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Possible strategies for hard coal mining in Poland as a result of production function analysis

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ABSTRACT

This paper contains an analysis of the hard coal production process in Poland with selected indicators such as productivity, marginal productivity and the substitution of production factors. Current organization of the hard coal mining process is mainly characterized by the decreasing economies of scale, the loss of the average and marginal productivity. Static model of the production function indicates a 50% decrease in the average productivity in the years 2005–2013. This indicates the incorrect use of available production factors and poses a threat to further existence of mining companies. The reduction of production costs will be inevitable in this situation. The obtained results of the analysis led to creation of two innovative strategies of: flexible and stable coal mining production.

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1. Introduction

1.1. *A foolish consistency is the hobgoblin of little minds (R. W. Emerson)*

The business environment of the company is continuously changing. We are not able to predict the azimuth or rate of changes. The perfect solution for mining companies would be the transformation into the so-called organizations in motion, simultaneously changing along with the environment. The self-appearance of changes does not cause an immediate organization reaction. They must be noticed, recognized and identified by the organization.

This will create the possibility to use appropriate organizational arrangements, which in turn will have a positive impact on the company financial results and ensure its competitive advantage. Competing undertakings, are those that are able to utilize effectively available resources and means of work.

The enterprise environment instability is not only a threat but also an opportunity. The company will be able to overtake the competition and take a leading position in the market, especially when it manages to react quickly enough. The tool that allows immediate reaction to occurring changes is the production function.

This function will enable to redefine the level of labor inputs, determinate their optimal, required level and the most adequate combination of production means. The article presents and characterizes two coal mining strategies of flexible and stable production.

It was determined to what extent and scope these strategies affect the production results, possible to achieve by coal companies. According to the literature and earlier studies (Tajduś et al., 2011; Przybyła and Rybak, 2007) the state-owned hard coal mining enterprises in Poland may find itself in the end-stage of company life cycle (Fig. 1). This means that it might still develop and survive in a volatile market, but it will be necessary to introduce innovative organizational changes (which will enable to reduce hard coal production costs), such as the proposed coal mining strategies. They may become a factor enabling the company survival in the market and beat the competition. The company will be able to exclude irregularities disclosed during our analysis (O'Neill, 1986).

The coal as dispositional fuel, available in large quantities (compared with crude oil or natural gas) in all regions around the world may become a source that will be able to meet the growing global energy needs (Mohr and Evans, 2009; Hook et al., 2010; Sierpińska-Sawicz and Bąk, 2016). That's why the survival of the coal mining industry has a strategic importance (Grammelis et al., 2004; Jonek-Kowalska, 2015).

The production function is a tool to determine the relationship between the involved resources, and obtained products during the

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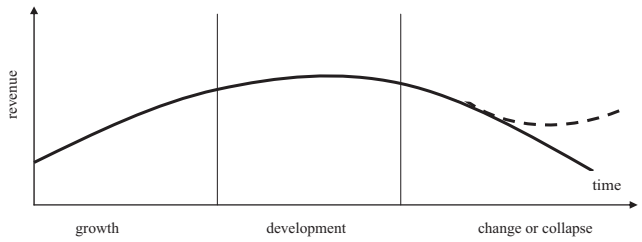

Fig. 1. The company life cycle.

production process. This makes it possible to designate in advance the level of workforce and physical capital resources in relation to the desired production level at a given time. Cobb–Douglas production function shows relation between inputs and production results (Lo Nigro, 2016).

Moreover, using the production function, we are able to determine the production level, that is achieved or could be achieved by company in the future (Ahmed et al., 2016). This fact is extremely important in the era of corporate efforts to loosen up their structures and for variation of fixed production costs. In the article is presented the analysis of the coal mine's production process in Poland in 2010 and also a comparison with the results of similar analysis performed by the authors in 2006. The paper also includes the results of dynamic and static Cobb–Douglas (C–D) production function of the last decade (years: 2004–2013). The ability to accurate estimation of the production process is important in view of seasonality, which is an integral part of the coal mining production process. The production function allows us to anticipate the level of production factors and their adjustment to the production's projected level in subsequent years.

Our previous research showed that the coal's level of demand varies throughout the year in each quarter. Seasonal decomposition based on the Census I and Census II and determined seasonality indicators show the largest decrease of sale in the second quarter of the year.

April sale is reduced by 12% in relation to average sales volume. The maximum sale was stated in the penultimate quarter of the year, between September and October, when it increases by about 18%. The analysis of autocorrelation and partial autocorrelation of coal sales also proved that a quarterly seasonality occurs there, as well as an annual (Rybak, 2011). Possibilities attributable to the production function seem to be highly desirable in view of these arguments.

The article consists of two parts:

1. the analysis of the coal mining condition
2. the solutions proposed for the identified problems.

2. The estimation of the production function

The performed analysis concerns the whole hard coal production in Poland taking into account only the state-owned enterprises.

Such factors of production as: electric power costs, depreciation costs, employment and annual labor costs were taken into account. The factors with the highest correlation coefficient value, i.e. the amount of electric power, depreciation and annual human labor were selected for further calculations. They were chosen on the basis of the aforementioned correlation coefficient factors and the amount of the hard coal production. A similar type of analysis was conducted by the authors in 2006. To enable a comparison with the earlier results, the explanatory variables used for the model construction remained unchanged.

The Cobb-Douglas production function models have been created for selected in this way combination of explanatory variables. They are described by the following equations (Przybyła et al., 2000; Goryl et al., 2007; Feldstein, 1967; Hajkova and Hurnik, 2007; Fraser, 2002; Urbano and Aparicio, 2016):

static function:

$$y_t = \beta AE^{\alpha 1} P_R^{a2} \tag{1}$$

dynamic function:

$$y_t = \beta AE^{\alpha 1} P_R^{a2} e^{\gamma t} \zeta_t \tag{2}$$

where:

1. y_t - production [t/year]
2. AE - energy expenditures and depreciation [PLN/year]
3. P_R - annual labor costs [PLN/year]
4. $\beta,\alpha_1,\alpha_2,\gamma$ -model parameters.

The presented model was created on the basis of statistical coal mining data in Poland in 2010 and 2004–2010, using the program OriginPro 8.5.1. To facilitate the calculations, the model was brought to linear form. The results are presented in Table 1 that contains the parameters of the obtained models, as well as the correlation coefficient r, coefficient of determination $\left(R^2\right)$, adjusted coefficient of determination $(\bar{R}^2)$ and the residual sum of squares (RSS). All models are characterized by the correlation coefficient above 0.8. This means that the model fitting can be considered as good or very good.

It was found out, that in all cases (except for the dynamic function) $\alpha_1+\alpha_2<1$. This means that the production is increasing at a slower rate than expenditures for it. This constitutes a threat for the development of the hard coal mining industry.

The production function and its indicators are presented in this paper in order to examine the past (production 9 and 5 years ago) and present state of the Polish hard coal mining. The authors had also created the appropriate strategies to eliminate the identified problems.

This publication contains a comprehensive characterization of the production process, which is based on the following indicators:

1. average productivity;
2. marginal productivity;
3. substitution of production factors;
4. isoquants;
5. economies of scale.

Indicators are defined and described in the following subsections.

Table 1
Model parameters of Cobb–Douglas production function.
Source: Own calculations

Parameter	Static model 2004–2010	Dynamic model 2004–2010	Year 2010
β	58,23	73,33	0,10
α_1	0,55	0,19	0,43
α_2	0,33	0,81	0,47
γ		0,05	
r	0,89	0,91	0,82
R^2	0,79	0,83	0,67
$\bar{R}^2$	0,72	0,78	0,64
RSS	0,06	0,07	1,86

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