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PREDICTION OF NON-BRAZILIAN CRUDE STEEL PRODUCTION USING HOLT-WINTERS METHOD

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ABSTRACT

The objective of this study is to estimate the monthly production in tons of crude steel in Brazil from January to May 2017, on the basis of production data from January 1980 to December 2016, made available by IPEADATA, using smoothing time series techniques, and the additive and multiplicative models of Holt Winters, arriving at the conclusion that the one most appropriate to the dataset under analysis is the model with linear tendency and multiplicative seasonality, that according to the selection criterion that is the one that presents the lowest average absolute absolute error, in which its value was estimated at approximately 3.97%, from which it can forecast the monthly quantity of crude steel produced for the five subsequent periods.

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INTRODUCTION

Steel is a type of alloy that according to Maia (2002) is formed by iron, with the addition of minimum amounts of carbon, up to 2%, and other elements. According to Cavalcante *et al.* (2009), the steel oxidation process generates a large and diversified amount of solid waste for the steel industry, being possible to cite the steel slag which, due to its economic and environmental advantage, is widely used in paving. Castelo Branco (2004) says that the world production of crude steel passed, in a period of almost 100 years, from 30 million tons in the year 1901 to 847 million in 2000. And in 2007 the world's steel production already exceeded the mark of 1.34 billion tons (Siderurgia Brasileira, 2008).Still according to Ehlers (2005), Brazil represents one of the ten largest crude steel productions in the world, in 2003 (data registered until October) the country participated with 3.7% of world production. Already in Latin America, it leads, its production in the same year reached 52.5% of the total, in relation to the previous year (2002) that was of 24.4 passed to $25{,}9 \times 10^6$ tons, an increase of 6% (Siderurgia Brasileira, 2008). To estimate the amount of crude steel in tonnes to be produced in the first five months of 2017, time series techniques are used, which according to Ehlers (2005) are a collection of observations made sequentially in time, in the case of this study, the quantitative of the production of the previous months, and whose main characteristic is the dependence of neighboring observations, being of fundamental importance the study of this dependence to make predictions. Here the techniques used are the smoothing methods.

Time series Analysis

A time series is a set of observations ordered in time. These observations may be at regular intervals, as daily (stock prices,

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weather reports), weekly (information on money supply), monthly (unemployment rate, consumer price index [CPI]), quarterly (GDP), annually (government budget), ie every five years (industrial census of the United States), or decennial (demographic census) (Gujarati, D. N., and Porter, 2011). Souto *et al.* (2006) say state that a time series is classified as deterministic or stochastic. It is deterministic when future values can be accurately established by a mathematical functional relation, for example y = f (time)and is considered stochastic when future values of the series can only be approached in probabilistic terms, as a random variable of the type y = f (time, α), where α is the residual random term.

Exponential Smoothing Methods

Morettin and Toloi, (2008) argue that most forecasting methods are based on the idea that there is information contained in past observations about the pattern of time series behavior, having as purpose these methods, distinguish the pattern from any noise present in the observations and consequently use it to predict future values, smoothing is a large class of these forecasting methods in which they attempt to address the causes of fluctuations in the series.

Gujarati, D. N., and Porter (2011) say that they are methods to fit a suitable curve to the historical data of a given time series. There are a large number of such methods, such as simple exponential smoothing, Holt linear method, Holt-Winter method and its variations. The great popularity attributed to smoothing methods is due to simplicity, computational efficiency and reasonableness (Morettin and Toloi, 2008).

Simple Exponential Smoothing (SES)

According to (Morettin and Toloi, (2008), Simple Exponential Smoothing is a weighted average that gives more weight to the most recent observations, presenting the advantages of being easily understood, having an inexpensive application, great flexibility thanks to the variation of the smoothing constant (α), among others, and has as main disadvantage the difficulty in determining the most appropriate value for α. The SES can be described mathematically according Russo *et al.* (2012), as in (1).

$$\bar{Z}_t = \alpha \sum_{k=0}^{t-1} (1-\alpha)^k Z_{t-k} + (1-\alpha)^t . Z_0, \ t = 1, \dots, N, \quad (1)$$

where$\bar{Z}_t$is the exponentially smoothed value andαis called the smoothing constant, ranging from zero to one.

Holt-Winters Method

According to Gujarati, D. N., and Porter (2011), the Holt-Winters method is one of the most used for short-term forecasting, because it is simple to offer low operating costs, good accuracy and fast and automatic adjustment to changes in the series under analysis.According to Fonseca *et al.* (2016), Brown (1935) was the creator of the first exponential smoothing model, which was expanded by Holt (1957) and reprinted in 2004, being the Holt-Winters method used to smooth time series that show tendency and seasonality. In Table 1 shows the formulas for this method. Gujarati, D. N., and Porter (2011) also states that the model that was developed by Holt and Winters with the purpose of describing the techniques of forecasting for time series, can isolate in the series itself up to four factors, that is, the level, the linear trend, the seasonal factor and an unpredictable residue also sometimes called a random error. Where *S* represents the length of the Seasonality, L_t the series level, $b_t$is the trend, S_t is the seasonal component, F_{t+m} is the forecast for period *m* and Y_t corresponds to the observed value.

Holt Exponential Smoothing (HES)

When the Simple Exponential Smoothing method is applied to a series that has a linear trend either positive or negative, the forecast values are underestimated (or overestimated) continuously from the actual values. To avoid this type of error the HES is used, which smoothes the level and models the trend through a smoothing constant, which differs from the SES that softens only the level Russo *et al.* (2012).

Table 1. Holt-Winters Methods

	Additive Holt-Winters	Multiplicative Holt-Winters
Level	$L = \alpha(Y_t - S_{t-s}) + (1-\alpha)(L_{t-1} + b_{t-1})$	$L_t = \alpha \frac{Y_t}{S_{t-1}} + (1-\alpha)(L_{t-1} + b_{t-1})$
Trend	$b_t = \beta(L_t - L_{t-1}) + (1-\beta)b_{t-1}$	$b_t = \beta(L_t - L_{t-1}) + (1-\beta)b_{t-1}$
Seasonality	$S_t = \gamma(Y_t - L_t) + (1-\gamma)S_{t-s}$	$S_t = \gamma\left(\frac{Y_t}{L_t}\right) + (1-\gamma)S_{t-s}$
Prediction	$F_{t+m} = (L_t + b_{t-m)}S_{t-s+m}$	$F_{t+m} = (L_t + b_{t-m)}S_{t-s+m}$

Source: Albuquerque (2006); Fonseca et al. (2016).

Holt-Winters Seasonal Exponential Smoothing (HW)

According to Morettin and Toloi (2008), there are two types of procedures that depend on the characteristics of the series considered to be used, such procedures are based on three equations each with its smoothing constant, in which each one is associated with each component of the series standard, which are the level, the trend and the seasonality. The models are Additive and Multiplicative.

Decision Criteria

According toRusso (2002),Makridakis *et al.* (1998)andHill *et al.* (2015), a criterion widely used to validate the adjusted model, with a view to the realization of the forecasts is the MAPE (Mean Absolute Percentage Error),in which it is calculated from the forecasts a step forward generated by each estimated model. The same is formulated as follows in (2).

$$MAPE = \left| \frac{\sum \frac{y-\hat{y}}{y}}{n} \right| * 100\% \quad (2)$$

Where, *y* is the real value,$\hat{y}$correspondsto the smoothed value and *n*s the number of adjusted points.

MATERIALS AND METHODS

For the analysis of the study in question was used the monthly quantitative of the production of tons of crude steel in Brazil, data from the year January 1980 to December 2016,making a total of 444 observations available on the electronic address of the Institute of Applied Economic Research IPEA (2016), which is a federal public foundation linked to the Brazilian Ministry of Planning, Budget and Management (MPOG), and has as research activities to provide technical and institutional support to the government for the formulation, evaluation and improvement of public policies and development programs, besides carrying out social and economic studies. To analyze and model the data, make the calculations, plot the graphs, we used the software Stat soft (2004), a statistical program developed to carry out several analyzes such as the descriptive and even the prediction of time series, licensed to the Department of Statistics and Actuarial Sciences of the Federal University of Sergipe - Brazil.

RESULTS

With the data, a descriptive analysis can be presented considering the information of each year (Table 2), where it is possible to verify that in 1980, the year in which the counting starts,on average 1278 tonnes of crude steel were produced, with a higher average registered volume of 2918.8 in 2011, which corresponds to an increase of slightly more than 128% of the national production in a period of 31 years, having as average production amplitude 1640,8 tons. latest global financial crisis, which affects many sectors of a country's economy, including the industrial, with the passage of a few months a slight recovery is observed, causing production to grow again.

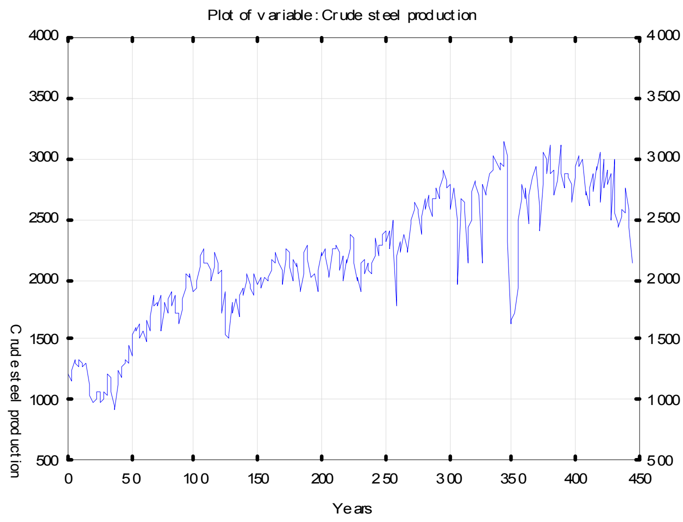

Fig. 1. Monthly crude steel production in Brazil

Table2. Annual descriptive analyzes

Year	Minimum	Maximum	Average	Variance	Standard Deviation	C.V. (%)
1980	1172.300	1351.000	1278.092	2464.6	49.645	3.884
1981	970.300	1308.900	1102.125	14503.7	120.431	10.927
1982	946.900	1238.100	1082.933	9151.9	95.666	8.834
1983	917.700	1446.600	1222.617	19735.2	140.482	11.490
1984	1376.600	1633.500	1532.142	4880.8	69.862	4.560
1985	1424.300	1866.100	1704.625	20354.9	142.670	8.370
1986	1583.600	1931.200	1769.442	11234.1	105.991	5.990
1987	1646.800	2036.600	1850.658	19797.3	140.703	7.603
1988	1904.200	2244.800	2054.742	15588.5	124.854	6.076
1989	1975.700	2220.700	2087.925	5345.4	73.1124	3.502
1990	1467.700	1963.300	1713.883	28961.9	170.182	9.930
1991	1694.100	2033.200	1884.858	11517.7	107.321	5.694
1992	1877.900	2079.000	1991.333	3899.8	62.448	3.136
1993	1875.100	2216.200	2100.225	9716.6	98.573	4.693
1994	1963.100	2252.400	2143.450	8200.8	90.558	4.225
1995	1912.200	2294.900	2083.175	14446.3	120.193	5.770
1996	1888.600	2238.800	2100.917	15378.1	124.009	5.903
1997	2015.400	2267.800	2179.258	7443.8	86.277	3.959
1998	1890.000	2378.000	2146.025	20194.5	142.107	6.629
1999	1888.800	2176.600	2079.867	6073.8	77.935	3.747
2000	2157.700	2447.700	2320.600	9729.0	98.636	4.250
2001	1772.800	2473.900	2226.417	41143.1	202.838	9.110
2002	2215.300	2644.800	2466.967	18528.3	136.119	5.5177
2003	2356.400	2769.400	2594.142	11220.1	105.925	4.083
2004	2572.700	2890.500	2744.725	6974.4	83.513	3.043
2005	1963.200	2761.300	2578.775	46007.4	214.493	8.318
2006	2130.700	2812.100	2575.833	41301.0	203.227	7.890
2007	2130.700	3010.900	2784.775	51461.7	226.852	8.146
2008	1646.000	3198.200	2805.325	182541.6	427.249	15.230
2009	1616.600	2797.000	2195.308	243241.8	493.196	22.466
2010	2407.000	2927.700	2737.200	30221.0	173.842	6.3511
2011	2676.500	3276.400	2918.808	33538.5	183.135	6.274
2012	2762.400	3153.800	2911.033	17102.8	130.778	4.492
2013	2629.400	3013.100	2858.250	18144.6	134.702	4.713
2014	2609.000	3051.600	2818.608	21802.0	147.655	5.239
2015	2461.700	2984.700	2770.317	35652.4	188.819	6.816
2016	2148.600	2767.600	2514.008	31916.4	178.652	7.106

Source: Prepared by the author.

But in later years there are small falls, possibly caused by the global economic crisis, with the latest data recorded in 2016 of an average of 2514 tonnes. The Fig 1 shows monthly production data sequentially arranged over time, being possible to observe that there is tendency of growth, with many peaks of seasonality, highlighted in the graph, possibly because it is in a period coinciding with the beginning of the

In order to forecast short-term domestic crude steel production, the Holt-Winters methodology was used, in which for its application were tested several models to find which is better fitted to the data under study, the least error and therefore provide the best prediction. In the next tables are presented no trend modeling (Table 3), linear trend (Table 4) and trend with exponential behavior

Table 3. Holt-Winters Models Without Trend

Seasonality	α	β	γ	Average error	Absolute average error	Sum of squares	Average squares	Mean percentage error	MAPE (%)
Without	0.70	-	-	0.22026	112.3909	11321688	25499.30	-0.37934	5.361933
Aditive	0.90	0.10	-	0.06246	86.39960	7695583	17332.39	-0.221642	4.153948
Multiplicative	0.90	0.10	-	0.03879	84.51274	7430581	16735.54	-0.223955	4.021374

Source: Prepared by the author

Table 4. Holt-Winters Models with Linear Trend

Seasonality	α	β	γ	Average error	Absolute average error	Sum of squares	Average squares	Mean percentage error	MAPE (%)
Without	0.70	-	0.10	-1.28223	114.0639	11073763	24940.91	-0.280258	5.347622
Aditive	0.90	0.10	0.10	-1.08325	87.04625	7323284	16493.88	-0.140727	4.125599
Multiplicative	0.90	0.10	0.10	-1.16671	84.88297	6989953	15743.14	-0.145422	3.966920

Source: Prepared by the author

Table5. Holt-Winters Models with Exponential Trend

Seasonality	α	β	γ	Average error	Absolute average error	Sum of squares	Average squares	Mean percentage error	MAPE (%)
Without	0.70	-	0.10	-5.50001	113.6962	11013522	24805.23	-0.420939	5.335732
Aditive	0.90	0.20	0.10	-5.56846	87.00446	7313165	16471.09	-0.338547	4.133227
Multiplicative	0.90	0.10	0.10	-5.45146	84.99615	6932184	15613.03	-0.329499	3.980840

Source: Prepared by the author.

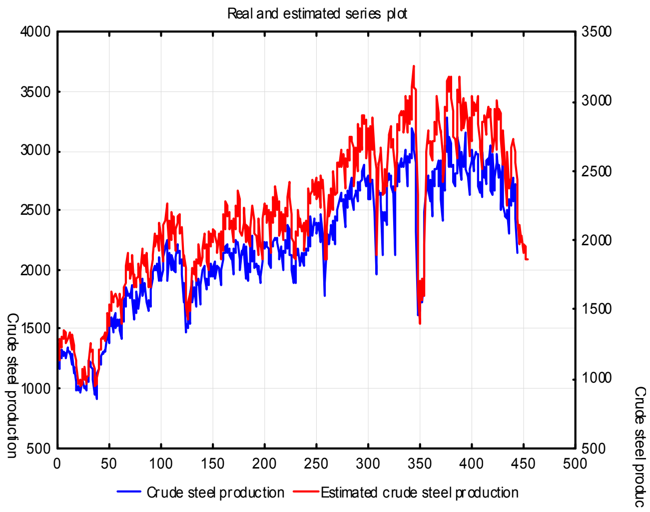

Fig. 2. Real and Estimated series

(Table 5), in which for all trend models are also exposed the absence of seasonality, additive seasonality and multiplicative seasonality. In order to choose the best model, the one with the lowest absolute percentage error. In table 3 of the three models presented considering the absent trend, the best is the one that presents multiplicative seasonality with MAPE value of 4.02%.

Table 4 shows the models with linear trend, where the best is the multiplicative seasonality that provided MAPE of approximately 3.97%, Including that which among all the results modeled better adjusted to the studied series providing the level smoothing constants (α) being 0.7, the seasonal effect (β) equal to 0.1 and that of the trend component (γ) being 0.1, to be used in forecasting. Table 5 presents the models with an exponential trend, where a good model for forecasting, which is the multiplicative seasonality with error of 3.98%, where the result is only slightly larger than the best model.

The Fig. 2 presents graphically the modeling of the estimated series in which it is possible to observe that it has adjusted well to the actual data arranged over time, demonstrating that the model chosen is the most suitable for forecasting, and it is also noted that the predicted values indicate that crude steel production in Brazil will continue with some falls as the months pass. Table 6 presents the values of five estimates in the interval between January and May 2017, based on the model chosen for the forecast, in which there is an oscillation between falls and slight increases in the monthly production of crude steel.

Table 6. Estimated values of crude steel production

Month/2017	Crude Steel (Tons)
January	2162.326
February	1965.229
March	2114.767
April	1983.536
May	2028.607

Source: Prepared by the author.

Conclusion

With the application of exponential smoothing methods to the data of the Brazilian crude steel production one can analyze the models and select the one that best suited the reality,which was the Holt-Winters with Linear Trend and Multiplicative Seasonality, indicating in approximately 3.97%, the lowest absolute percentage error, being a very good model for forecasting, which for the present study was for the months of January to May 2017, so that when arriving at the estimated data it is possible to conclude that the production continues tending to decrease.

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