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PROGNOSTIC MODELING OF TOTAL GLOBAL STEEL PRODUCTION

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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 prognosis. During the 2000-2015 period, the steel production trend has been increasing, with a small decrease recorded in 2009 (as a result of the global economic crisis) and in 2015.

These data (Figure 1) were used 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 (Ψ). 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.

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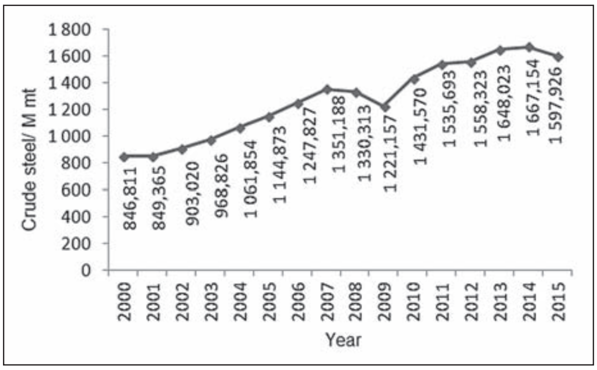

Figure 1 Total global steel production in 2000-2015 [1]

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: α is the model smoothing parameters with values from the (0,1] range, β_i is a weight assigned to the i[th] evaluation of the smoothed value, δ_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]:

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

ex ante prognoses are equal to:

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

Table 1 **Models used for prognosis of global crude steel production until 2020 [2]**

Model	Error		
	ex post		ex ante*
	Y	RMSE*	Y
Exponential-autoregressive model (k=2)	0,056	91,152	0,0547
	k=2, l=2, β_1=0,70, β_2=0,30, δ_1= 0,80, δ_2=0,20; min. value: RMSE*, α=0,6952		
Holt's linear model allowing for the trend suppression effect (multiplicative - two types of start-up)	0,056	85,683	0,748
	min.value: RMSE*, α=0,9832; β=0,013; Φ=0,9976 type of start-up: $F_1=y_{1;}$ $S_1=y_2/y_1$		
	0,057	86,313	0,759
	min.value: RMSE*, α=0,9976; β=0,0700; Φ=1,000 type of start-up: $F_1=y_{1;}$ S_1=1		
Holt's square model (two types of start-up)	0,036	60,182	0,0592
	min.value: RMSE*,α=0,0001; β=0,2474; Φ=0,3342 type of start-up: $F_1=y_{1;}$ $S_1=y_2-y_1$; $N_1=y_3-2y_2+y_{1;}$ $N_2=y_3-2y_2+y_1$		
	0,034	60,111	0,0791
	min.value: RMSE*,α=0,0002; β=0,5349; Φ=1,000 type of start-up: $F_1=y_1$; S_1=0; $N_1=0_;$ $N_2=y_3-2y_2+y_1$		
Holt's linear model allowing for the trend suppression effect (additive - two types of start-up)	0,055	84,820	0,0686
	min.value: RMSE*, α=0,9930; β=0,1404; Φ=0,9557 type of start-up: $F_1=y_1$; $S_{1=}y_2-y_1$		
	0,055	85,079	0,0675
	min.value: RMSE*, α=0,9976; β=0,1596; Φ=0,9379 about type of start-up: $F_1=y_1$; S_1=0		
Double exponential Brown smoothing model applied to the linear model	0,061	93,062	0,0875
	min.value: RMSE*, α=0,4952		
Triple exponential Brown smoothing model applied to the square model	0,062	98,802	0,0977
	min.value: RMSE*, α=0,312		

* error ex ante for 2015

where:

$$\begin{cases} 0 < \beta_i \leq 1;\ \sum_{i=1}^{k} \beta_i = 1;\ 0 < \ldots \leq \beta_{i+1} \leq \beta_i \leq \beta_{i-1} \leq \ldots \leq 1 \\ 0 < \delta_j \leq 1; \sum_{j=1}^{l} \delta_j = 1;\ 0 < \ldots \leq \delta_{j+1} \leq \delta_j \leq \delta_{j-1} \leq \ldots \leq 1 \end{cases}$$

Obtained prognoses Global crude steel/M mt in 2016-2020 (y^*_t): 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 $S_1 = y_2/y_1$ was selected because of its smaller error values (Ψ, RMSE*), where S_1 is a smoothed evaluation of increasing tendency for a time series, during time or period t. Parameters: α smoothing

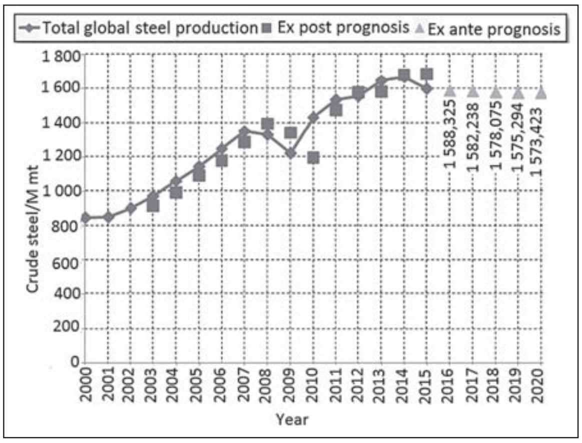

Figure 2 Pessimistic scenario for prognosis of global steel production until 2020 [2]

parameter of the level of the prognosed variable; β_i smoothing parameter of the increase caused by the increasing tendency; Φ smoothing parameter of a trend, with values in the range of (0,1] [3-5].

Expired prognoses (ex post) [3-5]:

$$\begin{cases} F_1 = y_1 \\ S_1 = \dfrac{y_2}{y_1} \\ F_t = \alpha \cdot y_t + (1-\alpha)\cdot(F_{t-1}\cdot S_{t-1})\cdot \Phi \quad dla\ t = 2,\ldots,n \\ S_t = \beta \cdot \dfrac{F_t}{F_{t-1}} + (1-\beta)\cdot S_{t-1}\cdot \Phi \quad dla\ t = 2,\ldots,n \\ y_t^* = F_{t-1}\cdot S_{t-1}\cdot \Phi \quad dla \quad t = 2,\ldots,n \end{cases}$$

Ex ante prognoses:

$$\begin{cases} F_n = \alpha \cdot y_n + (1-\alpha)\cdot(F_{n-1}\cdot S_{n-1})\cdot \Phi \\ S_n = \beta \cdot \dfrac{F_n}{F_{n-1}} + (1-\beta)\cdot S_{n-1}\cdot \Phi \\ y_T^* = F_n \cdot S_n^{(T-n)} \cdot \Phi^{T-n}\ dla \quad T = n+1,\ldots,\tau \end{cases}$$

Obtained prognoses Global crude steel/M mt in 2016-2020 (y^*_t): 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 62,822; 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]:

$$\begin{cases} F_1 = y_1 \\ S_1 = 0 \\ N_1 = 0 \\ N_2 = y_3 - 2y_2 + y_1 \\ F_t = \alpha \cdot y_t + (1-\alpha)\cdot(F_{t-1} + S_{t-1} + N_{t-1})\ \ dla\ t = 2,\ldots,n \end{cases}$$

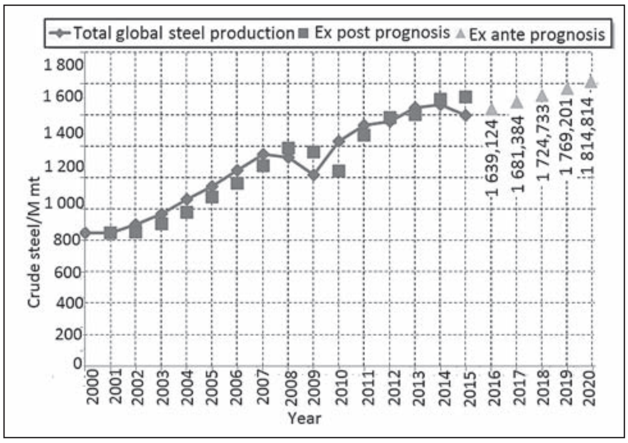

Figure 3 Optimistic scenario for prognosis of global steel production until 2020 – version 1 [2]

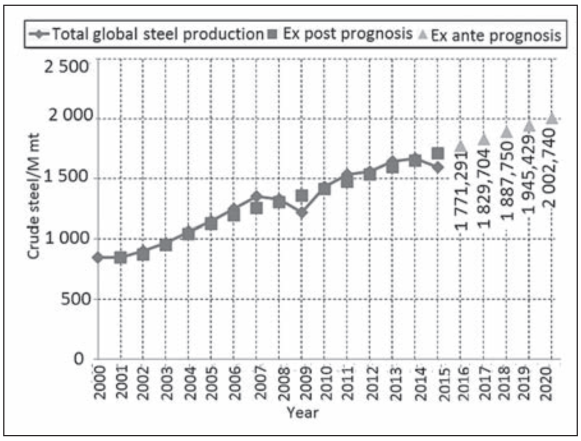

Figure 4 Very optimistic scenario for prognosis of global steel production until 2020 – version 2 [2]

$$\begin{cases} S_t = \beta \cdot (F_t - F_{t-1}) + (1-\beta) \cdot S_{t-1} \;\; dla \;\; t = 2,\dots,n \\ N_t = \Phi \cdot (F_t - 2 \cdot F_{t-1} + F_{t-2}) + (1-\Phi) \cdot N_{t-1} \;\; dla \;\; t = 3,\dots,n \\ y_t^* = F_{t-1} + S_{t-1} + \frac{1}{2} \cdot N_{t-1} \;\; dla \;\; t = 2,\dots,n \end{cases}$$

and prognosis ex ante:

$$\begin{cases} F_n = \alpha \cdot y_n + (1-\alpha) \cdot (F_{n-1} + S_{n-1} + N_{n-1}) \\ S_n = \beta \cdot (F_n - F_{n-1}) + (1-\beta) \cdot S_{n-1} \\ N_n = \Phi \cdot (F_n - 2 \cdot F_{n-1} + F_{n-2}) + (1-\Phi) \cdot N_{n-1} \\ y_T^* = F_n + (T-n) \cdot S_n + \frac{1}{2} \cdot (T-n)^2 \cdot N_n \;\; dla \;\; T = n+1,\dots,\tau \end{cases}$$

where: α is the smoothing parameter of the prognosed variable level, β_i is a smoothing parameter of an increase caused by an increasing tendency, Φ is a smoothing parameter of a non-linear trend increase. These parameters have values from the range of (0,1]. F_t smoothed evaluation of a level (average value) of time series at time or period t; S_t smoothed evaluation of an increasing tendency in a time series, at time or period t; N_t smoothed evaluation of a non-linear increase of an increasing tendency in a time series, at time or period t; the following **results of prognosis of global crude steel**/ M mt in 2016-2020 were obtained (y^*_t): y^*_{2016} = 1 771,291; y^*_{2017} = 1 829,704 ; y^*_{2018} = 1 887,750; y^*_{2019} = 1 945,429; y^*_{2020} = 2 002,740 (Figure 4).

The prognosis of over 2 billion tons of crude steel produced in the world in 2020 may be undermined using expert knowledge. This would require the global economy to accelerate substantially For comparison, using the same model and assuming the following start-up: $S_1=y_2-y_1$; $N_1=y_3-2y_2+y_1$; $N_2=y_3-2y_2+y_1$ lower **prognosis of global crude steel/M mt in 2016-2020 was obtained:** y^*_{2016} = 1 745,492; y^*_{2017} = 1 798,329; y^*_{2018} = 1 851,184; y^*_{2019} = 1 904,055; y^*_{2020} = 1 956,943.

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]:

$$\begin{cases} F_1 = y_1 \\ S_1 = y_2 - y_1 \\ F_t = \alpha \cdot y_t + (1-\alpha) \cdot (F_{t-1} + S_{t-1}) \cdot \Phi \;\; dla \;\; t = 2,\dots,n \\ S_t = \beta \cdot (F_t - F_{t-1}) + (1-\beta) \cdot S_{t-1} \cdot \Phi \;\; dla \;\; t = 2,\dots,n \\ y_t^* = F_{t-1} + S_{t-1} \cdot \Phi \;\; dla \;\; t = 2,\dots,n \end{cases}$$

prognosis ex ante are equal to:

$$\begin{cases} F_n = \alpha \cdot y_n + (1-\alpha) \cdot (F_{n-1} + S_{n-1}) \cdot \Phi \\ S_n = \beta \cdot (F_n - F_{n-1}) + (1-\beta) \cdot S_{n-1} \cdot \Phi \\ y_T^* = F_n + (T-n) \cdot S_n \cdot \Phi^{T-n} \;\; dla \;\; T = n+1,\dots,\tau \end{cases}$$

in the second model: S_1=0

where: α is the smoothing parameter of the prognosed variable level; β_i is the smoothing parameter of an increased caused by an increasing tendency; Φ trend extinction parameter. These parameters have values in a range of (0,1]. F_t smoothed evaluation of a level (average value) for a time series at time or period t; S_t smoothed evaluation of an increasing tendency in a time series, at time or period t.

Obtained prognoses for **global crude steel** / M mt in 2016-2020 (y^*_t): y^*_{2016} = 1 622,401; y^*_{2017} = 1 644,481 ; y^*_{2018} = 1 664,559; y^*_{2019} = 1 682,768; y^*_{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^*_t): y^*_{2016} = 1 618,178; y^*_{2017} = 1 635,903 ; y^*_{2018} = 1 651,347; y^*_{2019} = 1 664,725; y^*_{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

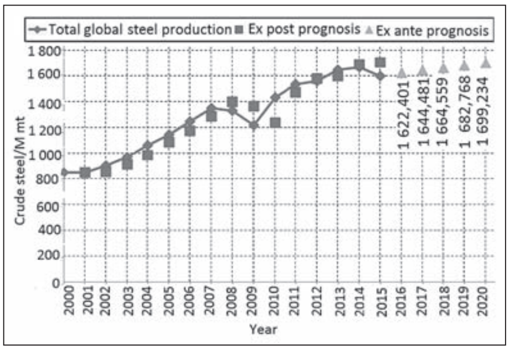

Figure 5 Moderate scenario for prognosis of global steel production until 2020 – version 1 [2]

square model. Ex post prognoses ex post are executed for the linear model according to [3-5]:

$$\begin{cases} G_1 = y_1 \\ H_1 = y_1 \\ G_t = \alpha \cdot y_t + (1-\alpha) \cdot G_{t-1} \quad dla\ t = 2,...,n \\ H_t = \alpha \cdot G_t + (1-\alpha) \cdot H_{t-1} \quad dla\ t = 2,...,n \\ F_t = 2 \cdot G_t - H_t \quad dla\ t = 2,...,n \\ S_t = \dfrac{\alpha}{1-\alpha} \cdot (G_t - H_t) \quad dla\ t = 2,...,n \\ y_t^* = F_{t-1} + S_{t-1} \quad dla\ \ t = 3,...,n \end{cases}$$

and for the ex ante prognosis:

$$\begin{cases} G_n = \alpha \cdot y_n + (1-\alpha) \cdot G_{n-1} \\ H_t = \alpha \cdot G_n + (1-\alpha) \cdot H_{n-1} \\ F_n = 2 \cdot G_n - H_n \\ S_n = \dfrac{\alpha}{1-\alpha} \cdot (G_n - H_n) \\ y_T^* = F_n + (T-n) \cdot S_n \quad dla\ \ T = n+1,...,\tau \end{cases}$$

and, respectively, for the square model:
ex post prognosis:

$$\begin{cases} G_1 = H_1 = M_1 = y_1 \\ G_t = \alpha \cdot y_t + (1-\alpha) \cdot G_{t-1} \quad dla\ t = 2,...,n \\ H_t = \alpha \cdot G_t + (1-\alpha) \cdot H_{t-1} \quad dla\ t = 2,...,n \\ M_t = \alpha \cdot H_t + (1-\alpha) \cdot M_{t-1} \quad dla\ t = 2,...,n \\ F_t = 3 \cdot G_t - 2H_t + M_t \quad dla\ t = 2,...,n \\ S_t = \dfrac{\alpha}{2 \cdot (1-\alpha)^2} \cdot (6 - 5 \cdot \alpha) \cdot G_t - (10 - 8 \cdot \alpha) \cdot H_t + (4 - 3 \cdot \alpha) \cdot M_t \quad dla\ t = 2,...,n \\ N_t = \left(\dfrac{\alpha}{1-\alpha}\right)^2 \cdot (G_t - 2 \cdot H_t + M_t) \quad dla\ t = 2,...,n \\ y_t^* = F_{t-1} + S_{t-1} \quad dla\ \ t = 3,...,n \end{cases}$$

ex ante prognosis:

$$\begin{cases} G_n = \alpha \cdot y_n + (1-\alpha) \cdot G_{n-1} \\ H_t = \alpha \cdot G_n + (1-\alpha) \cdot H_{n-1} \\ M_t = \alpha \cdot H_n + (1-\alpha) \cdot M_{n-1} \\ F_n = 3 \cdot G_n - 3 \cdot H_n + M_n \\ S_n = \dfrac{\alpha}{2 \cdot (1-\alpha)^2} \cdot (6 - 5 \cdot \alpha) \cdot G_n - (10 - 8 \cdot \alpha) \cdot H_n + (4 - 3 \cdot \alpha) \cdot M_n \\ N_n = \left(\dfrac{\alpha}{1-\alpha}\right)^2 \cdot (G_n - 2 \cdot H_n + M_n) \\ y_T^* = F_n + (T-n) \cdot S_n + \dfrac{1}{2} \cdot (T-n)^2 \cdot M_n \quad dla\ \ T = n+1,...,\tau \end{cases}$$

where: α is a smoothing parameter for the prognosed variable level with values from the range of (0,1] ; F_t smoothed evaluation of the level (average value) of a time series at time or during period t; S_t smoothed evaluation of an increased tendency in a time series at time or during period t; G_t first order smoothing operator; H_t second order smoothing operator; M_t third order smoothing operator. For the first of Brown models, the following **global crude steel prognoses were obtained** /M mt in 2016-2020 (y^*_t): y^*_{2016} = 1 657,941; y^*_{2017} = 1 682,335 ; y^*_{2018} = 1 706,729; y^*_{2019} = 1 731,123; y^*_{2020} = 1 755,517. Slightly higher values of global crude steel production were obtained for the second model: **Global crude steel** / M mt in 2016-2020 (y^*_t): y^*_{2016} = 1 693,049; y^*_{2017} = 1 721,491 ; y^*_{2018} = 1 749,933; y^*_{2019} = 1 778,374; y^*_{2020} = 1 806,816.

General conclusion: in case of all models in the moderate scenario, global crude steel production ranges between 1,62 bn tons and 1,8 bn tons. **General conclusion of all models**: global crude steel production ranges between 1,58 bn tons in 2016 and 1,57 bn tons in 2020 (pessimistic scenario); 1,64 bn tons in 2016 1nd 1,8 bn tons in 2020 (optimistic scenario/version1) and until 2 bn tons version 2 and 1,95 bn tons (version 3); 1,6 bn tons or 1,69bn tons in 2016 and about 1,7 bn tons or 1,8 bn tons in 2020 in moderato scenario (Table 2).

Table 2 **Prognosis of global steel production – all scenarios/M mt [2]**

Scenario	2016	2017	2018	2019	2020
Pessimistic	1 588	1 582	1 578	1 575	1 573
Optimistic/1	1 639	1 681	1 725	1 769	1 815
Optimistic/2	1 771	1 830	1 888	1 945	2 003
Optimistic/3	1 745	1 798	1 851	1 904	1 957
Moderate/1	1 622	1 644	1 664	1 683	1 699
Moderate/2	1 618	1 636	1 651	1 665	1 676
Moderate/3	1 658	1 682	1 707	1 731	1 755
Moderate/4	1 693	1 721	1 750	1 778	1 807

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 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].

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