Trend-seasonal components identification at the stage of time series pre-forecasting analysis

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Abstract. This article contains the economic processes trend-seasonality identification and its analysis. The object of research is the water delivery market - HOD (Home & Office Delivery). The subject of the study is the drinking mineral water sales time series (TS) in the Krasnodar Territory in 19-liter PET bottles. The authors applied the Chetverikov’s iterative filtering method to the time series, implemented in the MS Excel environment. As the work result a step-by-step illustration of the filtering application to time series is presented, deviations are estimated, trend and the wave intensity coefficient are given. The practical significance of the study is that the characteristics obtained are the basis for subsequent effective forecasting.

1. Introduction

In general, seasonal fluctuations are formed not only under the influence of natural and climatic factors, but also under the influence of other economic processes internal features. Their effective maintenance is carried out through the analysis of economic indicators, which are most often presented in the form of a chronological series of data reflecting the process under study development course. To implement the analysis, one indicator observations sequence is ordered relative to the another indicator increasing or decreasing values. This is how the time dynamic series is formed, which in our case is the monthly sales volumes time series.

The research subject can be influenced by persistent factors, as well as factors that are not inherent or periodic. That is, a problem arises, which solution is based on the analysis of time series and subsequent adequate forecasting of the economic objects future states. To highlight the above factors, the authors propose to use the analyzed data filtering by the Chetverikov’s method.

This article describes an iterative method for filtering data for 2013-2018 of mineral drinking water sales volumes monthly time series in the Krasnodar Territory in 19-liters PET bottles, in the same expression. The choice of the research subject is not accidental.

In 2020, the Chicago Mercantile Exchange, CME Group launched futures contracts linked to the spot price of water. NQH2O Futures is now driving the Nasdaq Veles California Water Index. In addition, today fresh water corresponds to the characteristics of the exchange-traded asset, and the demand for it is growing faster than for any other resource. Climate change, drought and population growth make water scarcity and water pricing a hot topic for years to come. Consequently, the competent management of the water market as a whole implies a detailed analysis of its indicators and characteristics, among which the seasonality is especially worth highlighting [1].
2. Materials and methods

It is necessary to isolate the seasonal component from the time series to study seasonal changes separately from their occurrence reasons. In this regard, we will build a graph of sales volumes and its trend lines (Figures 1a-1d), which allows to notice the following characteristics.

First, there are ups in the time series associated with the increase in demand for water and a corresponding increase in sales. Peaks in sales are in the periods July-September and November-January. The factors influencing such a pronounced growth in sales are the hot summer-autumn period in the Krasnodar Territory and the pre-New Year excitement. The revealed visual periodicity indicates seasonal fluctuations inherent in the investigated time series. Secondly, there is a steady upward trend in sales. And thirdly, the investigated time series is complete.

Thus, if fluctuations with a constant period are observed in the economic process under study, then we can say that this process indicators studied time series is trend-seasonal. For such series, iterative filtering methods are applicable, where the trend is preliminarily highlighted, and then the seasonal component, which is calculated by multiple smoothing of the slip average time series.

**Figure 1.** Trend lines of mineral drinking water monthly sales volumes in the Krasnodar Territory for the period from April 2013 to September 2018: a) exponential; b) linear; c) logarithmic; d) power trendline.

Next, let us designate the tasks that arise in the trend-seasonal time series research [2] (Figure 2).
Figure 2. The three-season time series research scheme.

Chetverikov's iterative filtering method is reduced to the following actions:

1. The time series \( \{Y_t\} \) is aligned by using a smoothing average, the formula for which can be written as follows:
\[
Y'_t = \frac{\sum_{r=q}^q \alpha_r y_{t+r}}{\sum_{r=0}^r},
\]
by using the period \( T_0 \), equal to 12 months, while the first and last elements of the series will be with half weight: \( \alpha_{-r_0/2} = \alpha_{r_0/2} = \frac{1}{2} \). The resulting series is the first aligned row and a preliminary estimate of the trend \( Y'_t = U'_t \), which is further subtracted from the initial series and we obtain deviations from the aligned one \( l_t = Y_t - Y'_t \):

2. The calculation for each period (year) of the standard deviation according to the formula
\[
\sigma_i = \sqrt{\frac{\sum_{j=1}^{T_0} \bar{l}_{ij}^2 - (\sum_{j=1}^{T_0} \bar{l}_{ij})^2 / T_0}{T_0 - 1}}
\]
by which the individual deviations (monthly, quarterly) of each slip period \( \bar{l}_{ij} \) are then divided;

3. Calculation from the thus normalized deviations of the preliminary average seasonal wave
\[
V_j^1 = \frac{\sum_{i=1}^m \bar{l}_{ij}}{m};
\]

4. Multiplication of the obtained average preliminary wave by the standard deviation of each year and subsequent subtraction from the initial series (alignment of the second iteration) \( U_{ij}^1 = Y_{ij} - V_j^1 \sigma_i \);

5. The series obtained in the previous action is smoothed again, as the result of which we have a new trend estimation \( U_t^{(2)} \);

6. We calculate new deviations of the original series \( Y_t \) or \( U_t^{(2)} : l_t^{(2)} = Y_t - U_t^{(2)} \), which are
subjected to similar processing from points 2 and 3 to highlight the final average seasonality after multiplying the average seasonal wave on \( k_i \) wave intensity factor \( k_i = \frac{\textstyle \sum_{j=1}^{T_0} l_{ij}^{(2)}}{\textstyle \sum_{j=1}^{T_0} \varepsilon_{ij}^2} \), where 

\[ l_{ij}^{(2)} \] is the aligned series, and \( \varepsilon_{ij} \) is a random component equal to the difference between the aligned series and the final average seasonal wave \( \varepsilon_{ij} = l_{ij}^{(2)} - \mu_{ij}^{(2)} \).

The described method was developed in 1928 and allows to exclude the variable structure seasonal waves influence.

3. Results of applying the Chetverikov's iterative filtering method

Let us present the results of using the Chetverikov’s method. At stage 1 of the first iteration, we will calculate the average chronological for the period \( m = 12 \). When comparing the visualized aligned series obtained at the end of each iteration (time series (2)) and the initial time series, it can be seen that the alignment at the first iteration filtered out important indicators: the curve does not display the leaps corresponding to the increase in sales, although subsequent iterations retain these "peaks", repeating the initial series (Figure 3).

![Figure 3. Cumulative graph for aligned series after the first filtering without taking into account the seasonal component with a sliding period \( T = 12 \).]
Figure 4. Cumulative graph for aligned series after the first filtering without taking into account the seasonal component with a sliding period $T = 6$.

As you can see from the figure, the first iteration differs from the subsequent ones and has a smoother form. Taking into account the hypothesis that the time series has peaks repeating in periods of half a year (Figure 3 - graphic representation of the seasonal component coefficients), the authors proposed to carry out the analysis at the first iteration, using not an annual, but a half-year interval (Figure 4). Thus, the first iteration retains important indicators of increased demand.

Figure 5. Seasonal wave chart.

Figure 6. Initial sales volumes series and one adjusted by the Chetverikov’s method.

4. Conclusion
The more accurately the observed object behavior model is described, the more accurate the subsequent forecasting [3]. It is necessary to carry out a thorough analysis of time series and filtering values from seasonal components taking into account the content of the large amount of information about the ongoing processes within each fixed value that will increase the likelihood of making the forecast when solving economic problems.

In this research, the Chetverikov’s iterative filtration method is used, its choice is based on ease of use and satisfactory "purity" of the components obtained. However, it should be noted that against the background of all the positive aspects, there is one drawback that must be taken into account in further results analysis and detailing, namely, the use of a moving average leads to the information loss at the ends of the time series.
References

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