CONSUMPTION OF STEEL IN POLAND – QUANTITY ANALYSIS IN TIME

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Abstract: The steel market in Poland has increased over the last few years in the market economy. Domestic steel producers manufacture more crude steel and steel products. The consumption of steel increases more and more every year. The value of shipments from the Polish steel sector account for approx. 3% of industrial production. The Polish economy uses and processes over 8 million tonnes of steel (apparent consumption of crude steel/semi-products) yearly (average volume of steel consumption from 2000 to 2017). The largest user of crude steel is metal good, but the largest user of finished steel products is construction (more than 40%), followed by: machinery industry (15%), automotive (about 12%), transport equipment (4%), home appliances industry (3.5%) and other industry sectors, e.g. electrical equipment, electronics. Changes in domestic steel consumption are presented in the paper. The publication presents the historical trends and forecasts of quantity (volume) of steel consumption. The analysis of steel intensity was realised on the basis of apparent consumption of steel in device on: semi-products and finished steel products. Realised analysis is the base for building of scenarios of steel production by particular sectors of industry in Poland.

Keywords: enterprise transformation, Industry 4.0, heat treatment process.

1. Introduction

The industry sector processes and consumes many materials. Steel is a basic structural material, with a very wide range of applications. The functioning of the steel sector is strategic for economies in many countries. Steel intensity is a basic measure of the processing and use (consumption) of steel in industry. Steel intensity tests are carried out for a set settlement period. In the analysis of steel intensity (steel internist) should be taken into account the balance of foreign trade. The basic scope of the analysis is apparent steel use. Steel intensity analysis is prepared in quantitative, numerical (physical, natural units) or value (price) terms. The subject scope of the analyses may relate to crude steel as semi-products or finished steel products. The time range of steel intensity analysis can be past (historical) or future (predictive). The analysis also uses indicators: the amount or value of steel consumed per unit of GDP or per one inhabitant of a given country. The World Steel Association proposed a method for calculating the actual consumption of steel based on the following indicators: SWIP – Steel Weighted Industrial Production and TSU – True Steel Use (Worldsteel, 2012; 2017). In Poland, a popular method of measuring steel consumption is apparent steel use calculated as steel production minus export plus import. The scope of the apparent steel use analysis can be implemented and presented in relation to semi-products (crude steel) but steel products (finished steel products) in device on long and flat products and tube. When analysing steel consumption in the economy, it is assumed that there is an impact of input-output flows of steel products on the final level of consumption. The methodology avoids double or multiple classification of the amount of steel consumption by individual market participants is constantly improved (Worldsteel, 2012). Final steel consumption is also affected by the level of stocks of steel products at the end user. Analysing this phenomenon, you can encounter the following problems. In addition, the trend of apparent consumption of steel is overlapped by periodic fluctuations caused by the economic situation (such fluctuations may cause an increase or decrease in apparent consumption of steel in the analysed period).

The level of steel consumption is analysed by global and European steel organisations (e.g. World Steel Association, Eurofer, Eurostat). The scope of analysis varies for environments, and it is handled by economists, politicians, scientists and others. In Central and Eastern European countries, for many years, the topic of steel consumption has been analysed in relation to changes in the economy after the transformation from a centrally controlled economy to a market economy. This scope of analysis can be found in publications, among others, by employees of the Institute of Iron Metallurgy (Szulc, 2014; Szulc, Garbarz, Paduch, 2011) and university staff (Kardas, 2010). During the transition, the theme of steel consumption was also carried out by foreign authors in the field of changes in their countries (e.g. Morariu, and Bostan, 2012; Bostan, and Onofrei, 2012). The topic of steel consumption is a part of research in assessing the situation of the economy, e.g. in the case of the Central Statistical Office and the Polish Steel Association. The scope of the analysis of steel consumption is carried out on the basis of individual economies (Rębiasz, Garbarz, and Szulc, 2004; Rębiasz, 2003), the European economy (Eurofer & Oxford Economics, February 2018) and the global economy (Worldsteel & Oxford Economics, May 2019).

2. Resources and methods

A time series was used to analyse steel consumption in Poland as a function of time. The analysis performed was based on empirical data: steel production (million tonnes) and apparent consumption of steel (million tonnes) from 2000 to 2017. The data used is presented in Table 1. The empirical data is from the Polish Steel Association in Katowice. On the basis of empirical data, historical trends of steel intensity (apparent consumption of steel) in Poland in 2000-2017 were analysed, and forecasts of steel intensity (apparent consumption of steel) until 2022 were estimated. To calculate apparent consumption of steel the following formula was used:

apparent consumption of steel = steel production – export + import (1)

Empirical data was divided into: apparent consumption of semi-products and apparent consumption of finished products (Table 1).

Table 1.
Empirical data used in analysis of apparent steel use in Poland (million tonnes)

Year	Steel production	Apparent steel use/semi-products	Apparent steel use/finished steel products
2000	8.800	7.945	7.573
2001	8.400	7.500	7.106
2002	8.368	7.364	7.080
2003	9.107	8.217	7.716
2004	10.593	9.199	8.470
2005	8.444	7.494	8.374
2006	9.992	9.597	10.662
2007	10.632	9.759	12.051
2008	9.728	8.725	11.517
2009	7.129	6.625	8.194
2010	7.993	7.618	9.952
2011	8.779	8.267	11.021
2012	8.358	8.314	10.406
2013	7.950	8.199	10.397
2014	8.558	8.242	12.278
2015	9.198	8.759	12.579
2016	9.015	8.622	13.148
2017	10.330	10.076	13.601
2018	10.157	10.237	14.895

Source: Polish Steel Association (HIPH) in Katowice.

The research process was carried out in two stages:

1. Analysis of historical trend of apparent consumption of steel in device on: semi-products and finished steel products.
2. Building of forecasts of apparent consumption of steel in device on: semi-products and finished steel products and their analyses.

The structure of the analysis is presented in Figure 1.

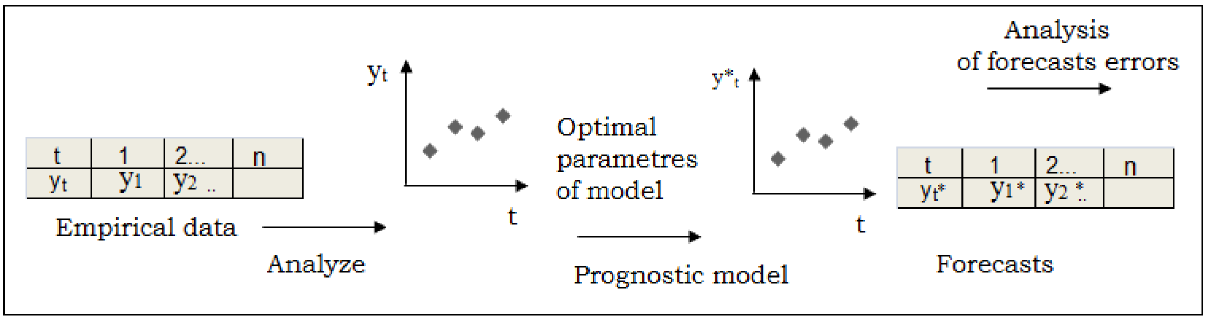

Figure 1. The structure of the analysis of apparent steel use. Source: own elaboration.

The time series (data from Table 1 – columns 3 and 4) are traditionally presented by means of a standard chart (Figure 2), in which the abscissa contained successive natural numbers ($t = 1, ..., 18$), representing subsequent years, and on the axis ordinates of the value of the studied phenomenon (quantity of apparent consumption of steel). Figure 2 is a form of presentation of the studied phenomenon as a one-dimensional time series (chronological series).

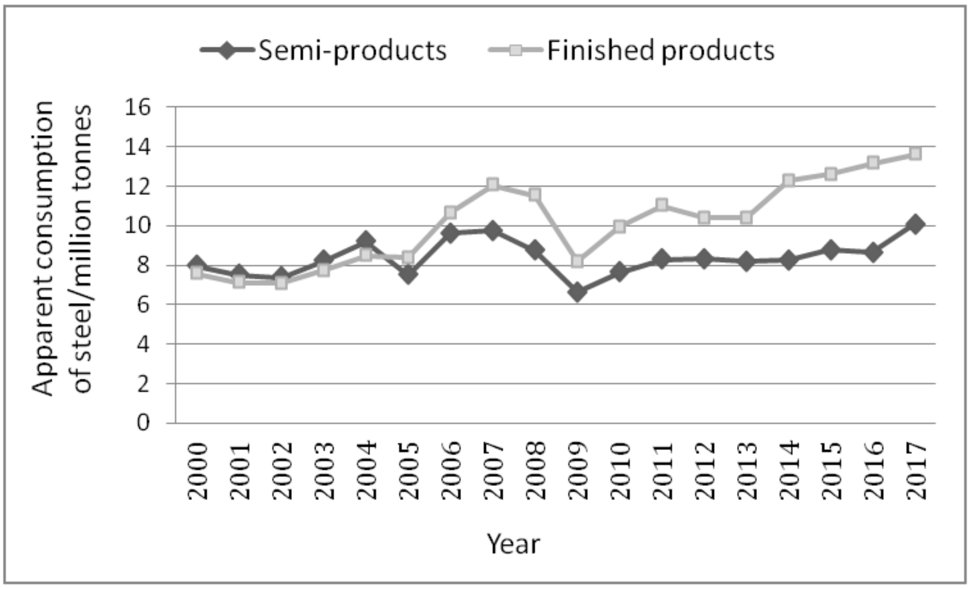

Figure 2. Apparent steel consumption in Poland from 2000 to 2017. Source: own elaboration.

On the basis of the visual assessment of the graph prepared, a development trend was found, but with periodic fluctuations caused by the economic situation. The highest level of periodic fluctuations was recorded in 2009 as a result of the impact of the global economic crisis on the Polish economy (Gajdzik, 2013).

The study did not assume "a priori" the use of analytical models in the form of a trend function for forecasting, due to the complexity of the phenomenon and the low level of matching (R2 – coefficient of determination). Classic forecasting methods for the linear function (linear function model) and nonlinear function (function models: exponential, logarithmic, power, hyperbolic and polynomial) were rejected. Various adaptation mechanisms (time series smoothing algorithms) were used for forecasting. Development tendency models were used to develop the forecasts. Models of developmental tendencies are models in which time is the only explanatory variable (Szkutnik, and Balcerowicz-Szkutnik, 2006, p. 14). They have the form:

$$Y = f(t, \xi) \tag{2}$$

Time in the form of a time series was the basis for preparing the forecast for 2018-2022. Real data on steel consumption in 2018 (last row in Table 1) was used to calculate the absolute (3) and relative forecast error (4) for a single moment, for $t = 2018$. Optimising the value of forecasts was also carried out on the basis of the root mean squared error of forecasts RMSE – Root Mean Square Error (5) and the mean relative prediction error (6) (Krawiec, 2014, pp. 7-10).

$$\Psi_t = y_t - y_t^* \tag{3}$$

$$\Psi_t = \frac{y_t - y_t^*}{y_t} * 100 \tag{4}$$

$$RMSE = \sqrt{\frac{1}{n-m}\sum_{t=m+1}^{n}(y_t - y_t^*)^2} \tag{5}$$

$$\Psi = \frac{1}{n-m}\sum_{t=m+1}^{n}\frac{|y_t - y_t^*|}{y_t} \tag{6}$$

where:

y_t – an empirical value, i.e. realisation of variable y in a t period of time ($t \in \overline{1,T}$),

y_t^* – the forecast value; n is the number of elements of the time series,

n – the number of elements in a time series,

m – the number of initial time moments t, for which an expired forecast has not been realised or is being treated as a part of the necessary start-up mechanism (Manikowski, and Tarapata, 2002, p. 70).

Forecasting knowledge is an integral part of the managerial process. It lowers the uncertainty and raises the accuracy of managerial decisions, which raises a company's efficiency. Pelikán (1999, p. 312) states that the forecasting results shape the inputs for the subsequent planning and decision-making step. The purpose of forecasting is to determine the future states of the studied phenomenon (Szkutnik, and Balcerowicz-Szkutnik, 2006, p. 9). The basic programming tool is the econometric model. According to Pawłowski (1980), the model is a formal structure that reflects the basic relationships between the phenomena studied. In this case, these are changes in steel consumption (semi-products and finished products) in Poland analysed in a given period of time (time series).

At the stage of forecasting of steel consumption using adaptive models, various models were tested: from elementary (naïve methods, simple moving average, weighted moving average – for time series with constant value (average) or with increasing tendency) to models of exponential smoothing (Holt's models, Brown's models, exponential autoregressive model, advanced exponential autoregressive model) and creep trend models.

The publication presents only optimal forecasts obtained using various methods. The forecasts whose errors were the smallest and the forecast trend characterised by high matching to empirical data were considered optimal.

The practical aspects of implementing forecasts of apparent consumption of steel for Poland using adaptive models are their use to develop development scenarios (optimistic, pessimistic and base/moderate scenarios) for individual industry sectors in Poland (Gajdzik, 2017; Gajdzik et al., 2018).

3. Steel consumption in historical analyses

An element of the analysis was steel production and consumption in Poland from 2000 to 2017 (Table 1). Trends of the examined phenomena have increases or decreases caused by the impact of the economic situations (Figure 3) in the years 2003-2005, 2007-2009 and 2012-2014 (cycles are marked with circles in Figure 3).

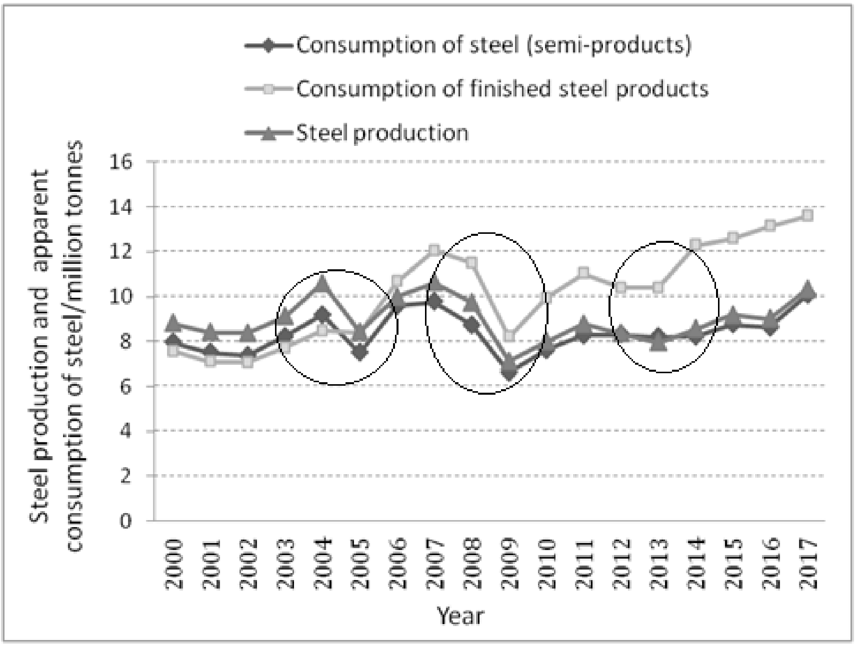

Figure 3. Steel production and apparent steel consumption in Poland from 2000 to 2017. Source: own elaboration.

The dynamics of changes in the volume of steel production (calculated year *t* to year *t-1*) indicate the largest increase in steel production in 2006 (18.3%) and the lowest in 2007 (6.4%). The largest decrease in the dynamics of production volume was in 2009 and amounted to -26.7%, and the smallest negative dynamics of changes were in 2002 (-0.4%) (Table 2). The average annual dynamics of steel size changes in the analysed period was 1.7%, and these were positive dynamics (increase in steel production in 2000-2017). On the other hand, the dynamics of explicit steel consumption (for semi-products) as an average annual value reached a level of 2.2% (increase in explicit steel consumption in 2000-2017). The highest increase in steel consumption (calculated year to year) was recorded in 2006 (28.1%), with the lowest in 2014 (0.5%). The largest decrease was in 2009 (-24.1%), and the smallest in 2013 (1.3%). The average annual change dynamics for final products was 4.3%. The highest increase in the consumption of final steel products was in 2006 (27.3%), and the lowest in 2015 (2.5%). The largest decrease in the dynamics of consumption of final products was in 2009 (-28.9%), and the lowest in 2013 (-0.1%). Changes in the dynamics of the studied phenomena are shown in Figure 4. The level of apparent annual consumption of crude steel (semi-finished products) in Poland was 8.362 million tonnes on average and 10.118 million tonnes on final products. Although the average annual consumption of finished steel products is higher, the consumption is still too low. Finished stall products are high value than crude steel − semi-products (opinion of Polish Steel Association, Report: Polish steel industry, 2018, p. 20).

Table 2.
Analysis of steel production and consumption in Poland from 2000 to 2017 (%)

Year	Steel production	Apparent steel use/semi-products	Apparent steel use/finished steel products
2000	-	-	-
2001	-4.545	-5.601	-6.167
2002	-0.381	-1.813	-0.366
2003	8.831	11.583	8.983
2004	16.317	11.951	9.772
2005	-20.287	-18.535	-1.133
2006	18.333	28.062	27.323
2007	6.405	1.688	13.028
2008	-8.503	-10.595	-4.431
2009	-26.717	-24.069	-28.853
2010	12.120	14.989	21.455
2011	9.834	8.519	10.742
2012	-4.796	0.569	-5.580
2013	-4.882	-1.383	-0.086
2014	7.648	0.524	18.092
2015	7.478	6.273	2.452
2016	-1.990	-1.564	4.523
2017	14.587	16.864	3.445
Average value	1.732	2.203	4.305

Source: own elaboration.

Commentary on Figure 4: the largest positive increases in steel production and consumption were in 2006. The Polish economy has benefited from the high demand for steel that appeared on the world market, among others, with the organisation of sporting events in 2007 and significant acceleration of development in the post-communist countries of Central and Eastern Europe (Gajdzik, 2012), as well as in Asian countries. In addition, in 2007, the EU Economic Commission recognised that the process of restructuring steel mills in Poland was completed (Gajdzik, 2018), and the result was the decision-making independence of steel mills in the production of steel and steel products. The largest negative increases for steel production and consumption were recorded in 2009 as a result of the impact of the global economic crisis on the Polish economy.

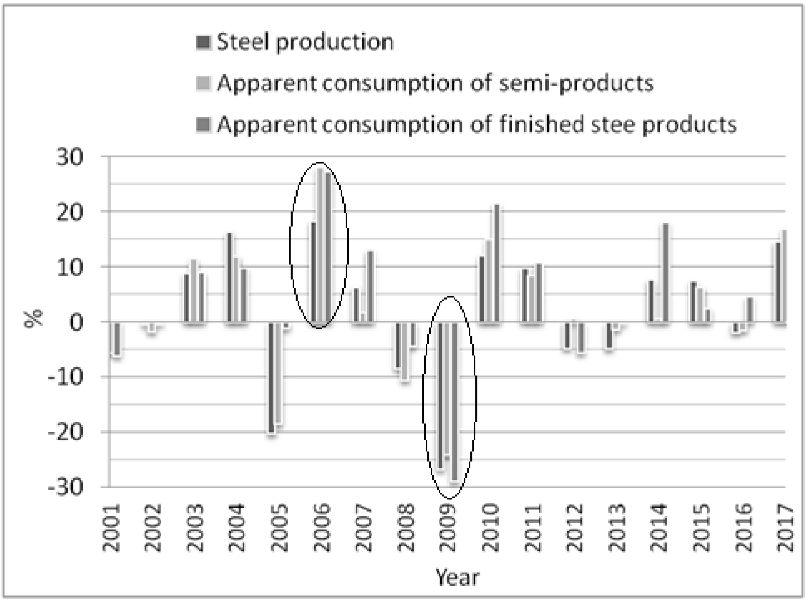

Figure 4. Changes in steel production and steel consumption in Poland from 2000 to 2017. Source: own elaboration.

4. Forecasts of steel consumption

Forecasting steel consumption is to provide the answer to the question: how will the volume (volume) of processed and consumed steel change in Poland in the coming years. The adopted forecasting period is a short-term period (forecasts until 2022). The scope of prognostic analysis is presented according to stages, which used individual types of models to forecast steel consumption. The presentation combined models obtained for the consumption of steel as crude steel (semi-products) and finished steel products.

4.1. Elementary models

Among the forecasts obtained on the basis of simple moving or weighted average moving models for a series forming around a constant value (elementary models), a better matching of forecasts was obtained for models with weights. The projected apparent consumption of crude steel (semi-products) did not exceed 9.8 million tonnes per year, but for finished products, the obtained projected apparent consumption was higher (13.4 million tonnes per year). The results of the analysis are presented in Figure 5.

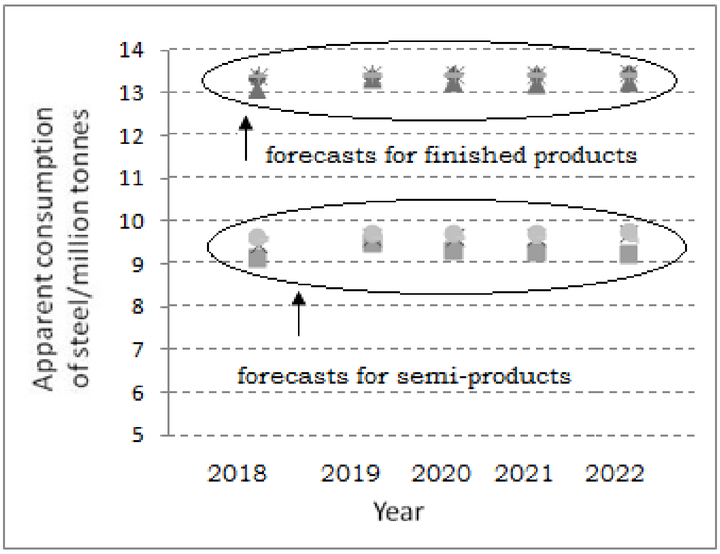

Figure 5. Forecasts of steel consumption for Poland until 2022 by using elementary models. Source: own elaboration.

By building forecasts using models of simple moving average for an increasing time series, the required fit of these forecasts was not maintained (high forecast errors). The forecasts obtained annually for the consumption of semi-finished products reached a high level of 13.7 million tonnes in 2022, and for finished products, 15.8 million tonnes in 2022. The forecasted amounts of steel consumption for semi-products and finished products by using the models were much higher than the actual amounts of average annual consumption from 2000 to 2017.

4.2. 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 the analysed year or slightly above this value, and for finished steel products, it was below 13.5 million tonnes. The results are presented in Figure 6.

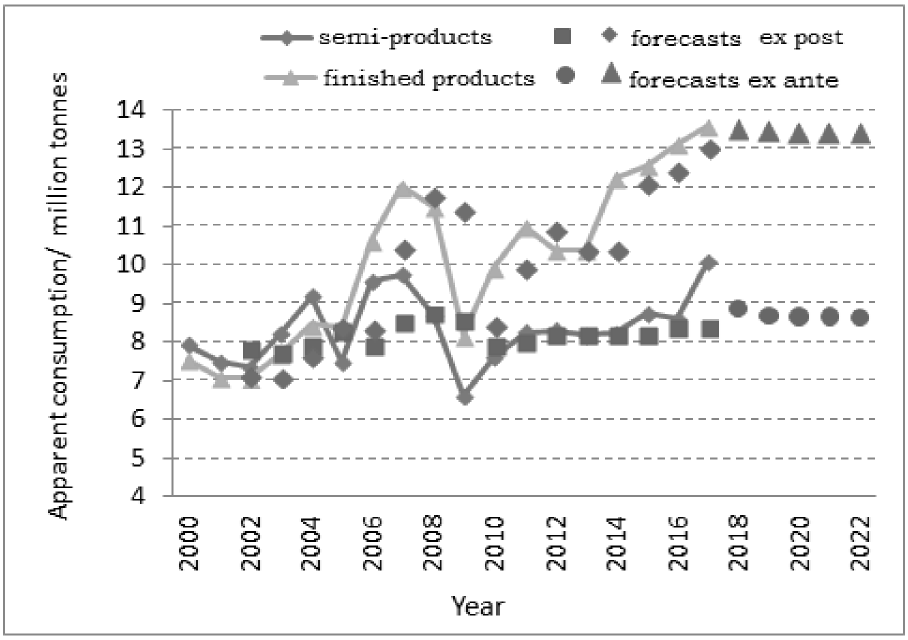

Figure 6. Forecasts of steel consumption for Poland until 2022 by using Brown's model. Source: own elaboration.

Forecasts below 9 million tonnes of semi-products consumed per year were also obtained in such models: Brown's double exponential smoothing (linear) and Brown's triple exponential smoothing (quadratic). For finished steel production, the forecasts were 13.4 million tonnes. In exponential-autoregency models, the annual forecast of steel consumption for semi-products in Poland also oscillated around 9 million tonnes or slightly above this amount, and for finished steel product: about 13.2 million tonnes. The results for exponential autoregressive models are presented in Figure 7.

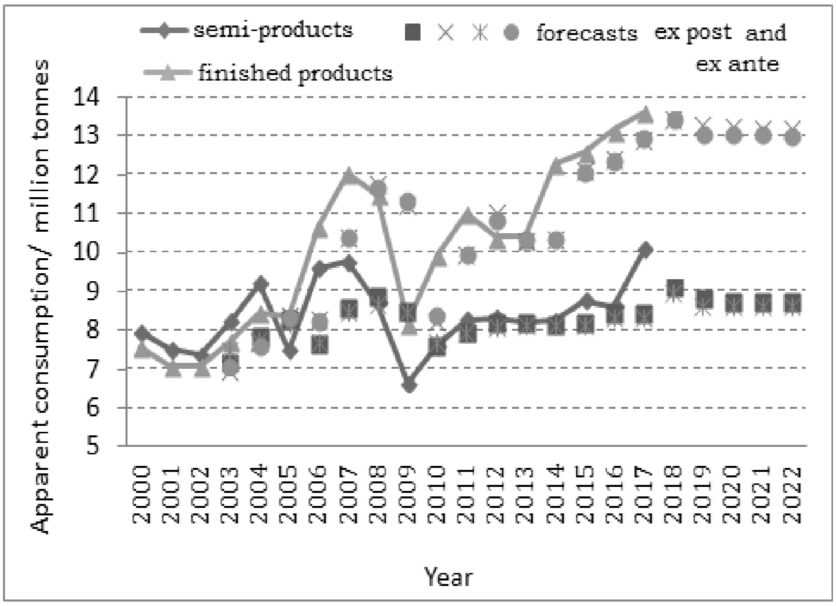

Figure 7. Forecasts of steel consumption for Poland until 2022 by using exponential autoregressive models (for different k: k = 2; k = 3). Source: own elaboration.

Good forecasts were also obtained for Holt's models: Holt's linear trend model with an additive trend and different start point (S1). The forecasted amounts of apparent consumption for semi-products amounted to 10.2 million tonnes on average per year, and for finished steel products, 16.1 million tonnes (average quantity for five years). The results are presented in Figure 8. For Holt's linear trend model with a multiplicative trend, the obtained forecasts were similar to forecasts for the linear trend model with an additive trend (when we compare these forecasts, we can say that forecasts for the additive trend were more optimal). After applying the trend quenching algorithm, forecasts with slightly lower or slightly higher values were obtained. In Holt's quadratic trend models with an additive formula for different start point (S1), the obtained forecasts were similar to forecasts for Holt's other models.

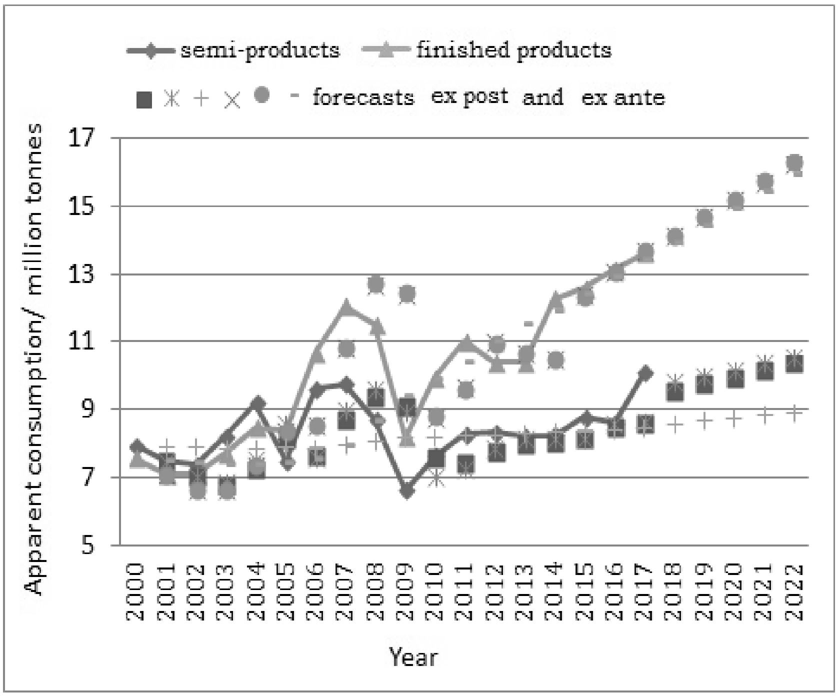

Figure 8. Forecasts of steel consumption for Poland until 2022 by using Holt's linear trend model with an additive trend (for different S_1: $S_1 = y_2\text{-}y_1$; $S_1 = 0$). Source: own elaboration.

Good fit forecasts for steel crude (semi products) (estimation Ψ) were obtained when the advanced exponential-autoregressive model was used for forecasting (Ψ = 8.4 %), but such a good fit was not obtained for finished steel products (Ψ > 10%). The following forecasts were obtained for semi-products: 9.237 (2018 year); 9.644 (2019); 10.051 (2020); 10.458 (2021); 10.865 (2022); for finished products: 14.100 (2018); 15.380 (2019); 16.660 (2020); 17.940 (2021); 19.220 (2022). However, using this model, it can be assumed that steel consumption in Poland in the coming years will grow faster than in the forecasts obtained using the Brown's models and Holt's model.

4.3. Creep trend models

The creeping trend method consists in smoothing the value of the trend determined on the basis of a time series using a constant (l) – all linear trends are determined on the basis of l adjacent consecutive time series observation. On the basis of theoretical values determined from linear regression, smoothed forecast values are then calculated (arithmetic means from the theoretical determined values for a given moment *t*). To obtain steel consumption forecasts, creep trend methods and harmonic weights methods were used (Z. Hellwig's method, 1967). Using this model in one and the other phenomenon studied, the best fit was obtained. The following forecast errors were obtained for semi-finished product forecasts: Ψ = 4%, $q_{t=2018}$ = (+) 0.076 million tonnes, and for finished products: Ψ = 3.7%, $q_{t=2018}$ = (−) 0.847 million tonnes. The average annual estimated apparent consumption of crude steel for Poland is 10.8 million tonnes (10.787 million tonnes), and the average annual forecast apparent consumption of final products is 15 million tonnes (14.942 million tonnes). The results of the analysis are presented in Figures 9 and 10.

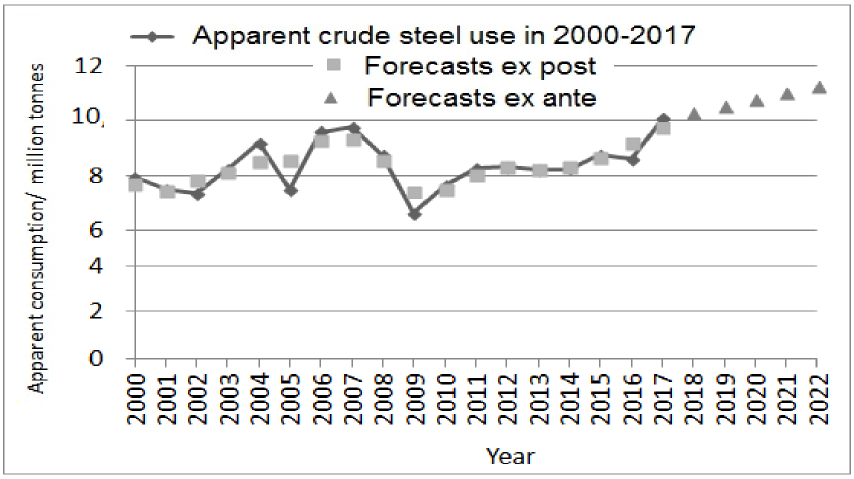

Figure 9. Forecasts of consumption of semi-products for Poland until 2022 by creep trend and harmonic weights methods. Source: own elaboration.

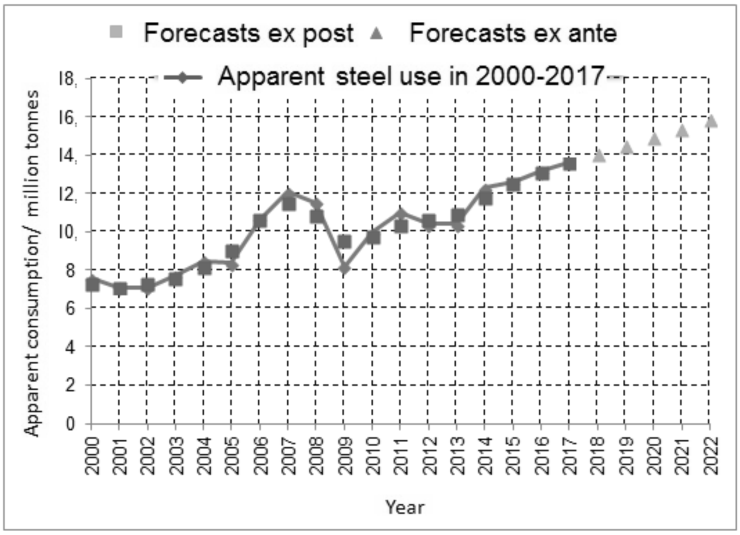

Figure 10. Forecasts of consumption of finished steel products for Poland until 2022 by creep trend and harmonic weights methods. Source: own elaboration.

5. Scenarios for steel consumption

The scenario is the result of a prognostic methodology. The scenario method consists in the construction of several variants of the future scenarios, i.e. constructing a logical, supposed description of events that may occur in the future. Scenarios allow you to define the right goals and prepare the right strategies (Gajdzik, 2017). The essence of the scenario method is to conduct systematic studies of the future of a company and its surroundings, which allow one to identify a possible hypothetical sequence of events leading to various probable effects. This scenario is a very simplistic but possible, hypothetical picture of the future. A favourable sequence of events that may occur will result in the completion of a particular scenario image of the future (Chermack et al., 2001). Scenarios are a form of transition from forecasting to planning. "The task of planning is to choose among the possible trajectories of the system one that is most desirable in light of the analysis of the demand for funds for its implementation and the means that the system can have in the given period for the purpose". The action plan as feasible, satisfies the probability (Rue and Holland, 1986). As a result of prognostic-scenario analysis, there are scenarios of the future which represent a comprehensive, hypothetical vision of the future of a company, including the selected segments of the environment. You can distinguish the following scenarios of the future:

- *base-case scenario*, describing the most likely situation,
- *worst-case scenario* or *best-case scenario*, which represent projections of the worst- and best-anticipated situation.

Average-case scenarios, as well as intermediate values between the baseline and extreme scenarios, are also often taken into account (Bensoussan, and Fleisher, 2010).

On the basis of the following scenarios, forecasts for apparent steel use in the coming years are offered:

- *base-case scenario* for a trend with growth and with steel consumption similar in quantity to average annual steel consumption in 2000-2017 but slightly higher, i.e. for semi-products about 8.6 million tonnes yearly, and for finished steel products about 13.3 million tonnes yearly; a greater increase in positive quantity consumed steel is expected for finished steel products than for semi-products (demand for finished steel products is higher than for semi-finished steel products),
- *worst-case scenario* for a trend with a decrease with steel consumption below the amount of steel consumed on average annually in 2000-2017, i.e. for semi-products below 8.4 million tonnes yearly, and for finished steel production below 10.1 million tonnes yearly (forecasts below the given average annual values were obtained sporadically for a given single year in the forecast period),

- *best-case scenario* for a trend with strong growth of steel consumption for crude steel and semi-products above 9 million tonnes yearly, and for finished steel products above 13 million tonnes yearly (in the first years), and from 15 to 16 million tonnes in 2022.

6. Conclusions

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 a linear function; there is a decrease or increase in demand for steel in the economy in specific periods,
- average annual apparent consumption of crude steel in Poland in 2000-2017 was 8.362 million tonnes, and average annual apparent consumption of steel products was 10.118 million tonnes,
- in many used forecasting models, forecasts of apparent consumption of crude steel for Poland did not exceed a level of 9 million tonnes yearly until 2022, but forecasts of apparent consumption of finished steel products were higher in particular models: 13 million tonnes yearly and more,
- projections at a level lower than 9 million tonnes of crude steel consumed annually can be considered as the baseline scenario for the Polish steel industry, and projections at a level lower than 13 million tonnes of finished steel products consumed annually can be considered as the baseline scenario for the Polish steel industry,
- development trends of apparent consumption of finished steel products is characterised by higher growth than apparent consumption of semi-products, which indicates the development of the steel market in Poland.

Optimistic scenarios of steel consumption in Poland should be analysed together with the level of utilisation of production capacity in the industry – such analysis will be carried out by the author of the paper in further research.

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