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AN EVALUATION OF PRACTICAL APPLICABILITY OF MULTI-ASSORTMENT PRODUCTION BREAK-EVEN ANALYSIS BASED ON MINING COMPANIES

OCENA PRAKTYCZNEJ PRZYDATNOŚCI METOD ANALIZY WIELOASORTYMENTOWEGO PROGU RENTOWNOŚCI PRODUKCJI NA PRZYKŁADZIE PRZEDSIĘBIORSTW GÓRNICZYCH

In the practice of mining companies, the vast majority of them produce more than one product. The analysis of the break-even, which is referred to as CVP (Cost-Volume-Profit) analysis (Wilkinson, 2005; Czopek, 2003) in their case is significantly constricted, given the necessity to include multi-assortment structure in the analysis, which may have more than 20 types of assortments (depending on the grain size) in their offer, as in the case of open-pit mines.

The article presents methods of evaluation of break-even (volume and value) for both a single-assortment production and a multi-assortment production. The complexity of problem of break-even evaluation for multi-assortment production has resulted in formation of many methods, and, simultaneously, various approaches to its analysis, especially differences in accounting fixed costs, which may be either totally accounted for among particular assortments, relating to the whole company or partially accounted for among particular assortments and partially relating to the company, as a whole. The evaluation of the chosen methods of break-even analysis, given the availability of data, was based on two examples of mining companies: an open-pit mine of rock materials and an underground hard coal mine. The selection of methods was set by the available data provided by the companies. The data for the analysis comes from internal documentation of the mines – financial statements, breakdowns and cost calculations.

Keywords: CVP analysis, multi-assortment break-even, costs

W praktyce przedsiębiorstw górniczych, zdecydowana większość z nich wytwarza więcej niż jeden produkt. Analiza progu rentowności będąca elementem analizy CVP (Cost-Volume-Profit), w przypadku tych przedsiębiorstw jest znacznie utrudniona ze względu na konieczność uwzględnienia struktury asortymentowej w analizie, która, jak w przypadku kopalń odkrywkowych może mieć nawet powyżej dwudziestu rodzajów asortymentów (w zależności od uziarnienia) w ofercie sprzedaży.

W artykule przedstawiono sposoby obliczania progów rentowności (ilościowych i wartościowych) zarówno przy produkcji jednoasortymentowej, jak i wieloasortymentowej. Złożoność problemu wyzna-

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czania progu rentowności przy produkcji wieloasortymentowej spowodowała wykształcenie wielu metod, a wraz z nimi różnych podejść do jego analizy, a w szczególności odmienne uwzględnianie kosztów stałych, które mogą być rozliczane w całości między poszczególne asortymenty, odnoszone do całego przedsiębiorstwa, bądź też w części rozliczone między poszczególne asortymenty, a w części odnoszone do przedsiębiorstwa, jako całości. Ocenę przydatności wybranych metod analizy progu rentowności, ze względu na dostępność danych, przeprowadzono na przykładzie dwóch przedsiębiorstw górniczych: kopalni odkrywkowej surowców skalnych oraz kopalni podziemnej węgla kamiennego. Wybór metod podyktowany był udostępnionymi przez analizowane przedsiębiorstwa danymi. Dane do analizy pochodzą z dokumentów wewnętrznych kopalń – sprawozdań finansowych, prowadzonych zestawień i kalkulacji kosztowych.

Słowa kluczowe: analiza CVP, wieloasortymentowy próg rentowności, koszty

1. Introduction

The basis for developing the strategic plan for mining companies are goals set by the current owner, which e.g. in the case of hard coal mining, arise from governmental programmes for planning its operation. Both the external (market) and the internal conditions enforce verification of the set purposes. The necessity to lower the prices of coal, the changes in the structure of assortment production (the demand for a bigger amount of culms results in e.g. grinding medium assortments), the necessity to mine more and many other factors cause knowledge on break-even to play a substantial role.

On the other hand, the hallmark of road rock materials mining is the structure of ownership of companies, which in the majority are privately owned with a significant share of foreign capital. Hence they are especially set on raising their market value, upholding their financial flow, profitability and profit, which is closely associated with precisely defining the structure and magnitude of production (Gałaś et al., 2009; Czopek, 2001).

Multi-assortment break-even analysis for mines is more complex in comparison to single-assortment break-even analysis, which is used by certain authors in reference to the mining industry. Evaluating the break-even of mines, based on an averaged selling price and averaged variable unit costs for different assortments of coal, and treating the sale of several assortments as one type of coal, has lead to simplified results and it may not be the basis for a precise analysis, evaluation and decision-making based on them (Gawlik, 2008; Jaśkowski, 1998; Łuczak et al., 2000; Magda et al., 2009, Snopkowski, 2012; Turek et al., 2011). Therefore, the publication presents the complexity of the problem of break-even evaluation for multi-assortment production.

2. Break-even for single-assortment production

The break-even analysis encapsulates the research of the so called break-even point (BEP), at which profit from sales cover exactly the costs (Czopek, 2003; Fuksa, 2011, 2012, 2013; Nowak, 2001, 2003; Nowak et al., 2004; Łuczak & Utrata, 2000; Sobańska, 2003).

The company does not gain profit, but does not suffer losses – the financial outcome equals zero. In compliance with this definition, BEP is situated at the point, where sales value (S) is equal to the level of the total cost (Kc), which may be written as:

$$S = Kc \tag{1}$$

where:

$$S = x \cdot c \text{ [PLN]} \tag{2}$$

and

$$Kc = Ks + x \cdot kjz \text{ [PLN]} \tag{3}$$

where:

- c — unit selling price, [PLN/Mg],
- kjz — variable unit cost of production, [PLN/Mg],
- Ks — total fixed cost of production, [PLN],
- x — the amount of production (sales), [Mg].

After inserting equations (1) and (2) to equation (3) we are given the dependency:

$$x \cdot c = Ks + x \cdot kjz \tag{4}$$

based on which, we may evaluate BEP in terms of:

– volume:

$$BEP = \frac{Ks}{c - kjz} \text{ [Mg]} \tag{5}$$

– value:

$$BEP' = \frac{Ks}{c - kjz} \cdot c = BEP \cdot c \text{ [PLN]} \tag{6}$$

– as a utilisation rate of the production capacity:

$$BEP'' = \frac{Ks}{x_m \cdot (c - kjz)} \cdot 100 = \frac{BEP}{x_m} \cdot 100 \text{ [\%]} \tag{7}$$

where: x_m — max capacity of production (sales), [Mg].

The presented method of evaluating BEP may be applicable only in single-assortment production. To establish the break-even for several assortments, one may use the methods presented in the next point.

It should be noted that for the calculation of the break-even in both cases, it will be necessary to be familiar with the fixed and variable costs (Czopek, 2000, 2003; Dyduch et al., 2012; Gawlik, 2008a, 2010; Kustra, 2008, 2013; Sierpińska & Kustra, 2007; Turek, 2013; Turek & Michalak, 2013; Turek et al., 2011; Schugart et al., 1988). The accuracy of their (fixed and variable costs) estimation depends on the reliability of the obtained results, which are the basis for making many production decisions.

3. Break-even for multi-assortment production

Evaluation of break-even for a company with a multi-assortment production, which a mining company undoubtedly is, is fairly complicated. In the literature of the field we may find various approaches to evaluation a multi-assortment break-even (Eichler, 2004; Fuksa, 2013; Karmańska, 2009; Nowak, 2001, 2003; Sobańska, 2003; Trzaskuś-Żak, 2010). However, the complexity of the issue results in differentiation of three main methods of the analysis. The application of a particular method is conditioned by a distinct approach to fixed costs on account of their influence on the method of carrying out the analysis (detail of information regarding fixed costs, cost accounting, etc. namely (Karmańska, 2009; Nahotko, 1997; Nowak, 2001, 2003; Nowak et al., 2004; Sobańska, 2003):

1. fixed costs are accounted for among particular assortments,
2. fixed costs are totally referred to the company,
3. fixed costs are partially accounted for among particular assortments, and partially are referred to the company – segmental analysis.

Using the first method (point 1) fixed costs are accounted for among particular assortments according to the key, being the contribution margin for particular products:

$$WNKs = \frac{Ks}{M} \quad [-] \tag{8}$$

where:
WNKs — fixed costs mark-up factor,
M — global contribution margin achieved through sales of all products:

$$M = \sum_{i=1}^{r} M_i = \sum_{i=1}^{r} m_i \cdot x_i = \sum_{i=1}^{r} (c_i - kjz_i) \cdot x_i \quad [\text{PLN}] \tag{9}$$

where: m — gross unit margin, [PLN/Mg].

Hence, the fixed costs mark-up for particular assortments is determined by the formula:

$$Ks_i = WNKs \cdot M_i \quad [\text{PLN}] \tag{10}$$

The volume break-even for particular assortments is determined by the formula:

$$BEP_i = \frac{Ks_i}{c_i - kjz_i} \quad [\text{Mg}] \tag{11}$$

Whereas, value break-even for particular assortments are determined by the dependency:

$$BEP_I' = c_i \cdot BEP_i \quad [\text{PLN}] \tag{12}$$

Hence, the value break-even for a mining company is determined by the formula:

$$BEP' = \sum_{i=1}^{r} c_i \cdot BEP_i \quad [\text{PLN}] \tag{13}$$

In the case, where fixed costs are fully attributed to the company (point 2) we distinguish three approaches to the analysis of a multi-assortment break-even.

In compliance with the first approach, in break-even evaluation one employs simplified assumptions, according to which the share of total variable costs within the total production is fixed and pre-specified. Then, the value break-even may be determined as follows (Nowak, 2001; Sobańska, 2003):

$$BEP_w' = \frac{Ks}{1 - \frac{\sum_{i=1}^{r} kjz_i \cdot x_i}{\sum_{i=1}^{r} c_i \cdot x_i}} \text{ [PLN]} \tag{14}$$

The aforementioned method of break-even determination is mainly purposed for *ex post* evaluation. Then, the actually applied assortment structure of production is known, which enables determining the relation between variable costs and the amount of sales. However, application of this relation in an *ex ante* analysis is of little use, since any change in the assortment structure may significantly alter the break-even volume. The established by the abovementioned formula "critical" amount of sales refers only to the pre-specified structure of production. The denominator of the formula expresses the average mark-up for this structure. It informs which part of the income from sales shall remain after covering variable costs in reference to all types of products, taking into account a determined share of those products in the income. The amount of sales (income) in the break-even may be recalculated into an amount of products of particular assortments using information on the assortments' share in the income and their prices (Wermut, 2000).

The second method is based on determining the BEP graphically through constructing an accumulated gross margin curve for all assortments (Sobańska, 2003). It is more accurate than mathematical calculations assuming average values for the whole mine. The graph provides the minimal value of income guaranteeing reaching the break-even.

Another method of determining the value break-even (for fixed costs as a whole) is a method based on a weighted-average margin for the mark-up. It additionally enables the evaluation of the volume break-even for particular assortments. The volume BEP for *i* assortment is determined through the dependency (Nowak, 2001):

$$BEP_i = \frac{Ks \cdot \frac{S_i}{\sum_{i=1}^{r} S_i}}{\sum_{i=1}^{r} \left(m_i \cdot \frac{S_i}{\sum_{i=1}^{r} S_i} \right)} \text{ [Mg]} \tag{15}$$

The value break-even of particular assortments is calculated as the product of the threshold quantity and the price of the given assortment, whereas the global break-even as the sum of individual value of individual assortments.

If a multi-level cost accounting is used in the company, which allows dividing fixed costs into two parts: for particular assortments (Ks_i) and for the whole company (Ks_o), then a segmental analysis of the break-even may be applied (point 3). In this method, fixed costs are divided into particular assortments in proportion to the global mark-up margin for those assortments (Nowak, 2001). Volume break-even are determined according to the formula:

$$xp_i = \frac{Ks_i \cdot \frac{M_i}{\sum_{i=1}^{r} M_i} \cdot Ks_o}{m_i} \text{ [Mg]} \tag{16}$$

The value break-even for particular assortments is determined as a product of the threshold amount and the price for the given assortment, whereas the global value break-even is the sum of individual value break-even for particular assortments.

Moreover, we may apply the method of determining a multi-assortment break-even for hard coal mines proposed in the paper (Fuksa, 2012, 2013). In compliance with this method, the volume break-even is evaluated by the formula:

$$PRI = \frac{Ks}{Q_s} \cdot \sum_{i=1}^{r} \frac{x_i}{(c_i - kjz_i)} \text{ [Mg]} \tag{17}$$

However, we propose to determine the value break-even, constituting the “critical” value of the income, which covers the incurred costs, through the formula:

$$PRW = \frac{Ks}{Q_s} \cdot \sum_{i=1}^{r} \frac{x_i \cdot c_i}{(c_i - kjz_i)} = \frac{Ks}{Q_s} \cdot \sum_{i=1}^{r} \frac{x_i}{(1 - \frac{kjz_i}{c_i})} \text{ [PLN]} \tag{18}$$

In case of a single-assortment production the break-even is a point, however, in case of producing many different goods it is a finite set of many points. A mine may achieve the alignment of the income from sales with total costs in many combinations of the assortment structure. Income from selling coal and total costs (for a single mine) is determined as follows:

$$S = \sum_{i=1}^{r} x_i \cdot c_i \text{ [PLN]} \tag{19}$$

$$Kc = \sum_{i=1}^{r} x_i \cdot kjz_i + Ks \text{ [PLN]} \tag{20}$$

Hence, the break-even may be inscribed as:

$$\sum_{i=1}^{r} x_i \cdot c_i = \sum_{i=1}^{r} x_i \cdot kjz_i + Ks \tag{21}$$

Formula 21 implies also, that there is no single value of income, which would guarantee achieving the break-even by a company, which consequently hinders a proper analysis and evaluation of the actual economic situation of the company, based on the quoted methods of multi-assortment break-even analysis, in reference to its volume and value (Fuksa, 2013).

4. Calculations and evaluation of the results

The break-even analysis has been carried out based on the example of two mining companies: an open-pit rock materials mine X and a hard coal mine Y.

In reference to the open-pit mine, we have implemented a segmental analysis (formula 16) and a method of determining the break-even including fixed costs totally attributed to the company (formula 14). However, in reference to the hard coal mine we have used methods described in formulas 14, 18 and 19.

4.1. Break-even analysis for an open-pit rock materials mine

In case of the segmental method (formula 16), the division of fixed and variable costs is carried out through the least squares method. The basis of the analysis constitutes total production costs (sum of costs: assortment A, B, C and D) and the total sales amount of the analysed assortments, which is presented in figure 1.

The next step, using divisional keys, was to divide the received values of fixed costs of the whole mine i.e. PLN 37,826,079.18 into particular production assortments A, B, C and D. The divisional keys were as follows the global margin, the unit margin, the variable unit cost and the price.

The sums of the costs of the total management and sales costs were added to the received fixed costs values, for each assortment individually. The received outcome of fixed costs for individual production assortments is presented in Table 1.

The next step involved calculating the volume and the value break-even. The results are presented in Tables 2 and 3.

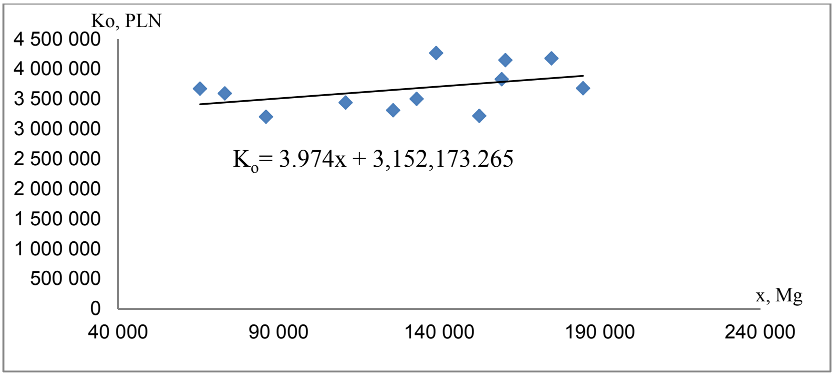

Fig. 1. Dependency between general costs and the amount of sales

The dessignated correlation coefficient $R = 0.42$ indicates a moderate relationship (according to J.P. Guilford's scale for correlation coefficient) and average correlation (according to the Stanisz scale) between treatment variables: total costs and sales volume (Fig. 1). Using the Student's t-distribution on the significance level 0.1 has occured that this correlation is statistically significant ($t_0 = 1.46664 > t_{test} = 1.372$). In the case of the weaker level of correlation coefficient, fixed and variable costs should be designated using the accountancy method (Sobańska, 2003). The submitted results of the least squares method used for designating the fixed and variable costs are: $Ks_{\%}$ = 85,88%, which is the value of 37,826,079.18 PLN, variable costs, take the value of Kz = 6 218 778,27 PLN, that is 14,12%. Despite the low value of the correlation coefficient R, the results of the least squares method were adopted for this analysis, due to the similar levels of fixed costs obtained using accountancy method (37,010,169.22 PLN) and the method of least squares (37,826,079.18 PLN). Factors included in the accountancy method were discussed with the former leadership of the analysed open-pit mine.

TABLE 1

Summary of fixed costs for individual assortments divided by divisional keys

Assortment	**Key M_i**	**Key m_i**	**Key k_{jzi}**	Key c_i
Fixed costs accounted for by divisional keys, K_{si}, PLN				
A	7,166,459.11	9,370,621.25	7,859,069.97	9,046,092.42
B	4,173,043.07	6,419,747.16	14,262,961.51	8,103,678.90
C	6,637,356.51	9,170,493.09	5,364,663.90	8,353,384.65
D	38,543,336.33	31,559,333.52	29,033,499.65	31,017,039.04

TABLE 2

Volume break-even for X mine after application of the segmental method

Assortment	**Key M_i**	**Key m_i**	**Key k_{jzi}**	**Key c_i**
volume break-even, Mg				
A	293,346.67	383,570.25	321,697.50	370,286.22
B	309,572.93	476,242.37	1,058,083.20	601,163.12
C	266,026.31	367,554.83	215,016.59	334,805.00
D	665,918.04	545,254.55	501,615.41	535,885.26
Global volume break-even	1,534,863.95	1,772,622.01	2,096,412.69	1,842,139.61

TABLE 3

Value break-even for X mine after application of the segmental method

Assortment	**Key M_i**	**Key m_i**	**Key k_{jzi}**	**Key c_i**
value break-even, PLN				
A	8,738,797.25	11,426,557.80	9,583,368.58	11,030,826.57
B	7,432,846.00	11,434,579.33	25,404,577.58	14,433,926.59
C	7,568,448.61	10,456,935.00	6,117,221.96	9,525,202.14
D	47,613,140.07	38,985,700.54	35,865,501.46	38,315,796.33
Global value break-even	71,353,231.93	72,303,772.66	76,970,669.58	73,305,751.64

However, using the approach, where we calculate the global break-even (formula 14), we have determined volume break-even in individual stages of the method (Tab. 4). Assuming that Ks = 56,520,195.02 PLN, the global value break-even amounts is 71,972,668.41 PLN.

TABLE 4

Share percentage of income for individual types of assortments from the analysed mine

Assortment	Income from sales, PLN	P – share percentage of income from sales, %	Share in value break-even, PLN	Volume break-even, Mg
A	10,242,495.21	14.07	10,129,329.30	340,024.48
B	5,424,867.90	7.45	5,364,930.34	223,445.66
C	9,285,132.05	12.76	9,182,543.72	322,760.76
D	47,824,259.34	65.71	47,295,865.05	661,480.63
Total	72,776,754.50	100.00	71,972,668.41	1,547,711.54

Having analysed the results for the open-pit mine X, we may assert, that after applying the approach, in which the fixed costs for the whole mine had been divided by various divisional keys, we have received different volume break-evens. For the assortment A the volume break-even amounted from 293,346.7 Mg after applying the global margin key, to 383,570.3 Mg after applying the unit margin key. In the second approach, where we begin with calculating the global value break-even, which in the next steps of the analysis consequently leads to determining the volume break-even, for the assortment A it amounted to 340,024.5 Mg. Therefore, the received results differ significantly. Hence, production decision-making for a multi-assortment mine is hindered considerably given the possibility to apply many different combinations of the assortment structure.

4.2. Break-even analysis for a hard coal mine

Table 5 presents maximal volumes of production and threshold sales volumes for individual assortments of coal for mine Y. Sales in these volumes result in achieving the break-even, but selling in smaller volumes results in being under the break-even and incurs a loss.

TABLE 5

Maximal production and threshold sales volumes of coal for mine Y, [Mg]

Coal assortment	Maximal production volume	Threshold sales volume (formula 18)	Threshold sales volume (formula 14)
Cobble	143,000	76,887	116,147
Nut coal	286,000	160,242	232,296
Fine coal IA	166,400	109,385	135,154
Fine coal IIA	2,004,600	1,850,488	1,628,181
BEP [Mg]		2,197,002	2,111,778
BEP' [PLN]		469,552,085	466,467,815

It may be observed, that threshold sales volumes of the same assortments, calculated by two different methods (Tab. 5) are vastly different. Not only threshold values presented in table 5 guarantee achieving the break-even. There is a finite amount of threshold sales volume combinations, as well as a finite amount of a "critical" income values covering costs (Tab. 5). A similar conclusion was drawn in case of mine X (Tab. 2-4).

As it was noted in works (Fuksa, 2012, 2013) and as it is observable in the analysis presented above, it is fairly troublesome, while interpreting the results, to determine the break-even by threshold sales volumes of assortments, or values of the "critical" income. In the case of multi-variant analyses of a company's economic situation, we propose calculating the percentage point (*PRP*) in a manner described in (Fuksa, 2012, 2013).

5. Summary

The break-even for multi-asortment production evaluation wchich consists of determining the boundary volumes of individual assortments and also the value of income covering the incurred costs, is very important. However, it is of little use and fairly complicated, especially in interpreting the obtained results.

The methods presented in this publication concerning the evaluation of multi-asortment production break-even can be used in every mining company. The possibility of application of particular method resulting from particular mine cost accounting and possibility of assignation of fixed costs.

The purpose of the analysis presented in this article is to assess the usefullness of the proposed methods in the literature of break-even evaluation of multi-assortment production. The proposed methods besides (Fuksa, 2012, 2013) allow for the calculation of only the quantitative and valuable break-even. It should be noted, that for each of the methods there are different results. That means, regardless of the method, there exists finitely many completely different variants of the solutions of boundary volumes of break-even of individual carbon assortments or raw rock assortments.

A clear statement of whether a company has reached the break-even, is below or above its value, it is not possible without additional calculations of the value of revenue.

For this reason, a calculation of the global quantitative break-even is devoid of practical usefulness. The sum of break-even quantities production assortments has a different value depending on the selected method and what is important, is not the only solution (Table 2:5). More useful is the determination of the volume break-even of one of the assortments for the assumed or guaranteed sale of other assortments, by the formula:

$$x_r = \frac{Ks - \sum_{i=1}^{r-1} x_i \cdot (c_i - kjz_i)}{c_r - kjz_r} \tag{22}$$

Similarly, with the „critical" value of break even. There are finitely large number of combinations of revenue covering total costs, which derives from the equation 21. The production quantity of individual assortments that generate revenues and costs are respectively on the left and right side of the equation. When price is at higher level greater revenue will be achieved from the sales of a particular product range (and also a larger percentage of revenue covering the incurred costs). Therefore, even a slight decline in sales quantity of product range can cause a significant decline in revenue and a decrease below the break even. In the case of a lower price, we will have to deal with lower sensitivity of income on changes in sales scale of the product range. With regard to the factors, which determine the level of multi-assortment production break-even include unit sales price, unit variable costs, the quantity of production of various assortments, fixed costs and structure of multi-asortment production.

The change in level of any determinant will affect in a decisive way the break-even level. An increase in sale prices, a decline in costs (fixed and variable) and also an increase in production (sale) lowers the break-even at which begins mine profitability, and of course vice versa.

A change of production structure influences the changing area of acceptable results of boundary volume of assortments. That is why, break-even analysis is only makes sense in current planning – for short periods-monthly. This is due to the dynamics of market conditions and internal conditions of mines. While in the case of changes in the value of fixed and variable costs, the boundary volume of production of individual assortments calculations can be immediately updated, but in the case of sale price changes it is already complicated. The prices of raw materials, such as coal are made up of quotations and are in correlation with other mineral raw materials. Therefore, forecasting the level of the sales prices for mineral resources is very difficult. It should also, in the case of price changes take their current value to the calculation algorithm. In a situation approaching break-even it is adviced to increase production volumes, which in turn is only possible in the case of unused production capacity (mine X). While increasing production in the absence of the possibility of selling it (mine Y) did not produce any effects. The sales volume of coal is currently the main determinant of the efficiency of the functioning and profitability of Polish mines (Gawlik, 2008b).

There is a need to take action for its growth through alternative forms of coal use in the present market conditions. In curent market conditions, Poland should decide on processing of relatively cheap coal, which can be difficult to sell, in an expensive semi-finished products and products of modern organic chemistry such as: aniline dyes, explosives, pharmaceuticals, perfumes, plastics, lacquers, paints, cleaner fuels (synthetic gasoline), synthetic fibers, which can be expensive to sell. The burning of "clean" coal should only take place in power stations and power plants, where apart of electricity can be obtained also the heat (Fuksa, 2016).

The obtained results in the form of threshold volumes or „critcal" value of revenue cannot provide a basis for making important production decisions. In the case of multivariant analysis of the economic situation of the companies there is proposed to calculate the percentage break-even (*PRP)* described in (Fuksa, 2012; Fuksa, 2013).

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