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AURELIA RYBAK[1], ANNA MANOWSKA[2]

The forecast of coal sales taking the factors influencing the demand for hard coal into account

Introduction

A turbulent environment is a term that, in recent years, has been increasingly used in relation to the environment in which enterprises operate around the world. A turbulent environment means a complex, uncertain and unstable environment (Wojtkowiak 2015; Krupski 2009). This type of environment means that the company's management does not have adequate information about the micro, and above all, the macro-environment. This is caused by constant changes. The environment of enterprises is becoming less and less predictable, changes appear faster and faster and they are more and more widespread. Their impact on the company is significant. The above-mentioned phenomena refer to all groups of macro-environmental factors of the enterprise, namely: social, political, economic, technological and international. The reason of this phenomenon is, among others, globalization, which results in markets becoming ever greater, while the life of products is shortened. The purpose of this publication is to present tools that can help mining enterprises to function on a volatile

✉ Corresponding Author: Aurelia Rybak; e-mail: aurelia.rybak@polsl.pl
[1] The Silesian University of Technology, Gliwice, Poland; ORCID: 0000-0002-5945-7991; e-mail: aurelia.rybak@polsl.pl
[2] The Silesian University of Technology, Gliwice, Poland; e-mail: anna.manowska@polsl.pl

market. This is particularly important in light of the seasonality of demand for coal. The changes may create problems for the company, but they are also a source of opportunities, the use of which may allow it to survive and grow in a competitive market.

Mining companies in Poland operate under extremely difficult environmental conditions. Many micro and macro factors affect their ability to survive and compete on the market. In the case of the microenvironment, companies have the opportunity to shape these factors, but unfortunately it is impossible for macro environmental factors.

Companies can only counteract the negative effects of these factors. The core activity of mining companies in Poland is hard coal production and sale. In order to adapt the level of coal production to the needs of a changing market, strategic planning based on planning methods such as forecasting is required.

Properly constructed, reliable forecasts will enable the company to adjust its production potential to market requirements and eliminate every form of waste. However, in order to make the right plans, the company must be aware of the potential demand drivers and which of them have a significant impact on the sales level. Therefore, within this paper, the authors have presented the ARMAX model allowing for many explanatory variables, i.e. factors influencing hard coal sales to be taken into account in the forecasts. Time series have become the most often used method for short and medium-term forecasts (Bunn and Karakatsani 2003).

1. Methods

The Auto regressive Moving Average with Exogenous Input models are used when predicted explanatory variables are required (Reinsel 2003). Model parameters are obtained by minimizing the quadratic prediction error criterion (Marmarelis i in. 2014). The model can be applied only to series with periodic or regular fluctuations due to the lack of the model learning mechanism.

ARMAX extends the ARIMA model (Cieślak 2001; Kot i in. 2007). The decomposed time series occurs here as an explanatory variable and the remaining exogenous variables represent the linear regression model, the residuals of whichh are subject to the ARIMA process (Grudkowska i Paśnicka 2007; Grudkowska i Nehrebecka 2009).

The model was built with statistical data on hard coal sales in Poland since 2010. The analysis was based on annual data. The data used to create the model was placed in Table 1. It was obtained from the Central Statistical Office (Poland), Statistical Review of World Energy, as well as from a coal company. The data obtained from the coal company was coded.

The ARMAX model was used during the analysis of the hard coal sales time series (Lima i in. 2009; Farnum i Stanton 1989; Hickey i in. 2012). The model is expressed by following formula:

Table 1. Data used to create the ARMAX (1,1,0) model

Tabela 1. Dane użyte do utworzenia modelu ARMAX (1,1,0)

Year	Coal sales [tonnes]	GDP [mln PLN]	Hard coal price [USD/tce]	Natural gas consumption [Mtoe]	Crude oil consumption [Mtoe]	Electricity production [Twh]	Electricity consumption [Mtoe]	Hard coal consumption [Mtoe]	Crude oil price [USD/tce]	Natural gas price [USD/tce]
2003	13 298 703	843 156	15.5	11	20	152	89	56	196	162
2004	13 079 519	924538	25.75	12	22	154	89	54	251	173
2005	12 619 437	983 302	21.5	12	22	157	91	55	349	235
2006	12 279 892	1 060 031	23	12	23	162	94	57	426	314
2007	11 579 332	1 176 737	31.75	12	24	159	94	56	478	321
2008	11 126 631	1 272 838	52.75	14	25	155	95	55	670	462
2009	9 615 432	1 344 505	25.25	13	25	152	92	52	417	341
2010	9 732 261	1 416 585	33	14	27	158	98	55	539	320
2011	9 929 839	1 528 127	43.5	14	27	164	99	55	742	420
2012	8 433 217	1 595 225	33	15	26	162	96	51	753	437
2013	9 044 790	1 656 341	29.25	15	24	165	96	53	730	429
2014	7 197 985	1 719 146	27	15	24	159	92	49	672	365
2015	7 126 118	1 789 696	20.25	15	25	165	95	50	356	264

Source: SRWE 2018, GUS 2018.

$$y(i) = z^{-k} \frac{Bz^{-1}}{Az^{-1}} u(i) + \frac{Cz^{-1}}{Az^{-1}} e(i)$$

$y(i)$ – output series,
$u(i)$ – input series,
$e(i)$ – white noise,
z^{-k} – delay,
Az^{-1}, Cz^{-1}, Bz^{-1} – ARMAX differential polynomials.

The structure of the ARMAX (p, q, b) model is determined by the following parameters:
- p – auto regressive terms,
- q – moving average terms,
- b – exogenous input terms.

The most important factors shaping the demand for hard coal are:
- the rate of economic growth and associated development of industrial production, in particular, the production of electricity, heat and steel,
- the efficiency of introducing new techniques and technologies to reduce production energy intensity,
- progress in heating technology,
- the share of natural gas and fuel oil for industry needs, processing and municipal sectors,
- preferences of individual consumers in choosing fuel for economic and heating purposes,
- competitiveness of hard coal substitutes.

Internal factors shaping the domestic hard coal market include:
- coal demand,
- level of production capacity and level of its use in mining,
- coal quality,
- coal prices,
- production costs which include the cost of coal extraction and enrichment,
- coal transport costs from the mine to the customer,
- climatic conditions.

The following explanatory variables were taken into account for the determination of annual sales volume of hard coal:
- GDP,
- the price of coal,
- the price of natural gas,
- the price of crude oil,
- hard coal consumption,
- consumption of natural gas,

- consumption of crude oil,
- electricity production,
- electricity consumption.

The data provided for carrying out the presented analysis was obtained from one of the Polish coal companies. The used method is extremely flexible and can be applied successfully for other companies or the entire coal mining industry in Poland.

1.1. Verification of the created model's credibility

Several models have been constructed for sales and explanatory variables. The most reliable and accurate one was selected from among them. Only these models whose parameters were statistically significant at a probability level $p = 0.05$ were selected.

Within this group models with the smallest ex-post errors were considered as well as those with the lowest values of the information criterion.

Information criteria make it possible to choose the best model for a dependent variable. It is assumed that the optimal model is the one for which the value of the information criterion is the lowest.

The most commonly used criteria are: AIC (Akaike criterion), BIC (Bayesian criterion Schwarz), Hannan Qiunn criterion (Piłatowska 2010; Na 2017). For the final, selected model, the criteria values are as follows:

- BIC information criterion 364,05,
- Hannan-Quinn information criterion 356,74,
- Akaike information criterion 358,72.

The Armax (1 1 0) model was used during the analysis of the annual hard coal sales time series. The estimation included 200 function evaluations and 78 gradient evaluations. The number of function and gradient evaluations indicate that a nonlinear numerical optimization is being done to maximize the likelihood function.

To confirm that the rest of the model has a normal distribution, the Doornik-Hansen test was carried out.

Null hypothesis: an empirical distributor has a normal distribution:

$$\text{Chi-square } (2) = 2.645 \text{ with the value of p } 0.26652$$

The rejection of the null hypothesis is decided on the basis of the so-called p value. If it is smaller than 0.05, the null hypothesis should be rejected and the alternative hypothesis accepted. If the p value is greater than 0.05, the null hypothesis has not been rejected.

Thanks to the Doornik-Hansen test, it was established that the rests of the created model have a normal distribution.

The log-likelihood is the natural logarithm of the reliability function, which is maximized by seeking parameters and using the maximum likelihood method. The log-likelihood of the model is −196,1028.

Ex-post errors of the created forecast are as follows:

Mean prediction error ME = –22960,
Mean squared error MSE = 5.2715e+08,
Root mean square error RMSE = 22960,
Mean absolute error MAE = 22960,
Mean percentage error MPE = –0.080548,
Mean absolute percentage error MAPE = 0.080548,
Theil's index = 0.12.

As it can be stated by analyzing the ex-post prediction errors listed in Table 1, the model is reliable. For example, the mean absolute percentage error MAPE measures the accuracy of a method for constructing a time-series model (Myttenaere i in. 2016; Glennon i in. 2018). For this model, the error is just under 0.1 percent (similar to MPE).

1.2. Characteristics of the ARMAX model

Observations from 2004–2016 were used to build the ARMAX model. The estimation was conducted using the Kalman filter. The dependent variable is represented by the hard coal sales volume. Ultimately, only variables mentioned in Table 1 were taken into account. The residuals of the variables were rejected due to the lack of statistical significance. The first two positions in Table 2 are model parameters. The time series was once differentiated. An auto regressive model was selected for further calculations. To evaluate it, 78 iterations were performed.

Forecasts of explanatory variables were made for 2016 and 2017. This was necessary in order to make it possible to determine the sales volume of hard coal in the mining company. During the decision on whether the variable is statistically significant, the value of Student's t-statistics and the level of p (probability) should be taken into account. If $p \leq \alpha$, the null hypothesis of the non-significance of the variable should be rejected and the alternative hypothesis of the significance of the variable must be accepted.

If $p > \alpha$, there are no grounds for rejecting the null hypothesis of non-significance.

The number of stars in the last column of Table 1 means:

*** $p < 0.01$,
** that $p < 0.05$,
* that $p < 0.1$.

The level of significance defines the risk of making a mistake that the recipient of the forecast is able to accept. For example, in the case of the crude oil price, it is $p < 0.1$. That is, the probability of error less than 10%, but greater than 5% occurs.

Table 2. Parameters of the ARMAX (1,1,0) model

Tabela 2. Parametry modelu ARMAX (1,1,0)

Model component	Value of the component	Standard error	Student's t	Probability value
const	−1,71661e+06	116219	−14,77	2,27e-49***
phi_1	−0,976020	0,0325117	−30,02	5,29e–198***
Hard coal price	21097,1	2852,54	7,396	1,40e-13***
Natural gas consumption	3,50323e+06	487974	7,179	7,02e-13***
Crude oil consumption	986898	285625	3,455	0,0005***
Electricity consumption	−1,69494e+06	306646	−5,527	3,25e-08***
Hard coal consumption	2,16958e+06	293797	−5,119	3,07e-07***
Crude oil price	2983,35	1725,37	1,729	0,0838*
Natural gas price	−11785,5	2302,39	−5,119	3,07e-07***
Electricity production	152729	26142,7	5,842	5,15e-09***

Source: own results.

A factor that was rejected during the model creation was the Gross Domestic Product (GDP). However, the impact of GDP is contained in other exogenous variables. The risk of making a mistake while creating the model in this case was more than 10%. The use of this explanatory variable to create the model would adversely affect its quality.

Forecast prepared in 2016 for 2017 predicted a decline in hard coal sales. However, this is no longer as significant as in years 2011–2014.

In April 2017, Polish mines sold less than 5.2 million tons of coal, which was the lowest monthly level of sales for more than two years. It also increased the amount of stored coal on the dumps – which was demonstrated by the data prepared by the Industrial Development Agency.

The graph below (Fig. 1) shows the final implementation of the projected value, i.e. hard coal sales volume and forecast for 2017.

1.3. The most important factors affecting hard coal sales

The time series of demand for hard coal is characterized by a slightly decreasing trend. This may mean that in the coming years we can still expect a decrease in demand for hard coal. The actual value of coal sales volume in 2017 confirmed the reliability of the model.

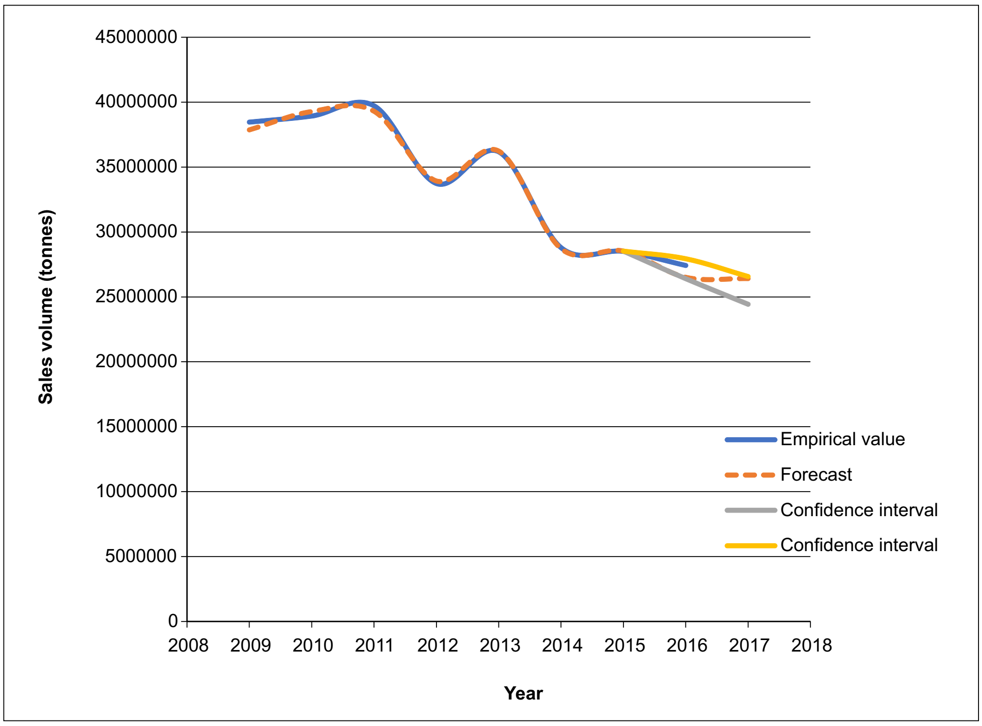

Fig. 1. The sales volume of hard coal estimated and actual values
Source: own results

Rys. 1. Wielkość sprzedaży węgla kamiennego szacowana oraz rzeczywista

The sales level is about 30,000,000 tons. Thus, the model can be successfully used for forecasts in subsequent years.

The analysis enabled the verification of the significance of the potential factor's influence on hard coal sales. It confirmed the suggested hypothesis that these are indeed factors that strongly influence the demand for hard coal. This knowledge will, in turn, be invaluable during strategic planning in a mining company.

This planning should take into account the forecasts, for example, using the shown model. An even better solution is to create scenarios for the mining company environment. Thanks to the presented method, it will be possible to select the appropriate factors contained in the scenarios. In turn, the forecast's confidence intervals can be used as alternative versions of future creating individual scenarios.

The forecasts indicate that the downward trend in hard coal sales will be maintained in the near future. The level of the current and future demand for hard coal depends on availability and the price of other fossil fuels (in Poland), namely natural gas and crude oil.

Renewable energy sources in Poland are not able to meet the growing demand for energy (Rybak i in. 2012).

The prices of coal, oil and gas are strongly correlated (Rybak and Manowska 2017). Naturally, the extraction cost has a huge impact on the price of hard coal and its competitiveness against other fossil fuels. In Poland, the problem is the high production cost and a high share of fixed costs, which are not declining with the reduction of mining volume.

The economic situation in the coal industry always depends on the costs of obtaining energy from other sources. Furthermore, the level of demand for energy is a very important factor shaping the level of hard coal sales in Poland.

Due to the fact that internal resources of natural gas and crude oil are unable to meet the demand for energy in our country, the hard coal position in this area will be irreplaceable in the coming years. However, again reference should be made to domestic coal prices, which have to compete with cheaper imported coal, among others, from Russia.

Conclusions

Mining companies in Poland operate in highly adverse environmental conditions. This concerns both the increasingly difficult geological and economic conditions. This is caused by the influence of both internal and external factors. The impact of macro-factors on the future demand for coal was analyzed. Due to the fact that coal companies have no influence on the impact of these environmental factors, they must develop appropriate strategies to counter their negative effects.

The authors of the article presented a mathematical model ARMAX, which was used to build a forecast for the volume of hard coal sales. The model includes eight explanatory variables, i.e. factors affecting the forecasted variable. Additional factors also mentioned in the article were taken into account. Ultimately, they were not included due to their negative impact on the credibility of the model. The accuracy of the presented model (MAPE error below 1%) allows for the creation of accurate forecasts. In addition, the forecast confidence interval is shown in Figure 1. Thus, information is obtained not only on one point determined by the forecast, but on the range in which the demand can move. For example, if for hard coal sales in next year the 95 percent confidence interval is 26,905,093 tons to 27,940,250 tons, it means that with a probability of 95%, at least 26,905,093 tons will be sold (pessimistic scenario) and 27,940,250 hard coal tons at most (optimistic scenario). The forecast, on the other hand, represents the most likely scenario. The presented model concerns one of the Polish coal companies. It can be used successfully in other enterprises and for the entire coal mining industry.

Creating a forecast is the first step in planning a hard coal mining strategy. Knowing the future needs we are able to plan the necessary level of production factors in advance. The right strategy, tailored to the environment, will allow the company to eliminate unnecessary costs and to optimize employment. It will also help the company to fully use machines and equipment and production capacity. Thanks to these efforts, the company will be able to reduce production costs and increase operating profit, thus survive in the turbulent environment.

The sales volume of a product also depends on the distribution network. Its analysis allows companies to optimize sales, which improves the efficiency and profitability of company's sales with immediate bearing on the growth of profits. A spatial analysis called geo-marketing comes to aid in this case.

While carrying out this type of analyses, the number of potential future customers, the cost of maintaining a point of sale at a given location, city, costs of coal transporting, the distribution of competition, potential of a given area at selected points and existing distribution points are taken into consideration.

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THE FORECAST OF COAL SALES TAKING THE FACTORS INFLUENCING THE DEMAND FOR HARD COAL INTO ACCOUNT

Keywords

environmental factors, forecasting, coal sales, ARMAX model

Abstract

In order to prepare a coal company for the development of future events, it is important to predict how can evolve the key environmental factors. This article presents the most important factors influencing the hard coal demand in Poland. They have been used as explanatory variables during the creation of a mathematical model of coal sales. In order to build the coal sales forecast, the authors used the ARMAX model. Its validation was performed based on such accuracy measures as: RMSE, MAPE and Theil's index. The conducted studies have allowed the statistically significant factors out of all factors taken into account to be identified. They also enabled the creation of the forecast of coal sales volume in Poland in the coming years. To maintain the predictability of the forecast, the mining company should continually control the macro environment. The proper demand forecast allows for the flexible and dynamic adjustment of production or stock levels to market changes. It also makes it possible to adapt the product range to the customer's requirements and expectations, which, in turn, translates into increased sales, the release of funds, reduced operating costs and increased financial liquidity of the coal company. Creating a forecast is the first step in planning a hard coal mining strategy. Knowing the future needs, we are able to plan the necessary level of production factors in advance. The right strategy, tailored to the environment, will allow the company to eliminate unnecessary costs and to optimize employment. It will also help the company to fully use machines and equipment and production capacity. Thanks to these efforts, the company will be able to reduce production costs and increase operating profit, thus survive in a turbulent environment.

PROGNOZA WIELKOŚCI SPRZEDAŻY WĘGLA Z UWZGLĘDNIENIEM CZYNNIKÓW KSZTAŁTUJĄCYCH POPYT NA WĘGIEL KAMIENNY

Słowa kluczowe

prognozowanie, sprzedaż węgla, model ARMAX, czynniki środowiska

Streszczenie

Aby przygotować się na rozwój przyszłych wydarzeń z niezbędnym wyprzedzeniem, należy wiedzieć, w jakim kierunku mogą podążać trendy rozwoju kluczowych czynników otoczenia wpływających na spółkę węglową. Artykuł prezentuje najistotniejsze czynniki wpływające na popyt na węgiel kamienny w Polsce. Zostały one wykorzystane jako zmienne objaśniające przy utworzeniu modelu matematycznego wielkości sprzedaży węgla w Polsce. W celu jego zbudowania posłużono się modelem ARMAX. Walidacja modelu została przeprowadzona w oparciu o takie miary dokładności jak: RMSE, MAPE i współczynnik Theila. Badania te umożliwiły na wyznaczenie spośród wszystkich branych pod uwagę czynników statystycznie istotnych oraz na utworzenie prognozy wielkości sprzedaży tego paliwa w Polsce w najbliższych latach. Aby trafność prognozy mogła zostać utrzymana, przedsiębiorstwo powinno kontrolować makrootoczenie. Właściwa prognoza popytu pozwala na elastyczne oraz dynamiczne dostosowanie poziomu produkcji czy zapasów do zmian zachodzących na rynku. Umożliwia ona także dostosowanie produkowanego asortymentu do wymagań i oczekiwań odbiorców, co z kolei przekłada się na zwiększenie sprzedaży, uwolnienie środków finansowych, zmniejszenie kosztów działalności przedsiębiorstwa oraz wzrost płynności finansowej kopalń. Stworzenie prognozy to pierwszy krok w planowaniu strategii wydobycia węgla kamiennego. Znając przyszłe potrzeby, jesteśmy w stanie z wyprzedzeniem zaplanować niezbędny poziom czynników produkcji. Odpowiednia strategia to taka, która jest dostosowana do otoczenia, pozwoli przedsiębiorstwu wyeliminować niepotrzebne koszty i zoptymalizować zatrudnienie. Pomoże to również firmie w pełni korzystać z maszyn i urządzeń oraz zdolności produkcyjnych. Dzięki tym staraniom firma będzie mogła obniżyć koszty produkcji i zwiększyć zysk operacyjny, dzięki czemu przetrwa w niespokojnym oraz zmiennym otoczeniu.