Conditions of Steel Industry in Poland After Restructuring – the Analysis by Using C-D Model

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INTRODUCTION

The steel industry (like the mining) is defined as heavy-duty and traditional industry (Stachowicz, 2001; Jezierski and Leszczyńska, 2003; Midor, 2015; Jonek-Kowalska, 2017; Kotelska, 2019). The sector is classified this way due to producing large volumes of steel for other sectors of industry (for further production of goods). The steel sector is still the key strategy for the development of economy. Nowadays the sector is categorized in the metals department, which is one of the top ten largest industrial sector. The value of shipments of the steel sector in 2019 amounted to 36.5 billion PLN, which accounted for nearly 3% of industrial production. The value of its property is estimated nearly 30.6 billion PLN. In the sector 24 thousand people are employed. 2019 saw about 9.3 million metric (MT) of crude steel produced in Poland. In the world ranking of steel industries, it has 19 position (information from Polish Steel Association in Katowice). Modern steel sector in Poland is different from the sector from 90s. The changes introduced in it together with the restructuring have adapted this sector to the conditions of market economy. Former state enterprises were privatized and unprofitable steel mills closed. From the group of several dozen steel mills, currently several steel mills operate on the market. The restructuring carried out in the 90s created conditions for the purchase of steel mills by foreign capital. Foreign capital is the owner of the largest steel mills in Poland (ArcelorMittal, CMC and Celsa). ArcelorMittal Poland S.A. is the largest steel producer in Poland. The owner of the enterprise is a large capital group, which owns steel mills in many countries and produces 100 million tonnes steel annually. This company also has the largest production potential in Poland and is able to produce over 70% of total annual steel production.

ABOUT RESTRUCTURING OF POLISH STEEL INDUSTRY

Restructuring as a process of radical change in many areas of activity of enterprises (Borowiecki, 1996) was necessary for them to function in market economy conditions. In the 90s, restructuring at the steel mills was carried out in accordance with government recovery programs in the areas of: assets,

technology, employment and management of steel mills (Gajdzik, 2012). In the period of Poland's accession to the EU structures, the restructuring was carried out according to the guidelines of the European Commission and its results were assessed on the basis of economic indicators – viability. Poland's membership in the EU has completed this stage of steelworks restructuring. The first decade of the current century is considered the time of completion of restructuring of steel mills, restructuring of a restructuring nature (more information about the type of restructuring in: Bitkowska, 2010). In the second half of the first decade of the 21st century, all steel mills gained financial liquidity and business efficiency (Gajdzik, 2011). After completing the restructuring, the smelters began to build their market advantage. It can be assumed that development restructuring begins at the end of the first decade of the present century, and its goal is to increase the value of enterprises.

POLISH STEEL INDUSTRY IN RESEARCH

The rehabilitation restructuring and implemented rehabilitation programs in the smelters initiated in the 1990s were evaluated by government institutions (ministries) and the European Commission. Steel market experts in Poland and scientists also assessed the progress and results of steel sector restructuring. They used quantitative methods (e.g. Szulc et al., 2011; Szulc, 2014, Gajdzik 2018) and qualitative assessments of implemented changes (e.g. Gajdzik, 2013). The scope of the research differed in the scope of the steel sector restructuring research in Poland. Comprehensive research (restructuring of the steel sector) was carried out by employees of the Institute of Iron Metallurgy (IMŻ-Gliwice), Silesian University of Technology, AGH University of Science and Technology, Częstochowa University of Technology. Section studies were carried out in the areas of: outsourcing (Foltys, 2007), strategic alliances (Sroka, 2012), employment restructuring (e.g. Paduch, Kardas, Kłos, Sankowska-Śliwa, 2007) and capital restructuring (Gajdzik, Sroka, 2012), occupational safety (Franosz, Nowacki, Lis, 2011, Małysa, 2019; Małysa, Nowacki, Lis, 2017), environmental protection (Gajdzik, Wyciślik, 2012) and quality management system (Gajdzik, Sitko, 2014).

APPLICATION C-D MODEL TO RESTRUCTURING ANALYSIS OF POLISH STEEL INDUSTRY
About C-D model
Cobb-Douglas model (1928; Douglas 1976) is the basic tool of econometric analysis of the production process. This model determines the relationship between live labour (employment) and objectified labour (assets) and the quantity or value of products obtained from these inputs (Chmiel, 1983, p. 97; Pawłowski, 1996, p. 202).
The production function in the C-D model is a power function (1):

$$P = b \cdot L^{\alpha} \cdot C^{\beta} \tag{1}$$

where:

P – production,
L – labour,
C – capital (physical capital as the balance value of fixed assets (cost of capital)),
b – function parameter (allows achieving better compliance of the actual quantities of the production function with theoretical values and is not subject to interpretation) (Pawłowski, 1976, p. 75).

The production function meets all the required properties of econometric modeling. It is well suited to empirical data, better than a linear function and a polynomial function. The function is continuous and differentiable. There is a fairly simple calculation algorithm for determining this function. To determine it, the tools available are used in the Excel spreadsheet or Statistica StatSoft statistical package. The power function is reduced to a linear form by logarithm. The classical least squares method is used to determine this form of function. The linear form of the production function is as follows (2):

$$ln\, Y_t = ln\, a + \alpha\, ln\, C_t + \beta\, ln\, L_t \qquad (2)$$

The function's popularity fell in the 1960s, when it was tested in analyzes of the condition of the economy (GDP) and production of individual industrial sectors. In Poland, after a period of economic transformation (initiated in 1989), the production function was again resumed in econometric analyzes (Kalinowski, 2002; Welfe, 2002; Welfe and Welfe, 2004; Franik, 2007; Grabowski, 2012). In the conditions of market economy, the function of production was more economically significant than in governmental management of the economy (socialism).

Cobb-Douglas production function is of great practical importance, because on its basis you can determine the impact of individual factors of production on the volume of production and production flexibility relative to individual factors and the effect of scale (flexibility of production scale). This function allows determining the substitutability of factors of production, i.e. replacing one factor of production with another factor. The function is also used to calculate the marginal productivity of a given factor (by using marginal calculations). The model is also used to determine the demand for individual production factors at planned production volumes. The C-D model is included in the basic models for assessing production efficiency.

Methodological principles

Assumptions for using the C-D model in the analysis of the steel sector were developed on the basis of Pawłowski (1976, pp. 65-70, 202-203). First principle is the homogeneity of production, that is, in the steel sector of steel production. Steel production is homogeneous. Condition No. 1 is met. The second rule is the consistency of the assortment – in the steel sector the steel assortment is ingots or slabs. The third rule concerns the invariability of the production technology used over a long period of time – steel production technology has been the same for years – steel smelting in converters and electric furnaces.

The fourth rule is to use the same materials at the entrance to the production of the product – materials in metallurgy are: iron ore and/or steel scrap – recycling. Another principle is related to this principle: material demand does not change radically in the long run – It has been assumed in the metallurgy for years that approximately 1.7 tonnes of iron ore are needed to produce 1 ton of steel. The last rule applies to quantitative relations between the volumes of inputs of individual factors of production and the volume of production, which are to change gradually over longer periods. In sector restructuring, this assumption was changed due to sharp cuts on the expenditure side (employment reduction and asset sales) and on the effects side (decrease in steel production). Here is the content: changes on the side of inputs and production effects occur in the same or similar proportions and concern all factors of the production process and the effects of their transformation.

The aim of realized study

The study assumed that its purpose is to conduct a procedure that results in a steel production model (or models). This is known as the model identification procedure. Model identification was carried out on the basis of Cobb-Douglas methodology. The aim of the study was to use the C-D model to determine the effectiveness of steel sector restructuring based on the recognition of the relationship between production factors and the volume of production. The model has a system structure – "black box" model (Fig. 1).
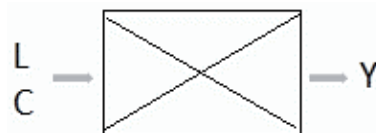

Fig. 1 Model "black box"

Quantitative relations between production factors (inputs) and production volume (effects of the transformation of "inputs" into "outputs") constitute the object of research.

The object of own research

The object of research is metallurgical production as steel production in the steel industry in Poland. Empirical data comes from individual enterprises forming the steel sector in Poland. Production is analyzed in quantitative terms as the volume of steel produced or valuable as clean production (net production) – value added generated in the steel sector or as sold production – revenues from sales of the manufactured product. Expenditures are assets (the value of the best-productive assets) and employment (number of employees or labour costs). All expenditures and effects are measurable, and value values are expressed in constant prices and not in current prices (GDP Deflator was used). The time range of the analysis covered the years 2000-2015 with a forecast for 2020.

The path of building of the model
In order to determine the structure of the model, the following path was adopted:

Stage 1: Identifying the structure of the model based on available information (empirical data) and selecting explanatory and explanatory variables for the model with the form (Lipiec-Zajchowska, 2003, p. 34):

$$Y_t = a \cdot C_t^{\alpha} \cdot L_t^{\beta} \tag{3}$$

where:
Y_t – production in time (t),
C_t – capital (property) in time (t),
L_t – labour (employment) in time (t),
a, α, β – function parameters.

Stage 2: Identification of a set of models as the basis for the description of the examined object (assessment of the statistical significance of the model according to econometric methodology). At this stage, a simple model (simplified model, base model) with two explanatory variables for the studied phenomenon was established. It was assumed that this model is the closest to the optimal in the light of the adopted criteria of econometric assessment. The structure of this model:
Y – net production (value added at constant prices generated in the steel industry during the year in terms of value (PLN '000),
X_1 – value of fixed assets at constant prices in the steel industry (PLN' 000)[1],
X_2 – employment (total) in the steel industry (people).
This model was used as an example of the analysis in this publication.

Stage 3: Construction of a set of models: a simple model is the basis for constructing subsequent models (complex models). Differentiating models consists in introducing further explanatory variables and/or refining the already introduced explanatory variables in the obtained model. The condition of the research object was described by means of the selection of explained and explanatory variables for the structure of models in order to analyze the recognition of the state of the steel sector in the conditions of restructuring. The groups of function parameters were presented in Fig. 2.

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[1] After converting production and assets into fixed prices, a better fit of the model was obtained than in the case of current prices.
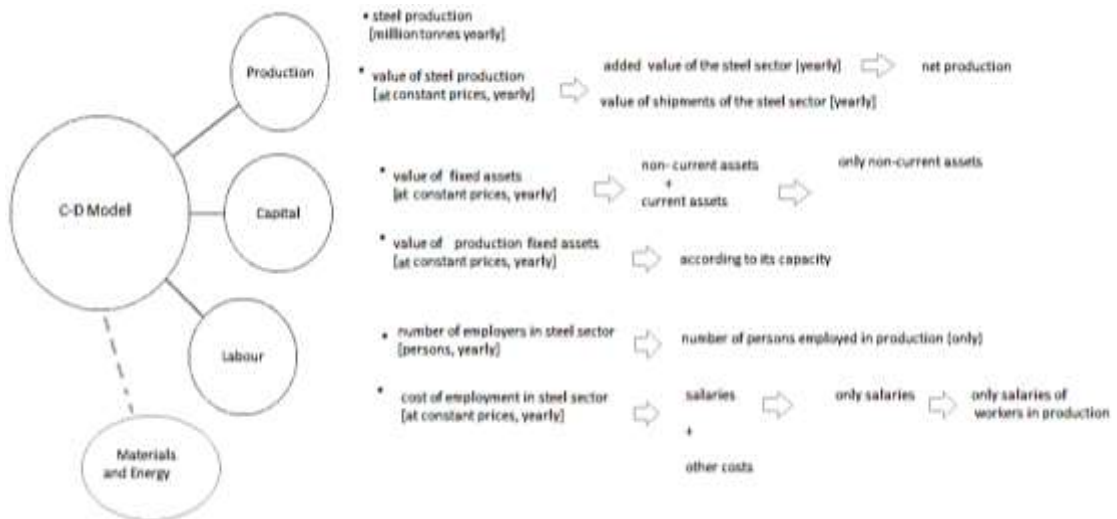
Fig. 2. The groups: *Y*, *C* and *L*

At this stage, a set of models (Fig. 3) with a high degree of detail is obtained. The obtained models are used for comparative assessments of the examined manufacturing process and form the basis for assessing the quality of this process.
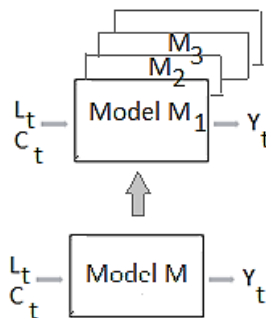

Fig. 3 Building the group models

Stage 4: Analysis of the models obtained and interpretation of the relationship between model components. Scope of calculations and analyzes:
1. Production: relations of the influence of factors of production on production.
2. Flexibility in steel production (determination of absolute and relative increments) (Kukuła, 2009, p. 159):

$$\frac{\Delta Y}{Y} = \left(1 + \frac{\Delta X_1}{X_1}\right)^{a1} \cdot \left(1 + \frac{\Delta X_2}{X_2}\right)^{a2} - 1 \tag{4}$$

3. The effect of scale of steel production (according to 5):

$$a = a_1 + a_2 \tag{5}$$

4. Collective output – steel industry performance (according to the formula):

$$W_t = a \cdot \left(\frac{C_t}{L_t}\right)^{\alpha} \cdot L_t^{\beta + \alpha - 1} \tag{6}$$

and performance flexibility based on individual factors.
5. Productivity of the steel sector's fixed assets (according to the formula):

$$P_t = a \cdot C_t^{\alpha + \beta - 1} \cdot \left(\frac{L_t}{C_t}\right)^{\beta} \tag{7}$$

and performance flexibility based on individual factors.
6. Forecasting changes in production, productivity, productivity, employment.

Stage 5: Application of the obtained models to assess the efficiency of restructuring of the steel sector based on the obtained transformation and coupling relations between model components (an example of inference is presented in the further part of the work). It is worth noting that the obtained models are an abstract (conceptual) form of the assessment of the production process under restructuring conditions, but based on the obtained dependencies, recommendations for future decision-making processes can be made.

ANALYSIS OF AN EXAMPLE MODEL AND ASSESSMENT OF THE EFFECTIVENESS OF RESTRUCTURING

Example of a model in a linearized function:

$$\ln(Y) = 9.5686 + 0.7799 \cdot \ln(X_1) + (-0.6523) \cdot \ln(X_2)$$
$$(3.0534) \qquad (0.0849) \qquad\qquad (0.1706) \tag{8}$$

and in a power function:

$$Y = 14308.22 \cdot X_1^{0.7799} \cdot X_2^{-0.6523} \tag{9}$$

where:

Y – net production (value added at constant prices generated by the steel industry during the year in terms of value (PLN '000),

X_1 – value of fixed assets at constant prices in the steel industry (PLN' 000)[2],

X_2 – employment (total) in the steel industry.

The statistics of parameters for the power model are presented in Table 1.

Table 1 The statistics of parameters for the model (9)

		a_2	a_1	b	
		−0.6523	0.7799	9.5686	Value for intercept (a) slope (b)
Correlation coefficient	Determination coefficient	0.1706	0.0849	3.0534	Standard error
R = 0.9934	R² = 0.9869	Standard error in model			Se = 0.0636
		F Stat.	Degrees of freedom df (l)		
		489.968	13		
		SS Regression			SS Residual standard deviation
		3.9680	0.0526		
Convergence coefficient	Residual variation coefficient	−3.82339	9.18290	3.13377	t Stat
$\varphi^2 = 0.0131$	$V_u = 0.00412$	b* = 14308.22			
	Significance level: p	0.0021115	0.0000005	0.0079151	
	for: p < 0.05	Significant	Significant		

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[2] After converting production and assets into fixed prices, a better fit of the model was obtained than in the case of current prices.
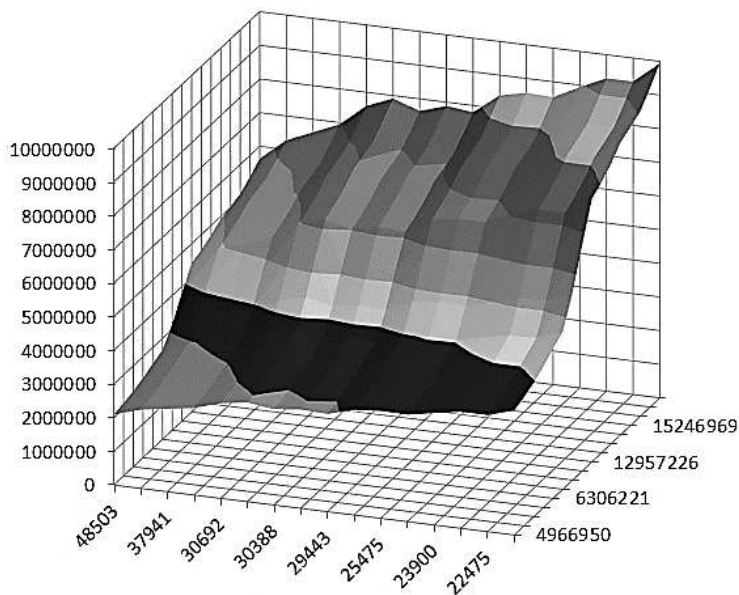
Fig. 4 Graphical form for the model (9)

Ad. 1) Interpretation of relationships: clean production is more influenced by fixed assets than employment growth ($a_1 > a_2$).

Ad. 2a) Interpretation based on the analysis of production flexibility (Y) in relation to fixed assets (X_1): increase in fixed assets by 1% results in an increase (average) of clean production by 0.7799% with unchanged level of employment.

Ad. 2b) Interpretation based on the analysis of production flexibility (Y) in relation to the number of employees (X_2): an increase in the number of employees in the steel industry by 1% causes a decrease in clean production by an average (on average) by 0.6523% while the value of fixed assets remains unchanged.

Ad. 2c) An increase of 1% in fixed assets results in an increase in production by exactly o 0.779145%, and an increase in employment of 1% results in a decrease in production by 0.64887%. Comparing the results obtained with the previous parameter values (points 2a and 2b), slight differences were obtained, but in absolute terms they can be quite large (and this should be remembered). This form of comparison can be a check of the correctness of interpretation of production flexibility according to the determined model (the greater the increase in arguments, the greater the approximation).

Ad. 3) The resulting scale of production effect: a = 0.1276. Interpretation: an increase in outlays (X_1 – fixed assets, X_2 – employment) is faster than an increase in effects (Y – value added). Decreasing productivity of production factors was obtained. A simultaneous increase in the value of fixed assets and the number of employees by 1% would increase pure production by only 0.1276%.

Ad. 4) Steel industry efficiency (E):

$$E = 14308.22 \cdot \left(\frac{X_1}{X_2}\right)^{0.7799} \cdot X_2^{-0.8724} \tag{10}$$

where:

E – steel industry efficiency calculated as value added at constant prices per 1 employee [PLN '000/person],

X_1/X_2 – technical equipment of labour as the value of fixed assets at constant prices per 1 employee [PLN '000/person].

X_2 – number of employers in steel industry [person].

To increase efficiency in steel industry steelworks plants have to reduce employment. The productivity calculated as net production per one employed in the steel industry is positively affected by technical labour equipment and a negative increase in the number of employees. Interpretation of productivity flexibility in relation to technical work equipment: an increase in technical equipment by 1% results in an increase (by an average) of 0.7799% with unchanged employment level. Interpretation of productivity elasticity relative to employment: a 1% increase in employment results in a fall 0.8724% in average (average) productivity with the same technical work equipment. Interpretation after an accurate calculation of power function indicators: a one-percent increase in the technical equipment of labour will increase productivity by 0.7790%, and a one-percent increase in employment will result in a decrease in efficiency by 0.8643%. Because $a_1 + a_2 < 1$ in the obtained model there is a negative scale effect (a = −0.0925), which means that the expenditure in the analyzed period grew faster than the effects obtained.

Ad. 5. Productivity of fixed assets (*P*):

$$P = 283240750.13 \cdot X_1^{-0.8724} \cdot \left(\frac{X_2}{X_1}\right)^{-0.6523} \tag{11}$$

where:

P – productivity calculated as value added at constant prices per unit of fixed assets (PLN '000),

X_1 – value of fixed assets at constant prices (PLN '000),

X_2/X_1 – ratio of the number of employees to the value of fixed assets at constant prices (PLN '000/person).

The impact (in minus) of fixed assets on productivity is greater than the effect of the ratio of the number of employees to fixed assets. Productivity of fixed assets in steel industry in Poland has to be changed but no by the growth of assets (like up to now). Nowadays steelworks plants in Poland use 75% their potential capacity in steel production. So they should reduce old technology and invest in automatization. 1% increase in non-current assets causes a decrease in the productivity of non-current assets by 0.8724% on average, with the employment/fixed assets ratio unchanged. An increase in the ratio of the number of employees to fixed assets by 1% results in a decrease in the productivity of fixed assets by 0.6523%, on average, if the fixed assets do not change.

Ad. 6. Forecasting changes

Based on the output data (used for the model), assuming that fixed assets and employment change exponentially and that this trend will continue in the following years, a forecast of production factors for 2020 (t_{21}) was established

based on the obtained production function (t_{21}), and the obtained values compared with the base period of 2000 (t_1). Results were presented in Table 2.

Table 2 Forecast of production indicators for steel industry in Poland

t	Year	Non-current assets in constant prices X_1	ln Y_{x1}	Employment/ persons X_2	ln Y_{X2}
1	2000	4966950	15.41832	48503	10.78938
21	2020	33002662	17.31210	16005	9.680681

After adding value to the obtained base model, the value of pure production was obtained: 18917298000 PLN. According to the forecast model, in 2020 the number of employees in the steel industry should be reduced to 16000 persons (Gajdzik, Szymszal, 2015) and the value of fixed assets should amount to 33002662 000 PLN.

The main problem: in 2019, the number of people employed in the steel sector was 24000, which means that to achieve efficiency in line with the model obtained, employment should be reduced by 8000 people. The reduction of employment in the steel sector in Poland is still under discussion, but in the conditions of production automation it is inevitable. Technical progress has always resulted in a reduction of employment. Employment reduction will contribute to increased productivity. Using the calculated performance model (formula 11): an increase in team work efficiency is achieved $E_{t21} = 512.8642$ thousand PLN/person.

CONCLUSION

Based on the analysis carried out, it can be concluded that after the completion of repair restructuring, the number of employees and the increase in the value of fixed assets (production) should still be reduced, this does not necessarily mean that it means investing in existing technologies. Steel mills should strive to automate production and apply industry 4.0 solutions. So was the restructuring of the steel sector effective? The restructuring effect can be assessed positively on the basis of efficiency gains, but when it comes to the relations between the impact of factors of production on the effects (production value), further reduction of staff and full automation of production is required. The C-D model also enables prediction of these factors, which allows corporate executives to plan changes in asset structure and employment.

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Abstract: The primary objective of the article is to identify conditions of restructuring from the point of view of Polish steel industry by using Cobb and Douglas model (C-D). Both in European economies and Polish economy, the steel industry is included to important branch of industry. The steel sector has been a permanent component of the Polish economy. Restructuring of metallurgy in Poland has been realized since 1990s. Finally after several years of changes (in the first decade of the 21st century) steel plants adjusted theirs operations to market economy conditions. Nowadays we think that the steel sector has competitive position on the domestic and European markets but if it is truth. On the base of C-D model, the author of the article presents results of the statistical analysis and answer the question about influence property and employment on production in steel industry. Obtained relations between particular components of production function show the condition of steel industry in Poland.

Keywords: restructuring, steel industry, C-D model