Time series research in the non-ferrous scrap recycling sector with identification of trend-seasonal components by Chetverikov method

Ya V Skibina

1 Kuban State Agrarian University named after I.T. Trubilin, 13, Kalinin str., Krasnodar, 350044, Russia

E-mail: yanaskibina@yandex.ru

Abstract. The article is devoted to identifying of trend-seasonal components using iterative methods of the non-ferrous scrap metal collection filtering. According to the study objectives and the results of the time series characteristics analysis, the Chetverikov method implementation as a method for data filtering is described stepwise. Calculations and construction of diagrams were carried out in MS Excel. The study result is a visualized stepwise filtering of the trend-seasonal time series of the non-ferrous scrap mass in two positions - copper and brass, as well as the values of the seasonal component and specific seasonality indices calculated using the Chetverikov method, which makes it possible to study further the use and predicting of the non-ferrous metal scrap collection rate in the region, to select effective forecasting methods and models.

1. Introduction
The growth of the metallurgical industry determines the successful development of a significant number of other economic sectors. The metallurgical complex plays an important role in the industry of any country, thus it is the basic economic industry. Russian metallurgy is a major player in the global metals market; it is one of the Russia's specialization branches within the international labor division. The metallurgical industry includes two main directions: ferrous and non-ferrous metallurgy. Ferrous metallurgy works with iron-based alloys and products. The second direction includes work on the alloys smelting and the products manufacture from non-ferrous metals (all metals except iron). Non-ferrous metals are corrosion and wear resistant, have good electrical conduction properties. These properties determine a wide range of non-ferrous metal applications in the national economy.

The achievement of effective economic indicators in this sector of the economy is associated, among other things, with the usage expansion of waste from metal and scrap metal. The non-ferrous scrap recycling is a promising direction in the development of the metallurgical industry and business organization in our country for the following reasons, which are revealed in these industry specifics [1, 2].

1. Materials intensify. For the majority of non-ferrous metals, Russian deposits are characterized by the poverty of mined ores. For example, in copper ore, the copper content ranges from 1% to 5%.
2. Energy intensity, resource consumption. The raw materials extraction, their processing and metal smelting is accompanied by the need for a large amount of fuel, electricity and water.
3. Labour effort.
4. The inaccessibility of ores, the problem of the transport infrastructure provision.
5. Impressive costs for the construction, technical and technological equipment of the full cycle metallurgical complex plants.
6. Environmental impact etc.

The relevance of non-ferrous metal processing is primarily due to the fact that industrial and manufacturing enterprises, taking into account modern trends in the development of the metallurgical
industry, are looking for real opportunities to reduce costs. The processing of non-ferrous scrap metal contributes to natural resources saving, the raw materials supply problem solving, reducing of production costs, as well as the costs of erecting, creating and maintaining of a full-cycle metallurgical plants complex infrastructure, time expenditures, labor inputs, is energetically more efficient in comparison with mining from ore material, helps to reduce the level of environmental pollution. The metals recycling leads to a reduction in a vast list of expenditure items, which in sum, will affect the metal products cost and lead to the price decrease of finished products for the end consumer. At the same time, recyclable materials are endowed with practically the same properties as primary ones and, unlike plastic and other recyclable materials, metal can be recycled and involved in economic circulation many times.

The prospect of economic research in the field of non-ferrous metals recycling is also determined by the state interest in the development of opportunities related to the organization of collection and processing of secondary metal. These trends are reflected in the draft Strategy for the development of the metallurgical industry in Russia for the period up to 2030 and in the order of the President of the Russian Federation dated February 23, 2019 draft number 277, 1b item- on improving the rules for handling scrap and waste of ferrous and non-ferrous metals, mechanisms for involving these scrap and waste into recycling, as well as the introduction of a procedure for their alienation by selling at public auctions, including digital platforms using. In the long term, in order to increase the use of secondary metal raw materials, it is planned to organize the construction of small plants for the scrap metal processing. In the medium term, measures are being developed and implemented to increase scrap collection in the country. Thus, economic research at all stages of the scrap metal recycling, including at its primary stage - the scrap metal collection, becomes relevant, since the identification of its economic indicators, in particular seasonal fluctuations, contributes to an increase in scrap collection.

2. Research methodology

By seasonal fluctuations we mean regular, periodic onset of intra-annual ups and downs in production, cargo and commodities turnover associated with the seasons change. Seasonality is a stable, time-repeating periodicity in the development of economic phenomena. It means any economic processes that are caused by calendar and (or) climatic reasons. To be able to use and influence seasonality purposefully, you need to be able to isolate, measure, analyze, and make forecasts regarding processes subjected to seasonal fluctuations, as well as carry out long-term, medium-term and current planning.

A time-ordered sequence of economic process observations is called a time series, and if the process is subject to periodic fluctuations with a definite and constant period equal to an annual interval, then this is a trend-seasonal time series [2].

At the beginning of the last century, Chetverikov developed an iterative method that makes it possible to exclude the influence of seasonal waves of variable structure. Using this method, we investigate the monthly time series of the non-ferrous scrap (copper, brass) metals mass handed over to scrap metal collection stations in Krasnodar. Copper and brass as the most frequently donated non-ferrous metals with daily weight values other than zero were selected for the study. The period of time series research is from 01/01/2016 to 01/01/2019.

3. Research stages

1. A visual assessment of the initial data diagram was made (monthly indicators of the copper and brass scrap mass for 2016-2019 with a discreteness of 1 year), which allowed us to assume the presence of seasonality in these time series (Fig. 1).
Figure 1. Monthly time series of scrap mass: A - copper, B – brass.

2. Further, the initial time series were investigated using the Chetverikov method for the presence of a seasonal component with the calculation of specific values of seasonality indices ($P_0 = 12$, $t = 4$, where $P_0$ is the number of months, and $t$ is the number of years, $P = t \times P_0 = 48$) :

1) The empirical series $X_p$ was smoothed, where $p = \overline{1, P}$ using a moving average with a smoothing period $P_0 = 12$;

2) A preliminary estimate of the trend was obtained $X'_p = U'_p$ or $X'_{kn} = U'_{kn}$, where $k = \overline{1, t}$ and $n = \overline{1, P_0}$.

3) The original empirical series is cleared from the trend $l_p = X_p - U'_p$ или $l_{kn} = X_{kn} - U'_{kn}$.

4) Calculated the mean-square deviation $\sigma_k$ of the value $l_{kn}$ for each year:

$$\sigma_k = \left(\frac{\sum_{n=1}^{P_0} l_{kn}^2 - \left(\sum_{n=1}^{P_0} l_{kn}\right)^2 / P_0}{P_0 - 1}\right)^{1/2}$$

5) A normalized residual series was obtained $\overline{l_{kn}}$ by dividing the individual values of each month by the deviations of the corresponding year $\overline{l_{kn}} = \frac{l_{kn}}{\sigma_k}$.

6) The preliminary average seasonal wave is calculated: $V_n^{(1)} = \frac{\sum_{k=1}^{t} \overline{l_{kn}}}{t}$

7) A series devoid of the preliminary seasonal wave is obtained: $\overline{U_{kn}} = X_{kn} - V_n^{(1)} \sigma_k$.

8) The second iteration is performed, the result is a new trend estimate $U_{kn}^{(2)}$. The deviation of the series $U_{kn}^{(2)}$ from the original empirical series $X_{kn}$: $l^{(2)} = X_{kn} - U_{kn}^{(2)}$ is calculated. The resulting deviations are processed again to calculate new values of the seasonal wave $V_n^{(2)}$.

When comparing the values of the seasonal wave coefficients obtained at the first and second iterations, we notice that they differ slightly from each other (Fig. 2).

Figure 2. Comparison of the seasonal wave coefficients values: A - copper, B – brass.
9) The seasonal component final values of the time series were calculated. In this regard, the values of the random component $\varepsilon_{kn}$ were first calculated, then the values of the intensity coefficients $S_k$ were found for each year (except for the first and the last, since after repeated smoothing there were only 4 values left in them), and finally, the final values of the seasonal component $V_{kn}$ of the time series were determined. Calculations were made according to the formulas and are presented in Figure 3:

\begin{align}
\varepsilon_{kn} &= l_{kn}^{(2)} - V_n^{(2)} \\
S_k &= \frac{\sum_{n=1}^{N} l_{kn}^{(2)} \varepsilon_{kn}}{\sum_{n=1}^{N} \varepsilon_{kn}^2} \\
V_{kn} &= V_n^{(2)} S_k
\end{align}

![Figure 3. The final values of the seasonal component: A - copper, B – brass.](image1)

10) At the final stage, the seasonality indices were calculated using formulas (4) and (5), a graphical representation of which is shown in Figure 4:

\begin{align}
I_{kn} &= \frac{u_{kn}^{(2)} + V_{kn}}{u_{kn}^{(2)}} \\
I_n &= \frac{\sum_{k=1}^{K} I_{kn}}{1} \times 100%
\end{align}

![Figure 4. Seasonal wave indices: A - copper, B – brass.](image2)

4. Results discussion and conclusion
Currently, one of the most promising and used forms of forecasting is forecasting based on a time series, which allows you to carry out all types of planning, calculate the amount of required resources, minimize risks and losses in economic activity. The author of the work plans to conduct further research of the time series presented in the work to predict the development dynamics of processes using nonlinear dynamics methods, for the effective usage of which it is necessary to perform a comprehensive analysis of time series, taking into account the seasonal component [3].
Using the Chetverikov method, which allows us to exclude the influence of variable structure seasonal waves, we conducted a study of the monthly time series of the non-ferrous scrap mass (for the items "copper", "brass") handed over to scrap metal collection stations in Krasnodar. According to the calculations for the selected positions, the seasonal wave values are higher than the trend in March, April, August and December. At the same time, for the position "copper" the peak is March and April, for the position "brass" the peak is April, August. According to the calculation results we can suggest that seasonal fluctuations in the non-ferrous scrap mass are determined by the following factors:

1. Seasonal fluctuations in demand. The scrap end consumers in the region are local metal processing plants, as well as plants in neighboring regions. The spring period for these enterprises is a period of active scrap purchase. They determine the purchase price for scrap in the region. The spring increase in demand entails the purchase price increase, which, in turn, increases the handover volume, and the scrap collection is growing. In the winter period, enterprises work mainly due to raw materials stocks, so demand decreases, collection rate decreases, as a result there is a winter collapse (November, January and February) of the non-ferrous scrap handover volume.

2. Weather and climatic conditions. Spring and summer months are comfortable for collecting metal scrap, carrying out transportation by any means of transport. This means the increase in the reception mass for both positions in the spring-summer season. The winter collapse is caused by ice in wagons and in the port area on export vector, the difficulty of cleaning winter scrap before electric melting at factories.

3. Calendar factor. For example, in December, the collection rate increases, due to the upcoming spending of the population on the eve of the New Year and the desire to receive money for the scrap handover, in January there is a decline due to long weekends during the New Year holidays.

References
[1] Popova E V and Skibina Ya V 2018 The current state and problems of development of the Russian metallurgical industry, determining the relevance of economic research in the field of collection and recycling of scrap metal *Tendencii razvitiya nauki i obrazovaniya* 45(2) 52-53
[2] Popova E V and Skibina Ya V 2019 Research of trend-seasonal time series in the sphere of recycling of ferrous and non-ferrous metals *Sovremennaya ekonomika: problemy i resheniya* 12(120) 40-48
[3] Kumratova A M, Popova E V and Piterskaya L Y 2019 Application of nonlinear dynamics methods for predictive testing the economic time series data *Indo American Journal of Pharmaceutical Sciences* 6(3) 5598–5602