

# TRENDS AND FORECASTS OF STEEL INTENSITY IN POLAND ON THE BASED APPARENT CRUDE STEEL USE UNTIL 2022

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The publication presents historical trends and forecasts of quantity (volume) of steel intensity in Poland. The analysis of steel intensity was realized on the based of apparent consumption of steel. Such formula was used: apparent steel use is production steel minus export of semi-products and plus import of semi-products. Empirical data were: yearly crude steel production, yearly export of crude steel (semi-products) and yearly import of crude steel (semi-products) from 2000 to 2017. On the based of empirical data trends of steel intensity in Poland in 2000-2017 were analyzed and forecasts of steel intensity until 2022 were estimated. Obtained forecasts of apparent crude steel use can be used in building of the scenarios for Polish steel industry.

*Keywords:* steel industry, consumption trend, forecasts, semi-products, Poland

## INTRODUCTION

Steel is the basic structural material with a very wide range of applications in the economy. The functioning of the steel sector is strategic for economies in many countries. Steel intensity is a basic measure of the processing and use and consumption of steel in industry. Steel intensity tests are carried out for a set settlement period. In the analysis of steel intensity should take into account the balance of foreign trade. The basic scope of the analysis is apparent steel use in Poland. Steel intensity analyzes is prepared in quantitative, numerical (physical, natural units) or value terms (price of product). The subject scope of the analyzes may relate to crude steel as semi-products or finished steel products. The time range of steel intensity analyzes can be past (historical) or future (predictive). Periodic analysis of steel intensity for the world are carried out by the World Steel Association. Worldsteel calculates the actual steel consumption using the SWIP - Steel Weighted Industrial Production indicator [1]. In assessing steel intensity of industry in individual countries (including in Polish steel industry) apparent steel use is more popular as the apparent consumption of finished steel products in the year [2].

## METHODOLOGY OF RESEARCH

This publication uses the methodology for analysis and prediction of steel intensity for crude steel use (semi-products). The scope of research included:

**Step 1.** Analysis of steel intensity trends on the based of empirical data about apparent consumption of

crude steel in Poland in 2000-2017. Such formula was used (1):

Apparent steel use = steel production – export of semi-products + import of semi-products (1)

Empirical data – statistical data – were from Polish Steel Association [2]. Empirical data were presented in Table 1. Obtained trends of steel intensity for Poland were compared with trends in UE and in the world.

**Step 2.** Forecasts of Polish apparent consumption until 2022. Forecasts were estimated on the based of empirical data (Table 1) by using econometric models according to methodology that was described in literature [3-5]. Due to the trend, classical forecasting methods for the linear function (linear function models) were rejected. Low level of matching ( $R^2$  - coefficient of determination) was obtained for classic non-linear models: exponential, logarithmic, power, hyperbolic and polynomial ( $R^2$  below 45 %). Inference for the future was carried out on the basis of econometric models - forecasting models based on time series - development tendency models (adaptive models). Justification for model selection:

- 1) Adaptive prognostic models use algorithms that smooth time series.
- 2) In adaptation models, relationships are sought between successive values of the forecast variable.
- 3) Adaptive models allow the identification of irregular changes in the time series (and such changes were observed in the studied phenomenon).
- 4) These adaptation models are used to determine short-term forecasts.

Forecasts of the studied phenomenon were set at 5 years.

To assess the reliability of the forecasts, the following were used:

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- the mean relative ex post forecast error – which informs about the share of absolute error per unit of real value of variable  $y$  and is calculated by Equation 2:

$$\psi = \frac{1}{n-m} \sum_{t=m+1}^n \frac{|y_t - y_t^*|}{y_t} \quad (2)$$

Where:  $y_t$  – empirical data;  $y_t^*$  – forecast’s value,  $n$  – number of elements of the time series;  $m$  – number of initial time moments  $t$ .

- Root Mean Square Error (RMSE) – which informs about average deviations of forecasts from empirical values in frames of the forecast verification interval; calculated by Equation 3:

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

- absolute forecast error for the apparent consumption of steel (crude steel) in Poland in 2018; calculated by Equation 4:

$$q_{t=2018} = y_t - y_t^* \quad (4)$$

On the base of analyzed forecast errors the best forecasts were presented in the publication.

### APPARENT CRUDE STEEL IN EMPIRICAL DATA

Empirical data is yearly steel consumption (in million metric/tonnes – Mmt) in Poland in 2000 - 2017 (Table 1).

The level of annual apparent steel consumption in Poland averaged 8,362 million tonnes. The lowest level was recorded in 2009 (6,625 million tonnes), and the highest in the last year examined (10,076 million tonnes) [6]. The average annual growth rate (year to year) amounted to

Table 1 Apparent steel use in Poland in 2000 – 2017/Mmt [2]

Year	Steel production	Export of semi-products	Import of semi-products	Apparent steel use*
2000	8,800	0,900	0,045	7,945
2001	8,400	0,948	0,048	7,500
2002	8,368	1,036	0,032	7,364
2003	9,107	0,977	0,087	8,217
2004	10,593	1,585	0,191	9,199
2005	8,444	1,250	0,299	7,494
2006	9,992	0,966	0,571	9,597
2007	10,632	1,569	0,696	9,759
2008	9,728	1,588	0,585	8,725
2009	7,129	0,661	0,157	6,625
2010	7,993	0,497	0,122	7,618
2011	8,779	0,862	0,350	8,267
2012	8,358	0,619	0,575	8,314
2013	7,950	0,354	0,602	8,199
2014	8,558	0,716	0,400	8,242
2015	9,198	0,675	0,237	8,759
2016	9,015	0,709	0,316	8,622
2017	10,330	0,589	0,336	10,076

\* Formula (1). Additional information: 8,800 Mmt = 8 800 000 tonnes.

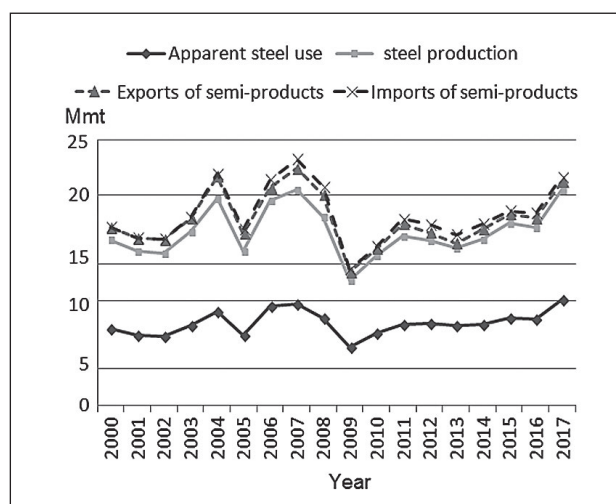


Figure 1 Apparent steel use in Poland in 2000 - 2017 [2]

2,1 %, with the largest decrease occurred in 2009 (-24,1 %) and the highest increase in 2006 (+28,1 %). After 2012, there were no decreases in apparent steel consumption in Poland (Figure 1). In analyzed period the balance in semi-products (Formula 5) in Poland in 2000-2017 was positive (negative balance in ingots and semi-products was only in 2013 (Figure 2).

Balance of trade in crude steel = export of semi-products – import of semi-products (5)

About 50 % export of semi-products in Poland was realized by: Russian, Brazil and Ukraine. Main importer was USA (15 %). Semi-products are used by sector: Metal in Poland (mainly).

Trends of apparent consumption of steel in Poland (Figure 1) compare with trends in UE (28 countries) and with trends of apparent consumption of steel in the world. Analyzed trends were presented on the Figure 3.

Steel consumption in the world increased after 2009, a slight decrease was recorded in 2015. The trend of steel consumption in the EU after 2009 was stable (it did not exceed 190 million tons of annual apparent consumption of crude steel). In Poland also after 2009 (global economic crisis) [6] there was an increase in steel consumption. The course of trends up to 2010 was

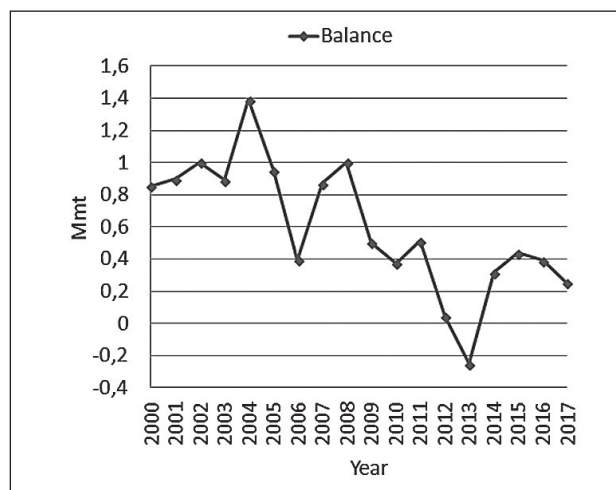
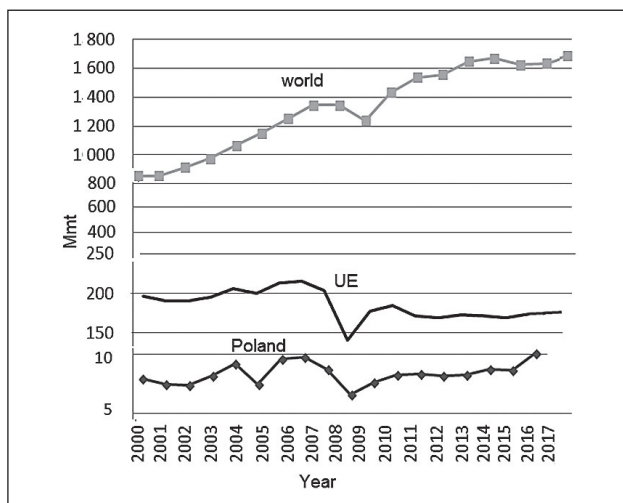


Figure 2 Balance of trade in crude steel in Poland in 2000 - 2017 [2]



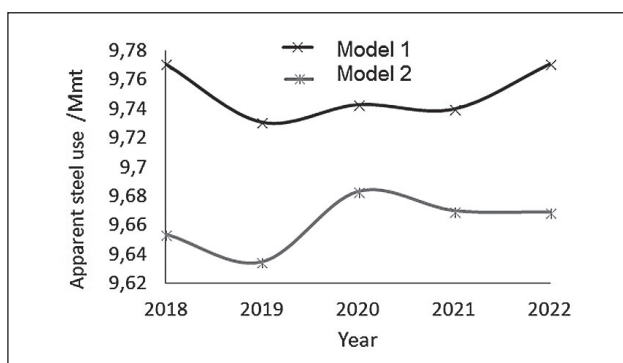
**Figure 3** Trends of apparent steel consumption in Poland, in UE and in the world in 2000 - 2017 [2,7,8]

strongly diversified, starting from 2010 trends were mild with low amplitudes of market fluctuations.

### FORECASTS OF APPARENT STEEL USE Elementary models

Among forecasts obtained on the basis of simple moving or weighted average moving models for a series forming around a constant value (elementary models), better matching of forecasts was obtained for models with weights. The projected apparent consumption of crude steel did not exceed 9,8 million tonnes per year. Obtained forecast trends are presented in Figure 4. After rejecting the forecast with high errors, the average annual forecast of 9,678 million tonnes was obtained.

By building forecasts using models of simple moving average for increasing time series, the required fit of these forecasts was not maintained (high forecast errors). The forecasts obtained annually exceeded the level of 10,5 million tonnes, reaching even 13,7 million tonnes in 2022. However, if one assumed an optimistic scenario for the development of the steel market in Poland, one could consider these quantities and carry out further research, e.g. using heuristic methods [9] for the purposes of developing scenarios for the examined object [10].

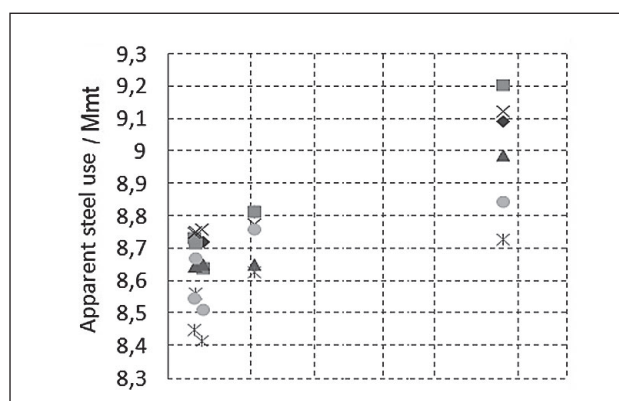


**Figure 4** Forecasts of apparent steel consumption for Poland until 2022 by using weighted moving average model for time series

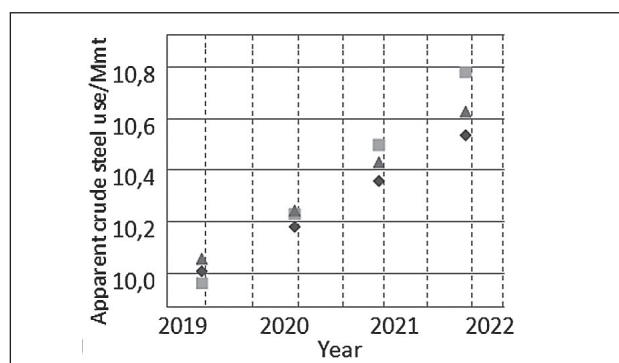
### Exponential smoothing models

In exponential smoothing models, a good fit of forecasts to empirical data was obtained in single exponential smoothing models (Brown's model). After exponential smoothing, the forecasts of apparent consumption steel were below 9 million tonnes in analyzed year or slightly above this value. Forecasts below 9 million tonnes of steel consumed per year were also obtained in such models: Brown's double exponential smoothing (linear) and Brown's triple exponential smoothing (quadratic). In exponential-autoregency models, also the annual forecast steel consumption in Poland oscillated around 9 million tonnes or slightly above this amount (Figure 5). Also, the forecasts received at Holt's quadratic trend models with additive formula for different start point (S1) were about 9 million tonnes of apparent consumption of steel yearly. Such a scenario can be considered real if the market demand for semi-products decreases in the coming years and the demand for the range of high value-added steel products increases. Now in Poland some high value-added steel products, is still too small in relation to the home market needs.

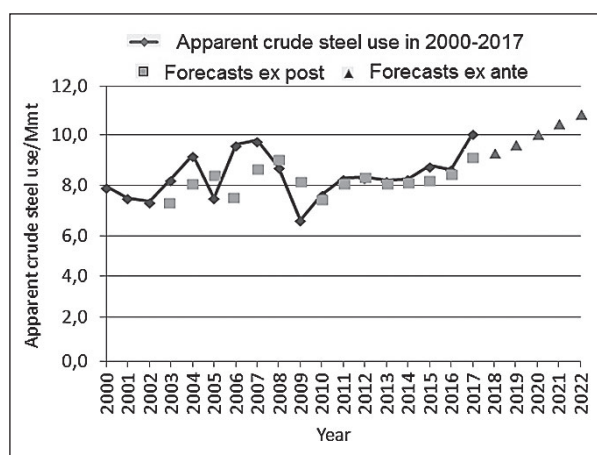
Good forecasts were also obtained for such Holt's models: Holt's linear trend model with additive trend or multiplicative trend and different start point (S1). The forecasted amounts of apparent steel consumption for Poland amounted to 10,2 million tonnes on average per



**Figure 5** Forecasts of apparent steel consumption for Poland until 2022 by using simple single exponential smoothing model (Brown's model) and exponential autoregressive model



**Figure 6** Forecasts of apparent steel consumption for Poland until 2022 by using Holt's linear trend model with additive trend or multiplicative trend



**Figure 7** Forecasts of apparent steel consumption for Poland until 2022 by using advanced exponential autoregressive model

year. After rejecting the forecasts for 2018, the obtained average is 10,4 million tons. The distribution of forecasts is presented in Figure 6.

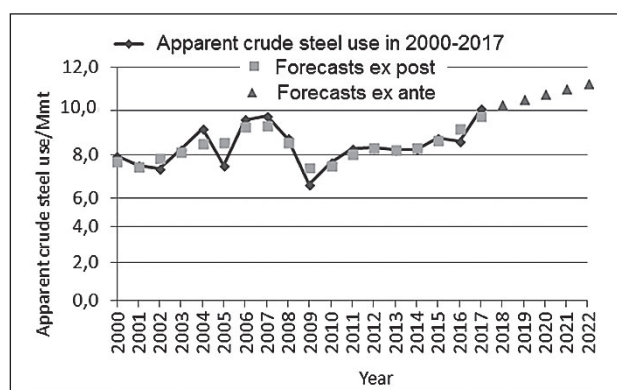
After applying the trend quenching algorithm (Holt's linear trend model with additive damped trend and Holt's linear trend model with multiplicative damped trend) forecasts with slightly lower or slightly higher values were obtained. Such high forecast values can be considered a very optimistic scenario. On the other hand, forecasting by using advanced exponential autoregressive model allowed obtaining average annual forecasts of 10,3 mil tons of apparent raw steel consumption in Poland - a model with very good matching of forecasts to empirical data (Figure 7). Even better matching of forecasts to empirical data ( $\Psi = 4\%$ ,  $q_{t=2018} = (+) 0,076$  million tonnes) obtained by using creep trend and harmonic weights method (Figure 8). The average annual forecast apparent consumption of crude steel for Poland is 10,787 million tonnes.

In autoregressive models (AR) at different levels (AR1,3,4,5; AR 1,2,4,5; AR 1,4,5 etc.), low forecast values were obtained with decreasing trends of apparent steel consumption in Poland until 2022 year. Using the data analysis tool - *Regression*, no statistical significance of these models was obtained, the model was also assessed using (*d*) Durbin-Watson statistics.

## CONCLUSION

Based on the analysis of development trends of the models of apparent consumption of steel in Poland in 2000-2017 and the estimated forecasts of apparent consumption of steel until 2022, the following conclusions were drawn:

- the trend of apparent consumption of steel is not linear function, there is a decrease or increase in demand for steel in the economy in specific periods,
- average annual apparent consumption of steel (crude steel) in Poland in 2000-2017 was 8,362 million tonnes,



**Figure 8** Forecasts of apparent steel consumption for Poland until 2022 by using creep trend and harmonic weights method

- in many used forecasting models, forecasts of apparent consumption of steel for Poland did not exceed the level of 9 million tonnes yearly until 2022,
- projections at a level lower than 9 million tons of crude steel consumed annually can be considered as the baseline scenario for Polish steel industry,
- forecasts of 10 million tonnes of steel consumed annually in Poland can be considered as an optimistic scenario for the coming years for the Polish steel industry.

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**Note:** The responsible for English language J. Jamrozik, Poland.