Impact of changes in coal prices and CO_2 allowances on power prices in selected European Union countries – correlation analysis in the short-term perspective

***Mariusz Andrzejewski*[1], *Patryk Dunal*[1] and *Łukasz Popławski*[1]**

Spreads on power markets serve as indexes that allow assessing the future profits of electric utility companies. The spread applicable to power generated from coal, including the cost of CO_2 allowances and power plant efficiency, has been termed Clean Dark Spread (CDS). A CDS index may serve at least two basic functions. On the one hand, it provides information on the future prices of power and profitability of power generation. On the other, it facilitates hedging to be applied not just by power plants but also by other entities operating on the market. Following deregulation of energy markets, energy has started to be traded on the exchanges and trading facilities, which is also reflected on Polish Power Exchange operating on the Polish market. Following the introduction of the European Union Emissions Trading Scheme, Polish energy generating companies hedge the prices of CO_2 emissions allowances with the use of foreign trading facilities, especially EEX. Since two out of three CDS constituents are traded on trading facilities, it seems fully substantiated also to introduce quotations of coal prices in Poland. This paper is aimed to present the crucial aspects of shaping coal prices in Poland and on international markets as well as to examine the impact of changes in coal prices and CO_2 emissions allowances on shaping power prices based on a comparative analysis between Germany and Poland. This study also includes the costs incurred by the coalmines by paying environmental charges on waste resulting from their economic activity.

Nonetheless, it should be noted that those charges do not affect the financial result. The analysis of the correlation has shown that the price of electricity on the Polish market is positively and strongly correlated both with the price of coal and the price of CO_2 emissions allowance, the latter correlation being stronger. Equally worth noting is the strong correlation between coal prices in Poland and the prices of CO_2 emissions allowances. With regard to the confirmed but rather not very strong positive correlation between steam coal prices on the Polish market and energy coal prices in the ARA zone, it should be noted that there is no liquid index in the domestic market, which hampers efficient portfolio management of the spread on energy production by the coal energy sector

Key words: *Dark Spread, price of power, price of coal, cost to coal mines of environmental charges, CO_2 emissions allowances.*

Introduction

The development of the energy sector in terms of the use of derivative instruments to stabilize financial performance encouraged creating similar opportunities within purchases of primary power carriers, in particular of coal which is one of the fundamental fuels in global terms. Perennial contracts have been, and still are being replaced with spot and forward transactions, with delivery on a specified date. This necessitated the construction of appropriate price indexes which facilitate monitoring and analyzing market trends as well reporting and modelling the behaviour of other entities (Shiv Prakash and Hooman, 2018; Gavurova and Šoltés, 2013; Straka et al., 2018), and which also are applied to controlling inside companies (Gonos et al., 2016; Stojanović, 2013; Khouri et al., 2017; Rosová 2010). Owing to the price indexes, coal-based power energy generating companies from Europe can effectively hedge their Clean Dark Spread which includes three major constituents: the price of power, the price of coal and the price of CO_2 emissions allowance.

On the European market, all these constituents are traded on transparent and efficient trading facilities. Poland does not offer any efficient hedging instruments for CDSs under the assumption that coal has been purchased in Poland whereas the derivative instruments are based on international coal. Such solutions also help to mitigate the risks (Domingues et al., 2017), and it is worth noting that similar steps are taken in other countries (Madzík et al., 2016; Kozina and Pieczonka, 2017). In keeping with the preceding, this paper is aimed at evaluating the impact of changing coal prices and the cost of CO_2 emissions allowances on energy pricing.

This study presents the crucial aspects of shaping the price of coal in Poland and on international markets. It also examines the impact made by the changing coal prices, the cost of CO_2 emissions allowances as well as the environmental charges levied on waste on shaping the prices of energy by means of a comparative analysis between Germany and Poland.

Calculation of spreads on power markets

In its simplest terms, the spread should be understood as a difference between two flows of cash related to the same asset or assets within the chain of generating added value. Hence, the spread may be the difference

[1] *Mariusz Andrzejewski, Patryk Dunal, Łukasz Popławski,* Faculty of Finance and Law, Cracow University of Economics, Rakowicka 27, 31-510 Cracow, Poland, mariusz.andrzejewski@uek.krakow.pl , dunalp@uek.krakow.pl , lukasz.poplawski@uek.krakow.pl

between the bid price (the purchase price) and the asking price (selling price) of an asset. In the case of the energy market (to be precise, the energy generating company) spread will represent the difference between the price of energy and the cost of fuel necessary for its generation.

Due to the fact that prices of fuels are subject to fluctuations, spreads for energy generating companies using various fuels are different. For this reason, various spreads have been designated for energy generated from various fuels. The value of spread for energy generated from coal, that is, Dark Spread, is calculated using the following formula (Abadie et al., 2008):

$$DS = PE - PC \text{ [PLN/MWh]} \tag{1}$$

where:

DS – Dark Spread [PLN/MWh]

PE – Price of Energy [PLN/MWh]

PC – Price of Coal used to generate 1 MWh of energy [PLN/MWh]

On the market level, two values are necessary for fixing the spreads: the price of energy and the price of coal necessary for its generation. The price of energy is the price quoted on a certain day. Within a day, the price of energy is volatile. Hence it would be opportune to set the value of spreads with the use of the average weighted price of energy in individual hours, and the weight would reflect the volume of energy sales at a certain hour. Apart from the price of energy, the cost of fuel has a decisive influence on the value of the spread. In the case of coal, that will be the coal reference price set for a given place on the globe. For Western European markets, that price is commonly close to CIF[2] price for ARA[3] ports, as more amply explained further in this study.

Once the price of coal, the price of energy, and the average efficiency of a power plant are familiar, it is possible to establish the value of the spread. Spreads are calculated for a specified energy market – in most cases; it is the market of one country. This is due to the fact that the power systems of individual countries are independent of one another. Hence there are different quotations for energy. The values of spreads are published by the agencies which specialize in collecting information on raw materials and power markets (for example, ArgusMedia). Those centers gather information from various sources, and for that reason, there might be negligible differences in quoted spreads.

The value of the spread is decided by the efficiency of a power plant, which in turn depends on the kind of burnt fuel. The estimated efficiency ratio for coal-fired power plants is approximately 38 %. Formula (1) will be transformed once it is provided with the efficiency ratio. Because the price of coal necessary to generate 1 MWh depends on the price of 1 ton of coal and power plant efficiency, the following formula is used:

$$ER = PC / E \; [PLN/MWh] \tag{2}$$

where:

ER – Efficiency Ratio [PLN/MWh]

PC – Price of Coal [PLN/MWh]

E – power plant efficiency [%]

After substitution we obtain:

$$DS = PE - (PC / E) \text{ [PLN/MWh]} \tag{3}$$

In order to unify how DS is calculated within a single market, the efficiency ratios of a power plant should be clearly defined. To give an example, those ratios for calculating German Dark Spread and Polish Dark Spread stand at 35 %. The efficiency of 35 % of burning coal was defined for coal of average calorific content of 6100 kcal/kg (1 Mg of such coal equals approximately 7.1 MWh). In case of spreads published by brokerage agencies, the negligible difference between the calorific content of coal accepted for Dark Spread calculations and the one which is applied for setting transaction costs on fuel markets is of no substance. That is because they are more a profitability coefficient for the whole industry rather than for a single company.

The spread value should be adjusted by the cost of CO_2 emissions allowance since that cost translates directly into the price of energy generated from the use of fossil fuels. It has been accepted that to generate

[2] CIF – according to Incoterms(R)2010: Cost, Insurance and Freight.

[3] ARA – main ports for European market: Amsterdam, Rotterdam, Antwerp.

1MWh; it is necessary to burn fuels, which, in case of coal, results in the emissions of 0.96 Mg CO_2 (Camargo et al., 2018). The formula, including CO_2 emissions allowance cost, is as follows:

$$CDS = DS - C\ CO_2\ x\ 0.96 \text{ [PLN/MWh]} \quad (4)$$

where:

C CO_2 – price of 1 ton CO_2 emissions allowance

After substitution, the final formula for calculating spread value is as follows:

$$CDS = CE - (CW/E) - C\ CO_2\ x\ 0.96 \text{ [PLN/MWh]} \quad (5)$$

The CDS coefficient may serve at least two functions. On the one hand, it shows market trends in these areas based on which allows predicting indirectly about the future prices of energy and profitability of energy generation. On the other hand, it allows power plants as well as other entities operating on the market to hedge.

Determinants shaping energy prices and the structure of costs of its generation

One of the most important elements of the functioning of the mining industry is planning (Nehring et al., 2018; Pawliczek et al.; 2015, Straka et al., 2017) and financial issues (Czillingová et al., 2012), especially the sources of financing (Markulik et al.; 2018) and information aspect too (Małkus and Wawak, 2015). In the process of making decisions in mining industry, not solely financial ones, more and more important role is attributed to various coefficients (Vilamova et al.; 2016, Sánchez-González et al., 2017; Zimon and Domingues, 2018) and methods (Johannsen and Fill, 2017; Lohrmann and Reichert, 2016; Camargo et al., 2018), including multicriteria ones (Straka et al., 2014), even though in Poland and Slovakia the human factor (social and political factor) (Cehlár et al., 2015), remains a significant determinant.

The value of CDS depends on the cost of energy generation in a power plant. Hence, each energy generating company may assess whether their spread, that is, profit made on 1 MWh is lower or higher than the market average and look at their competitive advantage relative other entities. Energy generating companies who wish to use spreads in their analysis of profitability and production should observe the following procedure; when spread on the market is too large, that is, it is more than sufficient to cover variable and fixed costs, it is beneficial to generate energy from a chosen fuel. When the spread is too little (or adverse), and it does not suffice to cover even variable costs, then it is more beneficial to halt energy generation and sell fuel purchased on the market or store it till spread has become larger. Such a solution is not feasible over a short period of time since a power plant cannot simply have their power blocks switched off to offset current changes of spread values. It is beyond any doubt that in the long term, spread value should remain above a certain figure, which varies from plant to plant as each of them has to bear certain costs, apart from the cost of fuel, necessary for the functioning of the whole facility. Clear values of spreads show merely the profit (or the loss) on sales of energy and they do not include other costs of a power plant. Figure 1 presents the structure of costs of energy generation depending on the type of fuel.

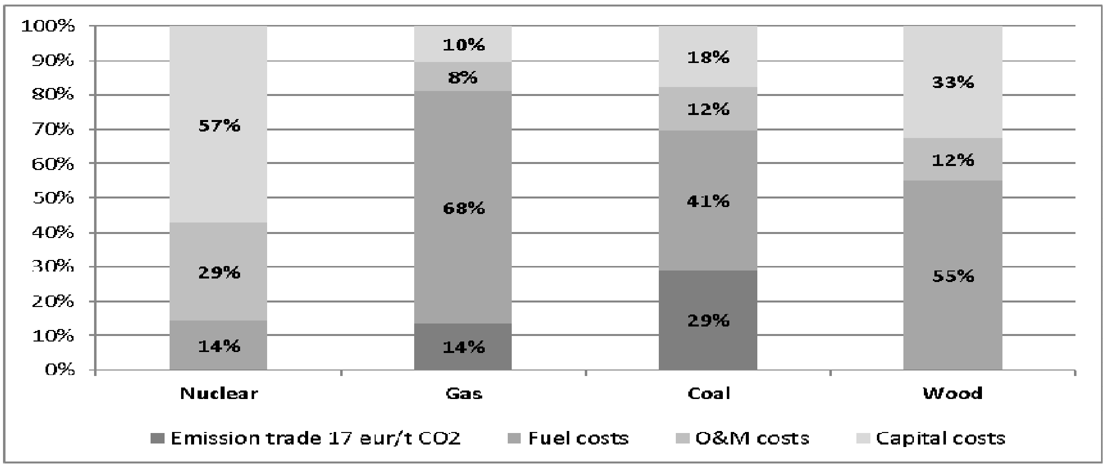

Fig. 1. Energy generation costs, including emissions trading.
Source: Authors' elaboration based on T. Risto, K. Aija, Comparison of electricity generation costs, Lappeenranta University of Technology, Lappeenranta 2008, p. 9.

All three variables used in the calculation of spread – the price of coal, the price of CO_2 emissions allowance, and the price of energy, are market variables on the international markets and as such, they are not dependent on the decisions made by the individual market entities. The market price of energy, which is subject to cyclical (daily, annual) fluctuations exert the biggest impact on the value of spreads. That price depends on the following variables (Lorenz and Grudziński, 2009; Straka, 2010; Blistan et al, 2012):

- ambient temperature (the season of the year) and the power of wind in places where wind turbines have been installed (the impact on coal-generated energy in merit order), merit order – a system of classification of the available resources in the context of power generation, with reference to the cost of generation, used by the operator of the national power generation system. In a centralized system of grid management, it means that the facility with the lowest marginal costs have power fed to the grid first to meet the demand,
- water level of rivers (as a source of hydropower and also a cooling agent for Main Activity Producer Electricity Plants), such incident occurred in Poland in August 2015, when due to high ambient temperature and low river water level, power plants in Połaniec and Kozienice experienced difficulties with cooling (and consequently with power generation),
- the profitability of coal-fired power plants calculated with the sales margin in Main Activity Producer Electricity Plants (CDS),
- the global volume of energy generation by nuclear plants and renewable sources,
- scheduled overhauls of power plants and their maintenance (usually they are scheduled for the period of lower energy and heat consumption). Also, random malfunctions of power generators and disruptions of the transmission grid,
- limitations in global rail transport of coal from the mines to the seaports,
- changes in ocean and Mediterranean freight charges and the cost of rail transport,
- currency exchange rate fluctuations.

The prices of fossil fuels are not subject to cyclical changes. They are dependent on the long term expectations of the market participants about supply and demand for a certain fuel. A similar situation may be observed on the market of emissions allowances. The prices of allowances much depend on the current economic situation. With the increase in the demand for energy (including energy generated by burning fossil fuels), the prices of allowances should rise. By comparing the three constituents, we might try to assess the value of spreads on the energy market.

When the price of one constituent changes due to non-fundamental factors (for example, owing to the changes on the stock exchange or a rapid increase in the consumption of energy caused by a rise/drop of ambient temperature which result in boosting energy price) spreads may be subject to volatile changes over a short timeframe. That is because the other factors affecting the volume of spreads will not adjust to new conditions. Due to that volatility, spreads may reach negative values within certain timeframes. However, such a situation may not persist for too long as power plants would not find energy generation profitable. A smaller supply of energy would contribute to raising its price, which in turn would result in the increased spread and restoring profitability.

The above premises refer to an energy generating company which sells energy and buys fuels on the spot market. In this way, they help to show the current profitability of energy generation with the use of a certain fuel. Nonetheless, fuels are purchased in advance with the use of futures contracts. For this reason, presenting current values of spreads in the situation when a power plant has to generate a certain volume of energy is not very helpful for an energy generating company in determining current profitability of energy generation. The situation would change once a power plant was in a position to increase or decrease the volume of generated energy. Under such circumstances, it could react to the current situation on the market and adjust its output. At this point, the analysis of the volume of spreads might be useful to adjust the volume of output to the grid. In view of the fact that energy is a commodity which may not be stored, such a solution is not feasible for a greater number of power plants. Once a massive adjustment of energy supply is not an option, the use of hedging may be the solution. By gathering market information on the prices of energy, correlating it with the forecasts and instituting proper hedging instruments for the purchase of fuels and energy sales, an energy generating company may successfully predict future profits and the costs of operation.

The greater the diversity of fossil fuels burnt by power plants, the greater the opportunity for changing the type of spread on the market. For this reason, the use of spreads will depend on diversification of energy sources on the market.

The methods for setting coal prices on the Polish and international markets

International trade of energy coal is organized via trading facilities which allow transactions without the necessity for the parties to meet face to face. GlobalCOAL, a partnership headquartered in London, which was founded in April 2001 by a group of participants in the international coal market, operates in this area. Transactions are made via a dedicated computer system which allows its users to bid in real time with the adjustments for the quality of coal.

Due to supply and demand forces, global trading facilities (mainly globalCOAL and ICE) conduct buy-sell transactions. Information about those is aggregated into price indexes. In economic sciences, a price index means a mathematical formula, most often expressed with arithmetic mean or weighted price of a selected group of commodities. It is worth noting that an index may be structured either on a wide range of commodities or their single class. On international markets, coal price indexes express energy coal prices relative to standardized quality (ICIS Services, 2018).

The most popular quality benchmark is coal with working calorific value of 6000 kcal/kg (25.12 MJ/kg) and sulfur content below 1.0 %. On international markets, coal price indexes are based on the application of Incoterms®2010, which have been described further in this chapter. Exporters prices are expressed as FOB (Free on Board), whereas importers prefer CIF (Cost Insurance Price) in the port of entry (Lorenz, 2009).

API (Average Price Index) elaborated by Tradition Financial Services in 1997 (Hiemstra, 2004) is the most commonly recognized coal market indexes. API indexes are typical derivative indexes based on weekly coefficients published by Argus Coal Daily and McCloskey Coal Report. For the European market, API 2 (CIF ARA) index is most appropriate. It has been structured as an arithmetic mean of two indexes; Argus CIF ARA and McCloskey’s NWE steam coal marker. API 2 is based on the working standard coal calorific value of 6000 kcal/kg (25.12 MJ/kg).

As they are widely recognized on the market and subject to daily quotations, the above index is commonly applied in risk management. This has been proved by making that index a benchmark price for financial derivatives such as forwards, swaps or futures.

Unlike the international markets, in Poland, energy coal prices are mutually negotiated by the parties. In the command economy which operated before the economic transformation of 1989, coal prices were arbitrarily (Blaschke, 1999 and 2000) set by the Minister of Mining, and approved by the State Price Commission (Lorenz, 2011). Since 1990, price formulae started to be used in coal trade; these were mathematical formulae applied to calculate the price of coal with the use of quality parameters. According to the new formulae, the price of coal is adjusted to ash and sulfur content as these parameters are crucial from the exploitation and environmental angle.

Also, buy/sell contracts stipulated thresholds for sulfur and ash content. Once the thresholds were exceeded in a single transaction, the seller would grant the buyer a discount, for example, 1 % off the price for each 1 % of ash over the permissible limit. Such a solution was adopted from the international trade practice where the coal calorific content reference price was set for coal with 6000 kcal/kg, ash content 12-15 % and sulfur content up to 1%. Hence, the transaction price of coal depended on the volume of deviation of quality parameters from the quality of reference (model) coal. Additionally, the price of coal depended on a special We coefficient, which was set to promote coal with lower ash content. That formula, popularly called Blashke formula, was adopted as binding for the domestic energy coal trade in May 1990 by the decision of the then Minister of Finance (Blaschke and Ney, 1998).

At this point, it is worth mentioning that the basic provisions of the formula which was to promote low sulfur and ash coal were off the mark in view of high (over 30 %) inflation and devaluation of Polish currency. Paradoxically, the too large price differential of coal with a low or high content of ash and sulfur resulted in dropping demand for the former, which brought the result opposite to what was intended (Winkler, 2011).

It should be mentioned that in 1992 coal prices in Poland were freed, and the use of the 1990 pricing formula was no longer mandatory. Nevertheless, the use of formulae had become accepted market practice, and price formulae were still widely used in purchase and sale transactions of steam coal.

When Poland joined the European Union in 2004, legal regulations and numerous aspects of the markets were attuned to EU standards in various areas of the economy. The coal mining sector, by large embarked upon disintermediation, with coal mining companies entering into large contracts directly with main activity producer electricity plants. Likewise, the mentality underlying the planning and contracting quantities of deliveries changed. The change consisted in the fact that energy generating companies no longer bought coal by the ton, but rather purchased chemical energy contained in the coal, viewing coal from the angle of the purpose of energy generation. This change in mentality resulted in a changeover in how coal prices came to be calculated – the prices were quoted in Polish zlotys per gigajoule (PLN/GJ) instead of the hitherto quotation in Polish zlotys per ton of coal (PLN/t). It is also worth mentioning that as the internet matured and became a household name, coal mining companies began posting their sales offers on their websites (Lorenz, 2009). Price lists are approved by the companies’ management boards based on the price of reference coal in the coal class with a calorific value exceeding or equal to 21 MJ/kg and sulfur content of up to 0.8 %. Prices for various classes are calculated as a function of calorific value and sulfur content and presented in the form of a price matrix.

It is worth noting that price lists contain potential prices for spot transactions on the FCA coalmine basis under Incoterms® 2010. At the moment, no forward purchase and sale transactions are being arranged in Poland. In long-term contracts, use is mostly made of the pricing above formulae, taking into account changes in fuel markets as well as in the domestic and global economy. In the case of large customers, purchase prices are usually agreed during trade negotiations in which the decisive factors are: current market price of coal, contracted volume, contracted coal quality specification, delivery period, Incoterms® 2010 terms of delivery, payment terms and the parties' financial standing and assessment of the resulting credit risk. It is worth noting that in the case of public or municipal customers, coal purchases are made by way of tenders based on public procurement law. Tenders are also used for smaller private customers, in particular from the industrial sector.

There have been several attempts in Poland to create a national coal price index. Particularly notable are the following:

1. Polish Steam Coal Market Index PSCMI (Polski Indeks Rynku Węgla Energetycznego) - an index of historical quotations created as a result of the cooperation of the Polish Power Exchange plc (Towarowa Giełda Energii S.A. -TGE), Industrial Development Agency (Agencja Rozwoju Przemysłu S.A. - ARP) and the GSMiE Institute of the Polish Academy of Sciences (PAN) in Krakow presented at a 2014 conference on "Issues of fossil fuels and energy in the national economy" held in Zakopane (Paszcza and Olejniczak, 2014) and available at www.polskirynekwegla.pl,
2. the concept of fixing thermal coal prices in Poland on the basis of the index of coal prices on the European market - a concept by A. Bocheński and P. Dunal (2006) presented in 2016 at the conference on the "Issues of Fossil Fuels and Energy" held in Zakopane organized by the Polish Academy of Sciences and proposing a pricing formula based on the API2 price index, which would lay ground for the publication of spot and forward prices as well as conclusion of hedging transactions in coal trade (Bocheński and Dunal, 2006).

Summarizing the considerations in this chapter, it should be noted that increased trade on international coal trading platforms has inspired groups of experts to create price indexes of thermal coal, which constitutes the main source material adopted for empirical studies. Price indexes are a very important analytical tool constituting the basis for market players' pursuit of the transaction, investment, and financial policies. The importance of coal price indexes is continuously growing due to their proliferation and improvement of their construction. The increase in the transparency of individual markets as well as the creation of opportunities to reduce the risk inherent in economic activity due to price volatility arising from the development of global financial markets indicates that the introduction of coal price indexes has proven to be a success (Andrzejewski et al., 2015).

Analysis of short-term correlation of prices of energy, coal and CO_2 emissions allowances

In line with the objective of this study, an analysis was made of the short-term correlation of prices of energy, coal, and CO_2 emissions allowances. The most popular price indexes for individual CDS components were selected for the analysis, which were considered as the most representative and reliable information regarding the discussed market variables. The analysis compares the Polish and German markets. The two markets have been selected for comparison because of their proximity to each other (Germany and Poland are neighboring states), as well as because Polish producers of coal-powered electricity acquire CO_2 emissions allowances via the German EEX platform. The analysis is based on data from EEX (European Energy Exchange, as regards energy prices in Germany and CO_2 emissions allowances), Polish Power Exchange (Towarowa Giełda Energii -TGE as regards energy prices in Poland), Argus Media (as regards coal prices according to the API2 CIF ARA index) and ARP (Industrial Development Agency, as regards coal prices on the Polish market).

It should be noted that for steam coal prices, there are no liquid price quotations on both the Polish and German market - for this reason, the API2 CIF ARA index was used for the analysis. In addition, Polish market participants carry out transactions on CO_2 emissions allowances using EEX, as there is no liquid market for this asset in Poland. The analysis utilizes the Pearson correlation coefficient and covers 13 months between April 2017 and April 2018. The results of the correlation analysis are presented in Table 1.

Tab. 1. Short-term correlation analysis of prices of coal, energy, and CO_2 allowances.

	Pearson correlation April 2017 – April 2018
API2 CIF ARA vs. Polish coal price	0.41
EEX energy price vs. TGE energy price	0.68
Polish coal price vs. TGE energy price	0.68
API2 CIF ARA vs. EEX energy price	0.72
CO_2 allowance vs. TGE energy price	0.77
CO_2 allowance vs. EEX energy price	0.45
CO_2 allowance vs. Polish coal price	0.86
CO_2 allowance vs. API2 CIF ARA	0.38

Source: author's work based on EEX, TGE, Argus Media, ARP data.

Based on the correlation analysis, the following conclusions can be drawn:

- there exists a relatively weak correlation between coal prices on the international market and the Polish market (0.41),
- there exists a relatively strong positive correlation between the energy price in Germany,
- and the same in Poland (0.68),
- the price of electricity in the Polish market is positively and strongly correlated both with the price of coal (0.68) and with the price of CO_2 emissions allowances (0.77), the latter correlation being stronger,
- the price of electricity in the German market is positively and strongly correlated only with the price of coal (0.72),
- the strength of correlation of the electricity price on the German market and the price of CO_2 emissions allowances is weak (0.45),
- there is a strong correlation between coal prices in Poland and prices of CO_2 emissions allowances (0.86),
- the strength of correlation of the coal price in the international market and the prices of CO_2 emission allowances is weak (0.38).

Costs to coal mines of environmental fees levied on economic activity in Poland

The costs borne by coal mines consist of several cost types, including the particularly interesting costs of environmental fees levied on the pursuit of business activity in Poland. It is widely alleged that the costs of waste generated by the mining industry constitute a heavy burden, which is why these charges are analyzed in part of the paper. In the general opinion of people, these costs are among the most important elements of the cost mix. In 2016, Poland generated 140 million Mg of waste, of which 8 % was a municipal waste (12 million Mg). Since 2000, the amount of waste generated in Poland (excluding municipal waste) ranged from 110-130 million Mg. The 128 million Mg of non-municipal waste in 2016 means a 2 % decrease in 2015. As in the previous years, the main sources of waste in 2016 included: mining and quarrying (about 52 % of the total generated waste, that is, 72.8 million Mg), industrial processing (21 %) and electricity production and supply (16 %). In the last decade, the largest share in the amount of generated waste has been waste generated during the exploration, extraction, physical and chemical processing of ores and other minerals (56 % in 2016) and waste from thermal processes (22 %). Out of the total amount of waste generated in 2016, 49 % of waste was recovered, 42 % was disposed of via storage, and 4 % was otherwise disposed of (2018 NFOŚiGW, Narodowy Fundusz Ochrony Środowiska i Gospodarki Wodnej, data).

Based on data from the Central Statistical Office yearbook 2017, in 2016, Poland generated over 67 million Mg of mining waste. In this case, the authors have data from all provincial marshal offices – based on the data, it appears that fees are only paid in the province of Dolnośląskie.

According to art. 26.3 of the Mining Waste Act, as regards inert mining waste other than hazardous and inert waste and waste not contaminating soil, the provisions of the Environmental Protection Law regarding charges do not apply, which means that the storage of such types of mining waste is not subject to environmental charges levied for waste storage. However, the regulations are different in the case of hazardous mining waste for which fees (and increased fees) are mandatory due to the use of the environment for waste storage. This situation occurs only in Dolnośląskie province, where the fees totaled (average currency exchange National Polish Bank ratios from the end of each year):

- 2013 - 4330 PLN (1044 EUR, by EUR/PLN 4.1472),
- 2014 - 8 923 PLN (2093 EUR, by EUR/PLN 4.2623),
- 2015 - 9 171 PLN (2152 EUR, by EUR/PLN 4.2615),
- 2016 - 8 510 PLN (1924 EUR, by EUR/PLN 4.4240),
- 2017 - 1 080 PLN (259 EUR, by EUR/PLN 4.1709).

For comparison, at the same time, total waste storage fees constituting a charge for using the environment are presented in Table 1. They were the highest in 2014-2015.

Based on CSO data, the overall volume of waste on a year-by-year basis remained more or less unchanged, so based on this simple analysis, it should be stated the that the costs to coal mines of environmental fees arising from waste management related to the pursuit of economic activity in Poland are negligible as compared to other costs – they are in thousands of zlotys rather than in millions, and do not, therefore, constitute, as claimed, a heavy burden. Based on the analysis, it should be stated that the impact of environmental charges for waste on the price of electric energy is equally negligible

Tab. 2. Total waste storage fees constituting a charge for using the environment in 2013-2017 by voivodship (province).

Voivodship	2013	2014	2015	2016	2017
Dolnośląskie	3 007 448	4 615 841	4 069 391	3 236 629	2 774 241
Kujawsko-pomorskie	1 789 633	2 350 599	2 416 800	1 994 074	1 379 796
Lubelskie	1 571 129	2 286 342	1 733 485	1 206 589	767 087
Lubuskie	1 104 969	1 566 850	1 447 111	1 305 025	947 044
Łódzkie	6 677 684	13 456 336	14 792 246	16 205 767	15 363 163
Małopolskie	2 332 641	2 845 833	2 411 271	2 747 020	1 638 264
Mazowieckie	3 076 960	3 923 566	4 005 355	3 545 675	3 224 806
Opolskie	1 111 610	1 396 499	1 207 949	1 547 813	872 602
Podkarpackie	1 773 044	1 543 357	1 586 661	1 574 453	986 285
Podlaskie	591 707	887 688	1 001 810	1 026 683	978 951
Pomorskie	2 598 741	3 704 007	2 666 300	2 902 082	1 731 197
Śląskie	3 423 642	6 122 611	6 495 613	5 844 983	4 725 149
Świętokrzyskie	768 415	787 163	889 050	832 142	647 680
Warmińsko-mazurskie	1 254 886	1 622 478	1 592 788	1 389 949	1 338 442
Wielkopolskie	5 546 521	9 878 363	10 690 589	9 123 781	6 218 738
Zachodniopomorskie	4 535 545	4 937 863	4 701 592	5 320 515	4 840 908
Total	41 164 575	61 925 396	61 708 011	59 803 180	48 434 353

Source: NFOŚiGW, 2018 data.

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Summary

The analysis of the correlation shows that the price of electricity on the Polish market is positively and strongly correlated both with the price of coal (0.68) and the price of CO_2 emissions allowances (0.77), the latter correlation being stronger. Equally worth noting is the strong correlation between coal prices in Poland and the prices of CO_2 emissions allowances (0.86).

With regard to the confirmed but rather not very strong positive correlation between thermal coal prices on the Polish market and energy coal prices in the ARA zone (0.41), it should be noted that there is no liquid index in the domestic market, which hampers efficient portfolio management of the spread on energy production by the coal energy sector. In international markets (including the ARA zone), prices of coal and derivative instruments are a consequence of the needs related to securing CDS. In the wake of the deregulation of energy markets, energy has come to be transacted on commodity exchanges and trading platforms, which is also corroborated by the existence of the Polish Power Exchange (TGE) operating in the Polish market. Following the launch of the European Union Emissions Trading System (EU ETS), Polish power generating companies hedge the prices of CO_2 emission allowances on foreign trading platforms, in particular on the EEX. Given that the trade of two of the three CDS constituents takes place via trading platforms, the need to introduce quotations of coal prices in Poland also seems to be fully justified.

One advantage of high market liquidity is that it ensures a fair and representative valuation of a given traded commodity and transparency of information on the reference market price. The very existence of such information permits the effective allocation of resources in the economy, in particular with regard to assessing the profitability of investment projects and determining business strategies. There is no price index in the Polish coal market, which would provide a reliable reference price and permit effective price risk management. The main obstacle standing in the way of its introduction is limited access to information on transactions, as well as a lack of a clear methodology for its determination. Due to the high concentration of market power in the hands of a small number of entities in the fuel and energy sector and the resulting low degree of liquidity in the Polish coal market, the concept presented by A. Bocheński and P. Dunal (2016) regarding the connection of coal prices in Poland with Europe's most common and widely acknowledged API2 price index based on the price formula seems to be justified. The main reservations voiced by the players in the Polish coal market about the implementation of such a solution regard price volatility arising from international factors, including in particular the rate of economic growth in Asian countries. It should be explicitly affirmed here that the development of risk management systems in business entities offers a positive hedge against price volatility. The introduction of a pricing formula linked to the API2 index does not mean that producers (coalmining sector) and consumers (energy sector) of coal must be exposed to the risk of price volatility. This risk can be transferred in an effective, and even total way to intermediaries and financial institutions operating in international markets, which boast high-risk management skills and massive financial capabilities. Effective price risk management in Poland will lead to stability and predictability of mining and energy companies' results (Dunal, 2018).

Referring to the wholesale electricity market in Poland, it is worth adding that it currently relies on contracts that are settled after the actual delivery, which essentially curtails the possibility of its liquidity growth and the potential for the development of financial products that could be used to effectively manage the risk by electricity generating companies. Therefore, the development of the financial segment of this market is becoming a precondition for boosting not only the liquidity of the wholesale market but also for increasing access to products that best meet the financial risk management needs of trading entities (Wojtkowska-Łodej et al., 2014).

As regards the costs of environmental charges for waste arising in the course of business operations in Poland as borne by coal mines, it should be stated that these charges do not affect the bottom line, as they account for a very small amount and percentage of costs relative to other costs. Based on the above, it should be stated that the impact of environmental charges for waste on the price of electric energy is equally negligible.

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