The objective of this publication was to present the results of prognoses for steel production volume in the world. This work was created on the basis of statistical data. The volume of total steel production in the world from 2000 to 2015 was used in order to create the prognosis. The prognoses were created until 2020 – for a period of 5 years. Econometric methods were used to execute the prognoses. The minimum value of error (square root) was assumed as optimisation criterion of the point value of a prognosis. Individual prognoses were grouped according to change scenarios for the studied phenomenon, taking into account the trend nature.

**Key words:** steel production, econometric methods, prognoses, change scenarios

### INTRODUCTION

Steelwork companies operate in a global environment. The dynamics of changes in this environment results in the need to execute prognoses for individual phenomena, in particular for production volume. Planning of production strategies requires a set of problems and activities providing a chance to reach the desired results to be evaluated beforehand. Forecasting is an element of a planning process. Production volume forecasting is to engage the future, to answer the question: “What will happen?” The scope of forecasting presented in this paper included total steel production in the world, using econometric methods (adaptation models).

### FORECASTING METHODOLOGY FOR GLOBAL CRUDE STEEL

Data on total steel production in the world since 2000 was used in order to create the prognoses. The minimum value of one of the following errors of the point value of a prognosis was used as the optimisation criterion in adaptation models: square root calculated from the average square error of apparent prognoses (RMSE*) and the average value of relative errors of expired prognoses ($\Psi_{rel}$). A list of optimal models was placed in Table 1. Individual prognoses were grouped taking into account the nature of the trend: pessimistic for decreasing trends, optimistic – for an increasing trend, moderate, if the trend is between a pessimistic and an optimistic trend.

#### PESSIMISTIC SCENARIO FOR FORECASTED VOLUMES OF GLOBAL STEEL PRODUCTION

The exponential-autoregressive model (k=2) proved to be a better model for building a prognosis of total global crude steel production. Forecasting method assumption: $\alpha$ is the model smoothing parameters with values from the (0,1] range, $\beta_i$ is a weight assigned to the $i$th evaluation of the smoothed value, $\delta_j$ is the weight assigned to the increase of smoothed value evaluation, $G_t$ is a smoothing operator (evaluation of a smoothed value of a series), $F_t$ smoothed evaluation of a level (average value at time or during period t). Expired prognoses are equal to [3-5]:

\[
\begin{align*}
G_t &= y_t \quad \text{dla } t = 1,\ldots,k \\
G_t &= \alpha \cdot y_t + (1-\alpha) \cdot \sum_{i=1}^{k} (\beta_i \cdot G_{t-i}) \quad \text{dla } t > k \\
y_t^* &= G_n + \sum_{j=1}^{n} \delta_j \cdot (G_{t-j} - G_{t-j}) \quad \text{dla } t = l+2,\ldots,n \\
\end{align*}
\]

Ex ante prognoses are equal to:

\[
\begin{align*}
F_r &= G_r + \sum_{j=1}^{r} \delta_j \cdot (G_{r-j} - G_{r-j}) \\
y^*_t &= F_t \quad \text{dla } T = n+1,\ldots,T
\end{align*}
\]
where:

\[
\begin{align*}
0 < \beta_i \leq 1; \sum_{i=1}^{k} \beta_i = 1; 0 < \delta_i \leq \beta_i \leq \beta_{i-1} \leq \ldots \leq \beta_1 \leq 1 \quad & \text{or} \quad \sum_{i=1}^{k} \beta_i = 1; 0 < \delta_i \leq \delta_{i-1} \leq \ldots \leq \delta_1 \leq 1
\end{align*}
\]

Obtained prognoses Global crude steel/M mt in 2016-2020 (y*):
\[
y^{*}_{2016} = 1,588,325; y^{*}_{2017} = 1,582,238; y^{*}_{2018} = 1,578,075; y^{*}_{2019} = 1,575,294; y^{*}_{2020} = 1,573,423.
\]

The decreasing tendency of the trend for global steel production until 2020 was assumed as the pessimistic scenario.

**OPTIMISTIC SCENARIO FOR FORECASTED VOLUMES OF GLOBAL STEEL PRODUCTION**

In order to build a prognosis of steel production volume using Holt’s linear models allowing for the trend suppression effect (multiplicative - two types of start-up), a model with \( S_i = y_i/y_{i-1} \) was selected because of its smaller error values (\( \Psi^*, \text{RMSE}^* \)), where \( S_i \) is a smoothed evaluation of increasing tendency for a time series, during time or period \( t \). Parameters: \( \alpha \) smoothing parameter of the level of the prognosed variable; \( \beta_i \) smoothing parameter of the increase caused by the increasing tendency; \( \Phi \) smoothing parameter of a trend, with values in the range of \((0,1]\) [3-5].

Expired prognoses (ex post) [3-5]:
\[
\begin{align*}
F_i &= y_i \\
S_i &= y_i/y_{i-1} \\
F_{i-1} &= \alpha \cdot y_{i-1} + (1-\alpha) \cdot \left( F_{i-1} \cdot S_{i-1} \cdot \Phi \right) \\
S_{i-1} &= \beta \cdot F_{i-1} + (1-\beta) \cdot S_{i-1} \\
y_i^* &= F_{i-1} \cdot S_{i-1} \cdot \Phi \\
F_{i-1} &= S_{i-1} \cdot \Phi^{-1} \cdot \Phi \cdot y_{i-1} \\
S_{i-1} &= \beta \cdot F_{i-1} + (1-\beta) \cdot S_{i-1} \\
y_i^* &= F_{i-1} \cdot S_{i-1} \cdot \Phi \\
F_{i-1} &= S_{i-1} \cdot \Phi^{-1} \cdot \Phi \cdot y_{i-1}
\end{align*}
\]

Ex ante prognoses:
\[
\begin{align*}
F_i &= y_i \\
S_i &= y_i/y_{i-1} \\
F_{i-1} &= \alpha \cdot y_{i-1} + (1-\alpha) \cdot \left( F_{i-1} \cdot S_{i-1} \cdot \Phi \right) \\
S_{i-1} &= \beta \cdot F_{i-1} + (1-\beta) \cdot S_{i-1} \\
y_i^* &= F_{i-1} \cdot S_{i-1} \cdot \Phi \\
F_{i-1} &= S_{i-1} \cdot \Phi^{-1} \cdot \Phi \cdot y_{i-1}
\end{align*}
\]

Obtained prognoses Global crude steel/M mt in 2016-2020 (y*):
\[
y^{*}_{2016} = 1,639,124; y^{*}_{2017} = 1,681,384; y^{*}_{2018} = 1,724,733; y^{*}_{2019} = 1,769,201; y^{*}_{2020} = 1,814,814.
\]

The increasing tendency of the trend for global steel production until 2020 was assumed as the optimistic scenario (Fig. 3).

Forecasting the global steel production according to the same model, but assuming a start-up: \( S_1 = 1 \), the following values in M mt were obtained: \( y^*_{2016} = 1,639,974; y^*_{2017} = 1,628,822; y^*_{2018} = 1,726,789; y^*_{2019} = 1,771,905; y^*_{2020} = 1,818,199 \). In regards to the prognosis (Figure 3), the volumes of steel production are higher, respectively, by 0.05 % in 2016, 0.085 % in 2017, 0.119 % in 2018, 0.153 % in 2019 and 0.186 % in 2020. Applying the next model: Holt’s square model with prognosis ex post [3-5]:
\[
\begin{align*}
F_i &= y_i \\
S_i &= y_i/y_{i-1} \\
F_{i-1} &= \alpha \cdot y_{i-1} + (1-\alpha) \cdot \left( F_{i-1} \cdot S_{i-1} \cdot N_{i-1} \cdot S_{i-1} \cdot N_{i-1} \cdot \Phi \right) \\
S_{i-1} &= \beta \cdot F_{i-1} + (1-\beta) \cdot S_{i-1} \\
y_i^* &= F_{i-1} \cdot S_{i-1} \cdot \Phi \\
F_{i-1} &= S_{i-1} \cdot \Phi^{-1} \cdot \Phi \cdot y_{i-1} \\
S_{i-1} &= \beta \cdot F_{i-1} + (1-\beta) \cdot S_{i-1} \\
y_i^* &= F_{i-1} \cdot S_{i-1} \cdot \Phi \\
F_{i-1} &= S_{i-1} \cdot \Phi^{-1} \cdot \Phi \cdot y_{i-1}
\end{align*}
\]
and prognosis ex ante:
\[
S_t = \Phi \left( F_t - 2 \cdot F_{t-1} + F_{t-2} \right) + (1 - \Phi) \cdot N_{t-1},
\]
\[
N_t = \Phi \cdot (F_t - 2 \cdot F_{t-1} + F_{t-2}) + (1 - \Phi) \cdot N_{t-1},
\]
\[
y'_t = F_{t-1} + S_{t-1} + \frac{1}{2} \cdot N_{t-1},
\]
de \(t = 2, ..., n\)

where: \(\alpha\) is the smoothing parameter of the prognosed variable level, \(\beta\) is a smoothing parameter of an increase caused by an increasing tendency, \(\Phi\) is a smoothing parameter of a non-linear trend increase. These parameters have values from the range of \((0, 1]\). 

Obtained prognoses for global crude steel/M mt in 2016-2020: \(y^\ast_{2016} = 1,771,291; y^\ast_{2017} = 1,829,704; y^\ast_{2018} = 1,887,768; y^\ast_{2019} = 1,945,429; y^\ast_{2020} = 2,002,740\) (Figure 4).

**MODERATE SCENARIO FOR FORECASTED VOLUMES OF GLOBAL STEEL PRODUCTION**

For building this prognosis, the Holt’s linear model allowing for the trend suppression effect (additive - two types of start-up) was selected: First model (Figure 5): prognosis ex post are equal to \([3-5]\):

\[
S_t = \beta \cdot (F_t - F_{t-1}) + (1 - \beta) \cdot S_{t-1},
\]
\[
N_t = \Phi \cdot (F_t - 2 \cdot F_{t-1} + F_{t-2}) + (1 - \Phi) \cdot N_{t-1},
\]
\[
y'_t = F_{t-1} + S_{t-1} + \frac{1}{2} \cdot N_{t-1},
\]
de \(t = 2, ..., n\)

prognosis ex ante are equal to:
\[
S_t = y_2 - y_1;
\]
\[
N_t = y_3 - y_{2}y_2 + y_1;
\]
\[
y'_t = F_{t-1} + (T-n) \cdot S_t + \frac{1}{2} \cdot N_t,\]
d\(e\) \(T = n + 1, ..., \tau\)

in the second model: \(S_t = 0\)

where: \(\alpha\) is the smoothing parameter of the prognosed variable level, \(\beta\) is the smoothing parameter of an increase caused by an increasing tendency, \(\Phi\) trend extinction parameter. These parameters have values in a range of \((0, 1]\). 

Obtained prognoses for global crude steel/M mt in 2016-2020: \(y^\ast_{2016} = 1,622,401; y^\ast_{2017} = 1,644,481; y^\ast_{2018} = 1,664,559; y^\ast_{2019} = 1,682,768; y^\ast_{2020} = 1,699,234\). 

The increasing tendency of the trend for global steel production until 2020 – moderate scenario (Figure 5). 

In the second model, the following prognoses for global crude steel production were obtained / M mt in 2016-2020: \(y^\ast_{2016} = 1,618,178; y^\ast_{2017} = 1,635,903; y^\ast_{2018} = 1,651,347; y^\ast_{2019} = 1,664,725; y^\ast_{2020} = 1,676,234\). 

The following conclusion was drawn on the basis of these two models the next five years will not see the global steel production exceeding 1,6 billion tons of crude steel per year, but in 9 months of 2016 world steel production was 1,997 M mt [1] so in all 2016 production will be on level about 1,557 M mt less in 2015 (decrease about 1%). In the situation my moderate model should be reduced about 3.5% (difference between prognosis in 2016 (Figure 5) and situation in 2016 (total world steel production for 9 months).

Additionally, prognoses according to assumptions of the Brown model were build – the double exponential Brown smoothing model for the linear model and the triple exponential Brown smoothing model for the...
square model. Ex post prognoses ex post are executed for the linear model according to [3–5]:

\[ G_t = y_t \]
\[ H_t = y_t \]
\[ G_t = \alpha \cdot y_t + (1-\alpha) \cdot G_{t-1} \text{ dla } t = 2,\ldots,n \]
\[ H_t = \alpha \cdot G_t + (1-\alpha) \cdot H_{t-1} \text{ dla } t = 2,\ldots,n \]
\[ F_t = 2 \cdot G_t - H_t \text{ dla } t = 2,\ldots,n \]
\[ S_t = \frac{1}{1-\alpha} (G_t - H_t) \text{ dla } t = 2,\ldots,n \]
\[ y_t^* = F_t \cdot S_t \text{ dla } t = 3,\ldots,n \]

and, respectively, for the square model:

\[ G_t = \alpha \cdot y_t + (1-\alpha) \cdot G_{t-1} \]
\[ H_t = \alpha \cdot G_t + (1-\alpha) \cdot H_{t-1} \]
\[ F_t = 2 \cdot G_t - H_t \]
\[ S_t = \frac{1}{1-\alpha} (G_t - H_t) \]
\[ y_t^* = F_t \cdot S_t \text{ dla } t = 3,\ldots,n \]

and respectively, for the square model:

\[ G_t = \alpha \cdot y_t + (1-\alpha) \cdot G_{t-1} \]
\[ H_t = \alpha \cdot G_t + (1-\alpha) \cdot H_{t-1} \]
\[ M_t = \alpha \cdot H_t + (1-\alpha) \cdot M_{t-1} \text{ dla } t = 2,\ldots,n \]
\[ F_t = 3 \cdot G_t - 2 \cdot H_t + M_t \text{ dla } t = 2,\ldots,n \]
\[ S_t = \frac{1}{1-\alpha} \cdot \left[ (G_t - 2 \cdot H_t + M_t) \right] \text{ dla } t = 2,\ldots,n \]
\[ y_t^* = F_t \cdot S_t \text{ dla } t = 3,\ldots,n \]

CONCLUSION

Prognoses of global crude steel production may be decreasing down to about 1,57 bn tons in 2020 or increasing up to the level of 1,8 bn tons in 2020 (in the basic scenario). Steelworks industry is one of the strategic sectors of industry. Fluctuations of trade cycles of economy may result in a decrease or in an increase of steel production in world and particular countries, for example changes in Polish steel production follow according to national economic situation and global (like economic crisis or UE policy) [6].

REFERENCES

[2] Own research based on statistic data

Note: Translation Agency Niusans, Gliwice, Poland is the translator responsible for the English version of this text.