy (MRPiPS) (https://www.gov.pl/web/rodzina),
- State Mining Authority (WUG),
- Polish Geological Institute (PIG),
- Central Institute for Labour Protection – National Research Institute (CIOP-PIB) (https://www.ciop.pl),
- Ministry of Finance (MF) (https://www.gov.pl/web/finanse),
- Social Insurance Institution (ZUS) (https://www.zus.pl).

The data from official statistics was also used to assess the social and environmental external costs and benefits of hard coal mines. Conversion rates, constants, and statistical values were adopted or calculated, based on literature data, to the level of prices from the period of 2016-2018. The list of data used for the analyses, together with the source, is given in Table 1.

TABLE 1

List of data used for the CBA of the hard coal mining sector in Poland

Name of data	Source of data	Unit	Values		
			2016	2017	2018
1	2	3	4	5	6
Valuation of social external costs and benefits of hard coal mines activities					
1. Benefits of cooperation with other entities					
Costs of materials	IDA JSC, 2019	thousand PLN	2,268,540.2	2,347,415.6	2,561,972.9
Costs of external service		thousand PLN	4,091,313.9	4,127,921.5	4,531,785.9
Labour cost contribution index (production)	own calculations based on NBP data	%	50%	50%	50%
Labour cost contribution index (services)	own calculations based on NBP data	%	70%	70%	70%
The average salary in the industry	GUS, 2020	PLN/month	4,799.52	5,041.91	5,464.42
The amount of unemployment benefit (100% allowance)	MRPiPS	PLN/month	831.10	831.10	831.10
The amount of contributions from the unemployment benefit (100% allowance)	MRPiPS	PLN/month	74.12	74.12	74.12
The amount of tax on unemployment benefit (100% allowance)	MRPiPS	PLN/month	38.00	38.00	38.00
The income tax from individuals	Constant based on MF regulation	%	19%	19%	19%
2. Benefits of tax receipts to the budgets of communes/districts					
Quantity of hard coal extraction, gross	IDA JSC, 2019	Mg	101,565,810	92,959,270	90,431,840
The coefficient of the amount of maintenance fees directed to communes/ districts, fixed on the basis of applicable legal regulations	The rate set by the Prime Minister	%	60%	60%	60%
The rate of exploitation fee for hard coal	The relevant regulation of the Council of Ministers	PLN/Mg	2.34	2.38	2.42
3. Employment – jobs created (maintained)					
Unemployment rate in the region	GUS, 2020	%	6.60%	5.10%	3.90%
The amount of social security contributions and applicable taxes	Constant based on MF regulation	%	60.09%	60.09%	60.09%

1	2	3	4	5	6
4. Accidents at work					
Light accidents	WUG, 2020b	number of people	1,234	1,279	1,355
Heavy accidents		number of people	4	8	4
Costs of remuneration (remuneration, ZUS, employee benefits) (average monthly)	IDA JSC, 2019, own calculation based on ZUS indicators	thousand PLN	735,578.1	766,889.2	882,362.8
Total registered employees		number of people	84,645	82,717	82,843
Other components of the cost of a light accident for the injured person and family (among others: costs of treatment, purchase of medicines, transport, purchase of indispensable things)	Constant based on CIOP – PIB research, updated with the inflation rate	PLN	787.06	802.80	815.64
Other components of the cost of a heavy accident for the injured person and family (among others: costs of treatment, purchase of medicines, transport, purchase of indispensable things)	Constant based on CIOP – PIB research, updated with the inflation rate	PLN	17,763.28	18,118.55	18,408.44
Light accident costs covered by the National Health Fund	Constant based on CIOP – PIB research, updated with the inflation rate	PLN	4,814.16	4,910.44	4,989.01
Heavy accident costs covered by the National Health Fund	Constant based on CIOP – PIB research, updated with the inflation rate	PLN	41,581.59	42,413.22	43,091.84
Occupational diseases					
Incidence – pneumoconiosis	WUG, 2020a	number of people	393	203	158
Incidence – hearing damage		number of people	20	13	14
Incidence – vibratory syndrome		number of people	6	1	2
Costs of remuneration (remuneration, ZUS, employee benefits) (average monthly)	IDA JSC, 2019	thousand PLN	735,578.1	766,889.2	882,362.8
Total registered employees		number of people	84,645	82,717	82,843
The average percentage of damage to health found in the case of occupational disease – pneumoconiosis	ZUS, 2019c; ZUS, 2018b; ZUS, 2017b	%	17.7%	20.0%	19.5%

1	2	3	4	5	6
The rate of one-off compensation from the Social Insurance Institution (ZUS) for an accident at work and occupational diseases for 1% damage to health	https:// www.zus.pl	PLN	780.00	809.00	854.00
Indicator of the average share of disability benefits granted in the case of established occupational disease – pneumoconiosis	ZUS, 2019a; ZUS, 2018a; ZUS, 2017a	%	21.2%	19.8%	19.8%
The minimum period of payment of sickness benefits by ZUS before obtaining disability benefits for occupational diseases	https:// www.zus.pl	months	6	6	6
The average period of collecting an occupational disease pension before receiving treatment benefits	https:// www.zus.pl	months	15	15	15
Index of treatment benefits	https:// www.zus.pl	-	0.50	0.50	0.50
The average amount of pension for incapacity for work (miners)	ZUS, 2019a; ZUS, 2018a; ZUS, 2017a	PLN	3,870.26	3,943.57	4,146.67
The average period of receiving pensions (miners)	ZUS, 2019b	months	285	285	285
Valuation of environmental external costs and benefits of hard coal mines activities					
1. Ecological losses in the aquatic environment					
Industrial water intake from the surface and underground intakes	IDA JSC, 2019	thousand m^3	9,471.3	9,616.4	9,870.6
Mining area	PIG, 2020	ha	76,399.1	72,428.8	67,166.9
Indicator of reduction of self-purification water capacity	Constant on the basis of scientific publications, updated with the inflation rate (Famielec, 1999)	PLN/m^3	0.68	0.69	0.70
Indicator of increased costs of treating excessively polluted water	Constant on the basis of scientific publications, updated with the inflation rate (Famielec, 1999)	PLN/m^3	0.35	0.36	0.37
Quantity of global agricultural production of the voivodship	GUS, 2020	PLN/ha	8,393	7,963	8,752
Share of arable land in the total area of the voivodship	GUS, 2020	%	51.0%	50.9%	50.9%

1	2	3	4	5	6
2. Ecological losses of hard coal, non-operational					
Extraction of hard coal, gross	IDA JSC, 2019	Mg	101,565,810	92,959,270	90,431,840
Revenues from sales of hard coal		thousand PLN	17,993,261.9	20,556,634.2	21,502,338.6
Sales of hard coal		Mg	70,217,060	65,309,328	63,249,888
Non-operational loss rate	Constant based on scientific publications (Mokrzycki, 1992)	%	20.7%	20.7%	20.7%
3. Ecological losses resulting from soil degradation					
Mining area	PIG, 2020	ha	76,399.1	72,428.8	67,166.9
Indicator of the additional costs of the negative effects of the chemical compounds' liquidation	Constant on the basis of scientific publications, updated with the inflation rate (Famielec, 1999)	PLN/ha	487.49	497.24	505.20
Share of arable land in the total area of the voivodship	GUS, 2020	%	51.0%	50.9%	50.9%
4. Ecological losses on the earth's surface					
Cost of a settlement for mining damage (including those financed by the budget subsidy)	IDA JSC, 2019	thousand PLN	251,410.6	245,548.2	371,276.2
Mining area	PIG, 2020	ha	76,399.1	72,428.8	67,166.9
Indicator of losses due to the transfer of agricultural and forestry land for industrial purposes	Constant on the basis of scientific publications, updated with the inflation rate (Famielec, 1999	PLN/ha	5,578.22	5,689.79	5,780.82
Cost of 1 m^3 of sawmill raw material	Constant based on scientific publications, updated with the inflation rate (Mokrzycki, 1992)	PLN/m^3	118.70	121.07	123.01
Share of forest land in Poland	GUS, 2020	%	29.6%	29.6%	29.6%
Annual wood growth with a layer of shrubs	Constant based on scientific publications (Mokrzycki, 1992)	m^3/ha*year	8.25	8.25	8.25
Wood growth decline indicator	Constant based on scientific publications (Mokrzycki, 1992)	-	0.25	0.25	0.25
Calculations of the financial aspects of hard coal mines activities					
Revenues of hard coal mining – total	IDA JSC, 2019	thousand PLN	26,414,943	36,866,836	33,779,799
Costs of current production		thousand PLN	26,266,362	33,214,564	32,517,974

Source: own development

5. Results of the analyses and discussion

The analysis has resulted in a comprehensive economic assessment of the operation of the hard coal mining sector in Poland in the years 2016-2018. The obtained results of the calculations of revenues, benefits, and costs are presented in Table 2. The results of the cost-benefit analysis (CBA) are also presented in Table 2.

TABLE 2

The results of the cost-benefit analysis (CBA) carried out for the hard coal mining sector in Poland in the years 2016-2018 concerning the total revenues of the sector

Item	Unit	2016	2017	2018
Financial income and social benefits				
Total income of the hard coal mining sector	thousand PLN	26,414,943.2	36,866,836.0	33,779,798.5
Benefits of employment	thousand PLN	2,784,003.9	2,934,578.3	3,415,912.6
External social benefits of cooperation	thousand PLN	4,095,598.5	4,194,602.4	4,651,479.4
Benefits of tax receipts to the budgets of communes/districts	thousand PLN	142,598.4	132,745.8	131,307.0
SUM of the revenues and social benefits (ΣB_n)	**thousand PLN**	**33,437,144.0**	**44,128,762.5**	**41,978,497.5**
Operating, environmental and social costs				
Total current production costs	thousand PLN	26,266,362.2	33,214,564.4	32,517,973.7
Costs of accidents at work – light	thousand PLN	6,911.9	7,307.2	7,865.3
Costs of accidents at work – heavy	thousand PLN	5,360.7	11,423.6	6,538.0
Costs of accidents at work – fatal	thousand PLN	12,904.9	10,708.3	22,846.4
Costs of occupational diseases – pneumoconiosis	thousand PLN	55,185.0	27,233.7	22,457.1
Costs of occupational diseases – hearing damage	thousand PLN	2,326.1	1,307.0	1,436.1
Costs of occupational diseases – vibration syndrome	thousand PLN	176.6	32.6	53.8
Ecological losses in the aquatic environment	thousand PLN	15,918.3	15,589.8	16,119.8
Non-operational ecological losses of hard coal	thousand PLN	5,387,473.4	6,056,752.7	6,363,816.5
Ecological losses resulting from soil degradation	thousand PLN	4,740.8	4,577.6	4,312.9
Ecological losses on the earth's surface	thousand PLN	264,281.3	256,864.4	377,008.9
SUM of the operating, environmental and social costs (ΣC_n)	**thousand PLN**	**32,021,641.2**	**39,606,361.3**	**39,340,428.5**
Difference between benefits and costs ($\Sigma B_n - \Sigma C_n$)	**thousand PLN**	**1,415,502.8**	**4,522,401.2**	**2,638,069.0**
Hard coal production	Mg	70,217,060	65,309,328	63,249,888
EV – unit economic benefit of the hard coal production	**PLN/Mg**	**20.2**	**69.2**	**41.7**

Source: Own calculation

The obtained results show that the adopted methodology of economic assessment, using the CBA and available data, enables the comprehensive assessment of the economic efficiency of the hard coal mining sector in Poland. The data necessary to perform the analyzes can be obtained both from the institution dealing with mining statistics in Poland (IDA JSC) and from publicly available official and statistical sources. The results presented in Table 2 indicate that the social costs and ecological losses caused by the activity of hard coal mining have a significant impact on its economic assessment. In the analysed period they constitute, on average, as much as approximately 17% of the sum of all categories of costs. On the other hand, a significant part of the costs of the current production is directly transferred to social benefits, increasing the local well-being of residents, and also contributing to the improvement of the situation in the region. In the analysed calculation period, it was estimated that on average about 24% of the costs of the current operation of the hard coal mining industry is a social benefit from the point of view of the local population, the region, and the general public.

The calculation of the EV indicators carried out shows that hard coal mining in Poland generated more financial and social benefits than financial, social and environmental costs in the years 2016-2018. What is particularly noteworthy are the results of the calculations for 2016, because in that year the hard coal mining industry in Poland recorded a negative net financial result of approximately PLN 3.6 million (Industrial Development Agency JSC, 2019). Despite this, the results of the economic analysis are positive.

6. Conclusions

The adopted methodology for performing the CBA of hard coal mining enables the comprehensive assessment of the hard coal mining sector in terms of economic efficiency. The results of the performed CBA give a broad assessment of hard coal mining, ranging from the most important environmental aspects (which include, in particular, the degradation of water and land) to social aspects which are relevant from a local and national perspective (direct employment, cooperation with other employers, costs of accidents at work and occupational diseases). This is possible due to the results of the CBA, which in addition to the financial aspects essential for the owner of the mine, take into account the environmental and social effects of activities related to coal mining. The adopted CBA methodology was used to assess the hard coal mining sector in the years 2016-2018. This was enabled by the availability of the data necessary to perform the analyses and the extent of the social and environmental aspects covered. Considering the total activity of the hard coal mining sector in Poland, this industry generated more financial, social and environmental benefits than costs in the analysed period. The benefits, as calculated per unit of extracted coal, ranged from PLN 20.2 / Mg in 2016 to PLN 69.2 / Mg in 2017. The conclusion based on analyses is that the most important among social benefits are external profits from cooperation. This shows that the impact of mining on the economy goes far beyond its core business. What is a cost for mining (e.g. expenditures on materials, energy, employee remuneration) is an influence, which enables other entities in the socio-economic environment, to operate and develop. On the other hand, on the side of environmental and social costs, the greatest value is attributed to non-operational ecological losses. Special attention should be given to the results for the year 2016. Despite the fact that this year the hard coal mining industry in Poland recorded negative net financial result, the results of economic analysis give a positive result. Positive results of the CBA analysis were also obtained during previous studies, results of which were presented in the

work of Krawczyk et al. (2016). However, those works were focused only on two selected coal mines from the Upper Silesian Coal Basin and may not be referred to for the assessment of the entire hard coal mining sector. This is why the authors of this paper have reverted to this subject, this time, however, covering the entire hard coal mining sector in Poland.

For numerous reasons, mainly financial, the rapid transformation of the Polish coal-based energy sector towards the use of technologies with significantly lower CO_2 emissions, or technologies which do not emit this greenhouse gas, is not possible. A long-term transitional period is needed for investments in new electricity generating units based on fuels other than coal. During this time, domestic coal-fired power plants will need fuels which can be obtained from domestic deposits, thus supporting the Polish economy.

Polish hard coal mining sector, in addition to financial, environmental and social costs, also generates a number of benefits for society and the national economy in the analyzed period, which more than compensate for these costs. The import of coal from abroad avoids these costs, but at the same time eliminates a number of benefits associated with the business sector.

The results of the analyses justify the existence of the hard coal mining industry in Poland, as long, as efficient restructuring activities aimed at reduced cost of coal production are continued. The calculated benefits represent only a small part of the coal production costs, which in the analysed period ranged from PLN 374.1 / Mg in 2016 to PLN 514.1 / Mg in 2018 (Industrial Development Agency JSC, 2019). With higher coal production costs, the results of the CBA analysis may turn out to be negative.

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