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ANALYSIS OF STEEL PRODUCTION TOTAL AND BY PROCESS IN POLAND AND ROMANIA WITH FORECAST UNTIL 2023

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The publication presents changes in steel production by process: Oxygen Blown Converter (OBC) and Electric Furnace (EF) in Poland and Romania. The publication consist of the analysis of steel production by process in these countries. The analysis was realized for two countries because Poland and Romania have a similar structure of steel production (the share of particular processes in total steel production).The analysis was realized in the period last 30 years (from 1989 to 2018) with forecast until 2023. In the long period of analysis, the steel mills in these countries were radical restructured and changed from steelworks plants controlled by public institutions (government) into the capital companies on modern European market.

Keywords: steel, production, OBC, EF, Poland, Romania

INTRODUCTION

In time of economic system transformation (in Poland since 1989) the steel plants (enterprises) have come a long way of transformation. The changes were deep and radical. The restructuring process in steel industry in Poland and other countries of the Middle-East Europe was started at the beginning of last decade 20-th century. The restructuring process was realized together with privatisation of steel plants in particular countries of the Middle-East Europe. The key aspect of restructuring in steel industries was restructuring of used technologies in steel mills. Restructured steel mills are still importance for the economies in particular countries. The range of analysis included steel production by process both in Poland and Romania, taking into consideration the share of two technologies: OBC and EF in steel production. Changes occurring in steel production by process in Polish steel industry were compared with situation in Romania where the restructuring took place in the same time and the changes in steel production by process were similar.

STEEL PRODUCTION IN POLAND AND ROMANIA IN LAST 30 YEARS

Steel production both in Poland and Romania decreased (as compared to 1989) in the analyzed period. In Poland, in 1989, steel mills produced 15 million tonnes of steel. In 2018, steel mills in Poland produced 10,2 million tonnes of steel. The Figure 1 shows dynamic (t_o = 1989) steel production in Poland. In the same period steel production in Romania decreased from 14 million tonnes in 1989 to 3,5 million tonnes in 2018. The Figure 2 shows analysed situation.

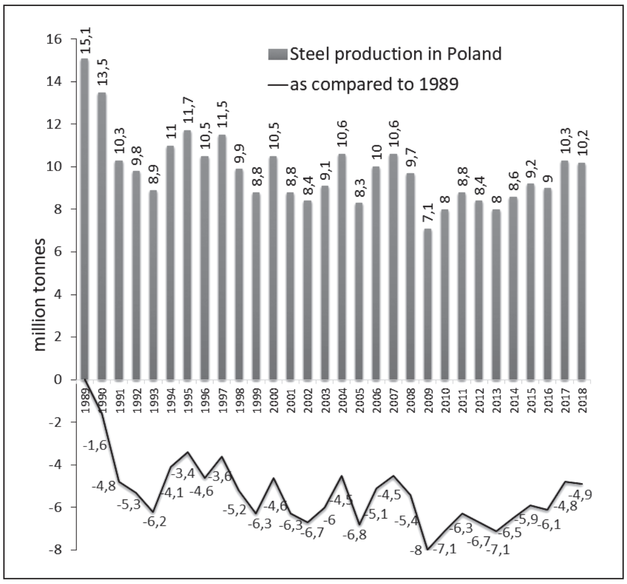

Figure 1 Steel production in Poland from 1989 to 2018 [1-4]

During the restructuring period, the main technological changes concerned the withdrawing of the technology Open Hearth Furnace (OHF). Steel production in OHF was reduced and eventually completed. In Poland, in 1989, OHF share of steel production was 36 % [1]. In May 2002, the OHF steel production was finished in Poland. Since 2003, the Polish steel industry has already used only two technologies: OBC and EF. In 2000, the OHF steel production was finished in Romania. In 1989, the share of OHF technology in steel production in Romania was 24,3 % [5-7]. OBC and EF are key technologies in steel industries in two countries

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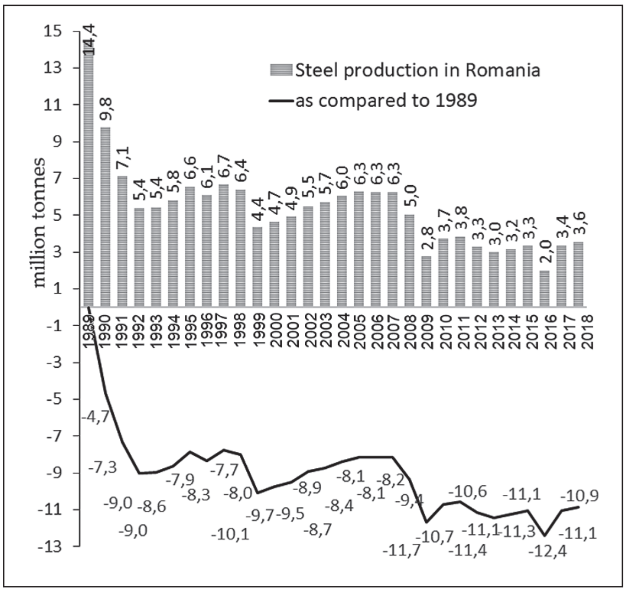

Figure 2 Steel production in Romania from 1989 to 2018 [4-7]

[8-9]. Steel production by process in Poland was presented in Table 1 and in Romania in Table 2.

METHODOLOLOGY

Steel production analysis was carried out using adaptive models. The moving average model was used to smooth the time series. The moving average acts as a filter, eliminating short-term fluctuations from the series. The model of simple moving average (around the average value) was used for the smoothing constant k (e.g. $k = 2$ and $k = 3$). The model of ex-post forecast is described by the following formula [10]:

$$y_t^* = \frac{1}{k}\sum_{i=t-k}^{t-1} y_i \tag{1}$$

for $t = k+1, ..., n$,

Where: n – number of elements of the time series, y_i – empirical data in period i, y^*_t – forecasts value in period t, k – smoothing constant.

The model of ex-ante forecast is described by the following formula [10]:

$$y_t^* = \frac{1}{k}\sum_{i=T-k}^{T-1} y_i \tag{2}$$

for $T = n + 1, \ldots, \tau$.

For the purposes of this study, root mean square error RMSE* (3) and mean error ψ (4), were determined. These errors were determined using mathematical relationships (3,4) [10]:

$$RMSE^* = \sqrt{\frac{1}{n-m}\cdot\sum_{t=m+1}^{n}(y_t - y_t^*)^2} \tag{3}$$

$$\Psi = \frac{1}{n-m}\cdot\sum_{t=m+n}^{n}\frac{\left|y_t - y_t^*\right|}{y_t} \tag{4}$$

Table 1 **Steel production by process in Poland [1-4]**

Years	OBC	EF	OHF	OBC	EF	OHF
	Million tonnes			%		
1989	7,3	2,1	5,7	47,8	16,4	35,7
1990	7,2	2,5	3,9	53,3	18,5	28,9
1991	6,5	1,9	1,9	63,1	18,4	18,4
1992	6,3	1,7	1,8	64,3	17,3	18,4
1993	6,2	2,0	1,7	69,7	22,5	19,1
1994	7,0	2,4	1,6	63,6	21,8	14,5
1995	7,6	2,6	1,6	65,0	22,2	13,7
1996	6,7	2,7	1,1	63,8	25,7	10,5
1997	7,5	3,0	1,0	65,2	26,1	8,7
1998	6,2	3,2	0,5	62,6	32,3	5,1
1999	5,4	3,0	0,4	61,4	34,1	4,5
2000	6,8	3,3	0,4	64,8	31,4	3,8
2001	5,8	2,8	0,2	65,9	31,8	2,3
2002	5,8	2,5	0,1	69,0	29,8	1,2
2003	6,2	2,9	0	68,1	31,9	0
2004	6,3	4,2	0	59,4	39,6	0
2005	4,4	3,9	0	53,0	47,0	0
2006	5,8	4,2	0	58,0	42,0	0
2007	6,2	4,5	0	58,5	42,5	0
2008	5,2	4,5	0	53,6	46,4	0
2009	3,2	3,9	0	45,1	54,9	0
2010	3,9	4,0	0	48,8	50,0	0
2011	4,4	4,4	0	50,0	50,0	0
2012	4,2	4,2	0	50,0	50,0	0
2013	4,4	3,6	0	55,0	45,0	0
2014	5,0	3,5	0	58,1	40,7	0
2015	5,3	3,9	0	57,6	42,4	0
2016	5,1	3,9	0	56,7	43,3	0
2017	5,7	4,6	0	55,3	44,7	0
2018	5,4	4,8	0	52,9	47,1	0

Table 2 **Steel production by process in Romania [4]**

Years	OBC	EF	OHF	OBC	EF	OHF
	Million tonnes			%		
1989	14,4	7,5	3,5	3,5	51,7	24,0
1990	9,8	5,3	2,4	2,1	54,0	24,3
1991	7,1	3,9	1,9	1,3	54,5	27,3
1992	5,4	2,8	1,7	0,9	52,6	30,9
1993	5,4	2,9	1,6	1,0	54,0	28,5
1994	5,8	3,3	1,5	1,0	56,5	26,1
1995	6,6	4,1	1,5	1,0	62,3	22,9
1996	6,1	3,8	1,3	0,9	63,3	21,3
1997	6,7	4,7	1,0	1,0	70,7	14,8
1998	6,4	4,7	1,0	0,7	73,4	16,1
1999	4,4	3,2	0,9	0,3	74,1	20,1
2000	4,7	3,4	1,3	0	73,7	28,4
2001	4,9	3,6	1,4	0	72,1	27,8
2002	5,5	4,5	1,0	0	82,1	17,9
2003	5,7	4,5	1,1	0	79,8	20,2
2004	6,0	4,7	1,4	0	77,5	22,5
2005	6,3	4,5	1,8	0	71,8	28,2
2006	6,3	4,4	1,9	0	69,7	30,3
2007	6,3	4,4	1,9	0	69,6	30,4
2008	5,0	3,3	1,7	0	66,4	33,6
2009	2,8	1,8	1,0	0	64,8	35,2
2010	3,7	2,0	1,7	0	53,5	46,5
2011	3,8	1,9	2,0	0	49,0	51,0
2012	3,3	1,9	1,4	0	56,8	43,2
2013	3,0	1,6	1,4	0	54,4	45,6
2014	3,2	1,8	1,3	0	58,4	41,6
2015	3,3	2,2	1,1	0	67,1	32,9
2016	2,0	0	2,0	0	0	100,0
2017	3,4	2,3	1,0	0	69,3	30,7
2018	3,6	2,2	1,4	0	61,3	38,7

Where: n – number of elements of the time series; y_t – empirical data; y_t^* – forecasts value; m – number of initial time moments t.

Using the moving average method, the forecast for 2019 was determined and using the exponential-autoregressive model (for $k = 2$ and $k = 3$), the short-term forecast (until 2023) was determined. The quality of forecasts was also assessed using other adaptive models included in the exponential smoothing group (simple exponential smoothing model, Brown exponential single smoothing model), but the lowest forecast errors were obtained in exponential-autoregressive models. In the exponential-autoregressive model for constant smoothing $k = 3$ first, k and l were selected ($k = 3$, $l = 2$) and restrictions on β and δ were imposed:

$$\begin{cases} 0 < \beta_i \leq 1; \sum_{i=1}^{k} \beta_i = 1; 0 < ... \leq \beta_{i+1} \leq \beta_i \leq \beta_{i-1} \leq ... \leq 1 \\ 0 < \delta_i \leq 1; \left\{ \sum_{i=1}^{k} \delta_i = 1; 0 < ... \leq \delta_{i+1} \leq \delta_i \leq \delta_{i-1} \leq ... \leq 1 \right. \end{cases} \quad (5)$$

Ex-post forecast describes mathematical dependencies:

$$\begin{cases} G_t = y_t \quad t = 1,...,k \\ G_t = \alpha \cdot y_t + (1-\alpha) \cdot \sum_{i=1}^{k} (\beta_i = G_{t-1}) \;\; t > k \\ y_t^* = G_{t-1} + \sum_{j=1}^{l} \delta_j \cdot (G_{t-j} - G_{t-j-1}) \;\; t = l+2,...,n \end{cases} \quad (6)$$

and ex-ante forecast describes mathematical dependencies:

$$\begin{cases} F_n = G_n + \sum_{j=1}^{l} \delta_j \cdot (G_{n-j+1} - G_{n-j}) \\ y_T^* = F_n \quad T = n+1,...,\tau \end{cases} \quad (7)$$

In the exponential-autoregressive model for $k = 2$, similarly to the previous model, first choose the constants k and l (e.g. $k = 2$, $l = 2$), and the limitations and equations of forecasts are the same (5-7). The optimal values of smoothing parameter α were determined using the Excel Solver.

ANALYSIS OF STEEL PRODUCTION TOTAL AND BY PROCESS IN POLAND AND ROMANIA WITH FORECAST UNTIL 2023

The point forecast value is equal to the arithmetic mean of the last k elements of the time series (Table 3).

Errors Ψ for particular forecasts (ex-post) of steel production in Poland were less than 13 %, and for particular forecasts of steel production in Romania were higher (20 %). Results of analysis were presented in Figures 3 and 4 (model for $k = 3$).

Short-term forecasts of steel production (ex-ante) built using exponential-autoregresive models show a downward trends. Results of analysis for total steel production were presented in Figures 5 and 6 (for $k = 3$) and in Table 4 – all obtained forecasts. Errors of forecast (ex -post): Ψ and RMSE for steel production in Poland were lower than steel production in Romania. The resulting prediction errors (ex-post) using the exponential-autoregresive model were 2-3 % lower than forecast errors (ex-post) using the moving average model.

Table 3 **Forecast of steel production by using the simple moving average model/ million tonnes**

	for $k = 2$		for $k = 3$	
	Poland	Romania	Poland	Romania
Total F/2019	10,35	3,45	9,83	2,97
Total E/2019	9,00	3,45	9,00	3,45
Total/A	9,82	5,36	9,82	5,36
Total/A for F ex-post	9,70	5,29	9,63	5,23
OBC F /2019	5,55	2,25	5,40	1,50
OBC E/2019	4,90	2,33	4,90	2,33
OBC /A	5,77	3,38	5,77	3,38
OBC/A for F ex-post	5,75	3,36	5,73	3,36
EF F /2019	4,70	1,20	4,43	1,47
EF E/2019	4,00	1,12	4,00	1,12
EF/A	3,36	1,53	3,36	1,53
EF/A for F ex-post	3,31	1,50	3,31	1,48

F- Forecast; A – Average, E – Empirical data (information about steel production in 2019 was published officially in second quarter 2020 – after review of the publication).

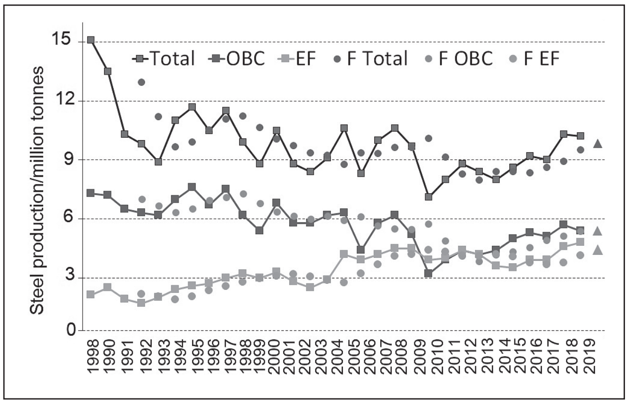

Figure 3 Steel production in Poland - moving average model

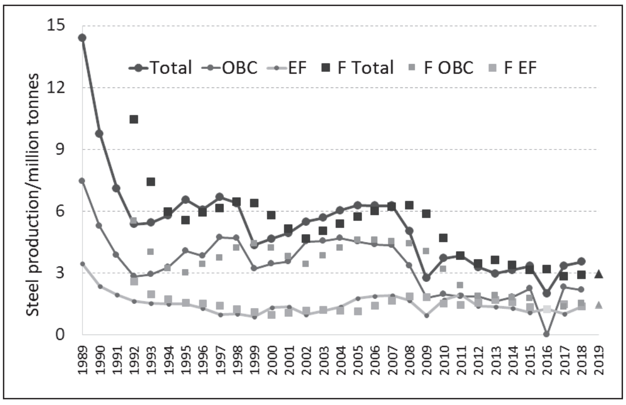

Figure 4 Steel production in Romania - moving average model

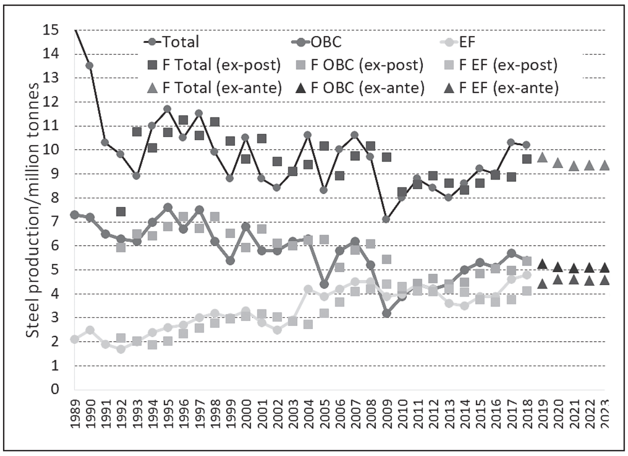

Figure 5 Steel production in Poland – exponential-autoregressive model

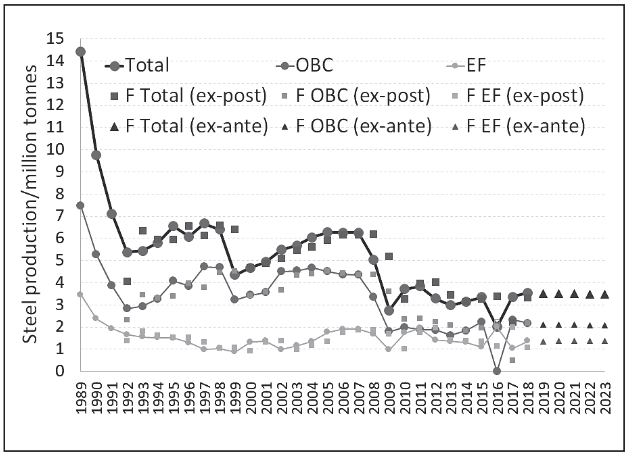

Figure 6 Steel production in Romania – exponential-autoregressive model

Table 4 **Forecasts of steel production by using exponential-autoregressive model / million tonnes**

Forecast	Years	for *k* = 2, l=2		for *k* = 3, l=2	
		Poland	Romania	Poland	Romania
Total	2019	9,840	3,469	9,705	3,512
	2020	9,399	3,511	9,464	3,523
	2021	9,431	3,488	9,331	3,506
	2022	9,437	3,478	9,355	3,484
	2023	9,440	3,473	9,357	3,479
β1= 0,70; β2= 0,30; δ1 =0,80; δ2=0,20		α=0,371 Ψ=0,106	α=0,490 Ψ=0,160	α=0,310 Ψ=0,108	α=0,466 Ψ=0,157
β1= 0,70; β2= 0,30; δ1 =0,80; δ2=0,20		(10,6 %) RMSE = 1,169	(16 %) RMSE = 0,921	(10,8 %) RMSE = 1,192	(15,7 %) RMSE = 0,854
OBC	2019	5,271	2,170	5,260	2,154
	2020	4,995	2,170	5,135	2,147
	2021	5,044	2,170	5,077	2,150
	2022	5,056	2,169	5,096	2,150
	2023	5,061	2,169	5,097	2,151
β1= 0,70; β2= 0,30; δ1 =0,80; δ2=0,20		α=0,347 Ψ=0,119	α=0,621 Ψ*=0,15	α=0,338 Ψ=0,120	α=0,566 Ψ*=0,136
β1= 0,70; β2= 0,30; δ1 =0,80; δ2=0,20		(11,9%) RMSE = 0,796	(15 %) RMSE* = 0,606	(12 %) RMSE = 0,801	(13,6 %) RMSE* = 0,575
EF	2019	4,756	1,3924	4,433	1,357
	2020	4,641	1,4379	4,611	1,371
	2021	4,634	1,4393	4,615	1,375
	2022	4,630	1,4397	4,553	1,374
	2023	4,628	1,4400	4,593	1,374
β1= 0,70; β2= 0,30; δ1 =0,80; δ2=0,20		α=0,533 Ψ=0,098	α=0,582 Ψ=0,225	α=0,536 Ψ=0,099	α=0,522 Ψ=0,228
β1= 0,70; β2= 0,30; δ1 =0,80; δ2=0,20		(9,8 %) RMSE = 0,414	(22,4 %) RMSE = 0,407	(9,9 %) RMSE = 0,414	(22,8 %) RMSE = 0,392

Ψ* and RMSE* - errors for the forecast without production OBC in 2016 (the production was zero – Table 2).

CONCLUSION

The use of adaptive model in forecasting steel production in two countries: Poland and Romania allows for the identification of trends in the steel production total and by process. On the basis of the analyses of the obtained forecasts it was found that:

– the quantity of steel production in the analyzed countries shows a decreasing trend – as compared to1989 and on the base of obtained forecasts,
– that decrease of steel production is faster in Romania than in Poland,
– the share of used technology: OBC and EF in total steel production decreases in two analyzed countries and the gap is getting smaller.

Prognostic models can be used to monitor the situation in steel industry in analyzed countries. The solution proposed in the study can be used by steel enterprises to build market strategies. These methods and others [11] can be used to optimized production.

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Note: The responsible for English language is lector from University, Poland