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Predictive Testing Of Economic And Natural Time Series Data Using Nonlinear Dynamics Methods.

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ABSTRACT

In this paper, the authors propose the use of adapted nonlinear dynamics methods for preparing time series data for the forecast procedure in order to identify chaotic dynamics and the selection of forecast methods and models. Each step of the proposed set of methods for preliminary data processing allows us to put forward proposals on certain properties of the time series under study. This, in turn, proves that to obtain reliable and reasonable conclusions about the type of behavior of the system under study, there are not enough results from one of the many existing tests. Only a comprehensive analysis will most accurately determine the type of behavior of the time series and its characteristics, which will allow to obtain a reliable forecast in the future.
Keywords: complex analysis, time series, nonlinear trend, visualization, attractor, pseudo-phase space.

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INTRODUCTION

For determining the development goals of any economic system, calculating the amount of necessary resources to achieve these goals, the implementation of long-term, medium-term and current planning are economic forecasts, which are compiled on the basis of statistical data (time series). Thus, forecasting allows minimizing possible risks and losses in planning and implementing development goals.

The authors of the paper propose to use adapted nonlinear dynamics methods for effective planning and forecasting of the dynamics of economic processes. To obtain reliable and reasonable conclusions about the type of behavior of the system under study, the results of one of the many existing tests are insufficient. Only a comprehensive analysis will most accurately determine the type of behavior of the time series and its characteristics, and obtain a reliable forecast [4, 5].

MATERIAL AND METHODS

For the analysis of economic series there are many different algorithms and research methods. Comprehensive analysis of time series (TS) involves a study in three stages:

1. At the first stage - preliminary processing of the time series:

- plotting the time series before and after the removal of the linear trend;
- construction of pseudo-phase space of dimension two;
- conducting a drift attractor test;
- Conducting a Gilmore graphic test.

The results of each step make it possible to judge the properties of the TS under study.

2. At the second stage, metric characteristics are calculated, allowing to diagnose the type of dynamics, namely:

- estimation of the correlation dimension;
- estimation of the maximum Lyapunov index;
- Kolmogorov K-entropy estimate;
- assessment of Hurst N;
- conducting the test of Brock's residues;
- conducting shuffling diagnostics.

3. At the third stage, the forecast is built.

Each step of the proposed set of methods for preprocessing of data allows us to put forward proposals on certain properties of the time series under study, below is a detailed description of each stage:

- The time series graph shows the dependence of the series values on time, i.e. axis - the date of observation, - the value of the time series. The construction of this graph allows you to determine the type of behavior of the system under study and the presence of a linear trend. Further analysis of the time series using nonlinear dynamics methods is appropriate when the series behaves as random. At the same step, using standard statistical methods, the time series is cleared from the trend.
- The pseudo-phase space shows the dependence of the current value of the time series () on the previous (). The construction of this graph makes it possible to judge the presence of a strange attractor and a joker, which testifies to the chaotic behavior of the system.
- The drift attractor test shows the dependence of the system parameters on time, which manifests itself in the drift of the attractor. A positive test result means that the points belonging to the first and last quarters of the series form sets of points displaced relative to each other. In identifying such a relationship, it is necessary to clean the row from a non-linear trend, which is caused by the drift of the attractor.

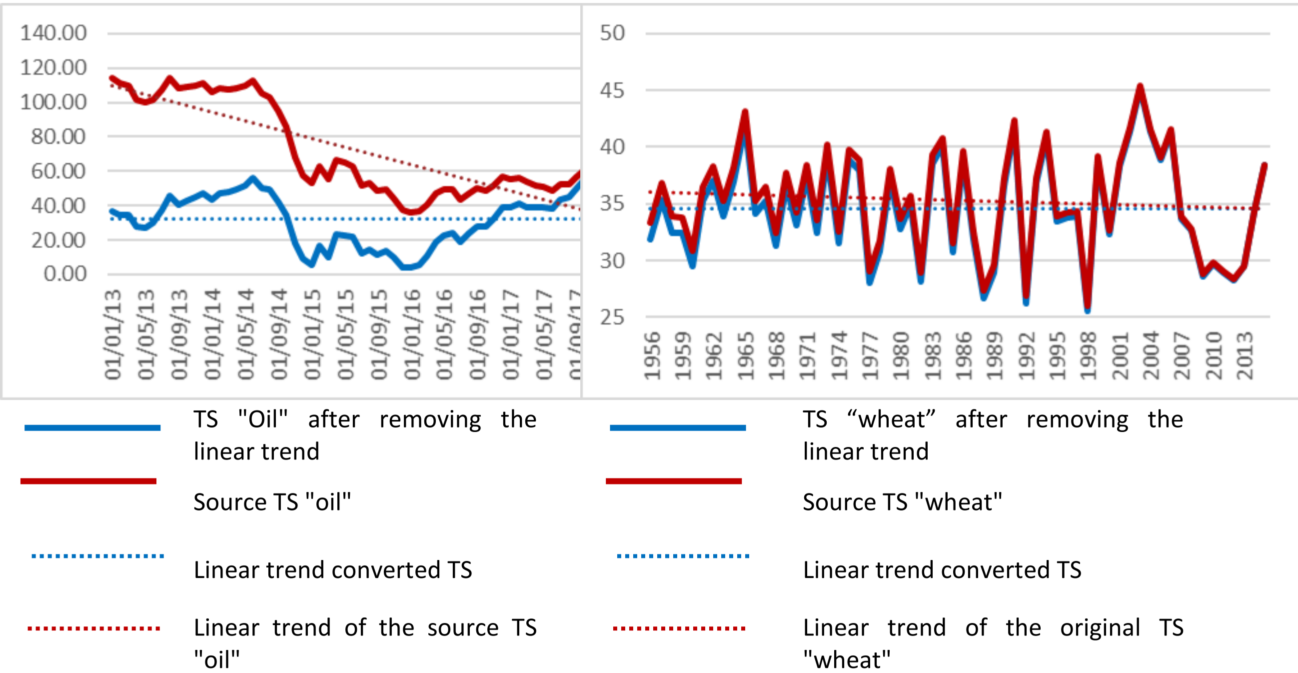
- Conducting a graphic test Gilmore allows you to identify unstable trajectories, the presence of a joker in the system, which are signs of chaotic behavior.

It should be noted that the implementation of the proposed steps is difficult without specialized programs, in this work, the Data Analysis and MS Excel programs were used to build graphs and conduct tests. The proposed methods were consistently tested on the following time series: prices for Brent oil, from 1.09.2012 to 1.09.2017, the number of observations in the studied rows is 61, and a natural time series of wheat yield is taken to compare the behavior of systems of various types Stavropol Territory - TS "wheat" (annual values for the period 1956 - 2015).

RESULTS AND DISCUSSION

Step 1. At the first step of the visualization stage, graphs of the time series values on the observation number were plotted. Further, a linear trend has been removed from these time series (in accordance with Figure 1):

1. By plotting the time series in MS Excel, we obtain the equation of the trend line and find its values at each point $x = [1; n]$, where n – number of observations in the time series under study.
2. The values of the cleared time series are equal to the difference between the initial values of the series and the values of the trend line.



a) b)

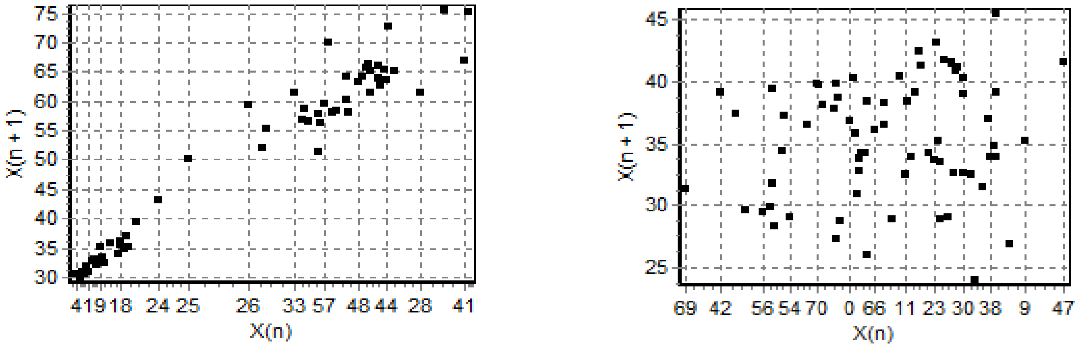
Figure 1: Time series charts before and after removing a linear trend:

(a) TS "oil" from 21.12.12 to 21.12.17; (b) TS "wheat" from 1956 to 2015

The time series in Figure 1a) has a clearly marked linear trend, i.e. It has a variable, non-cyclic component that describes the net impact of long-term factors, the effect of which is gradual. The visualization of Figures 1b) allows us to conclude that there is no clear linear trend in TS “wheat”.

Removing the linear trend from BP prepares them for further research in step 2.

Step 2. At the second step in the “Data analysis” program for all TSs under study, pseudo-phase spaces were constructed, reflecting the dependence of the values of the time series from the previous ones. The construction of pseudo-phase space makes it possible to hypothesize the presence of a strange attractor (in accordance with Figure 2). The visualization of Figure 2 makes it possible to conclude that the TS “oil” pseudo-phase space points are points condensed around the bisector of the positive orthant Cartesian coordinates. The scatter of pseudo-phase space points for TS “wheat” does not allow us to draw a similar conclusion. To confirm the hypothesis of the presence of a strange attractor, it is necessary to determine whether the system parameters depend on time, expressed in the drift of the attractor.



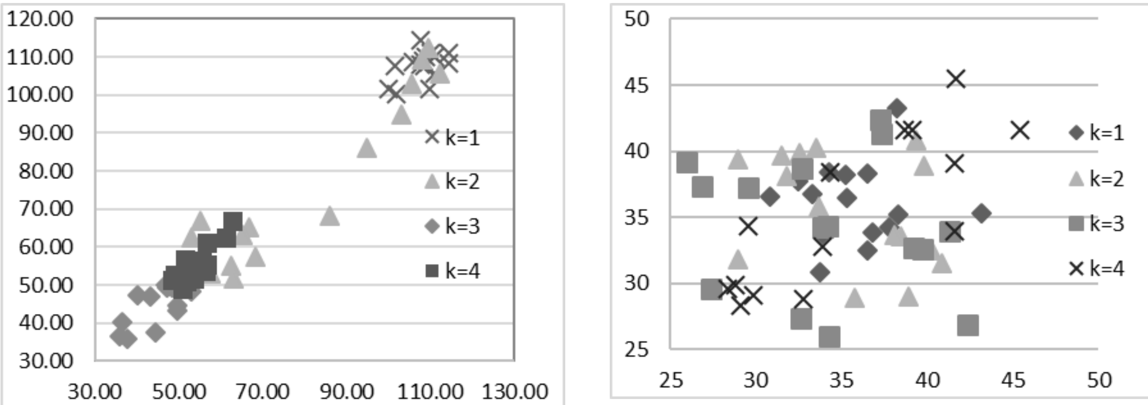
a) b)

Figure 2: Pseudo-phase time series spaces:

(a) TS "oil" from 21.12.12 to 21.12.17; (b) TS "wheat" from 1956 to 2015

Step 3. We determine whether the system parameters depend on time. For the test, the TS values are divided into $k = 4$ parts. The test results are shown in Figure 3.

Areas filled with the same markers suggest that there is drift in the time series of Brent crude oil prices. The visualization of the Cartesian space pattern for TS “wheat” does not allow us to determine the drifting attractor [7].



a) b)

Figure 3: Test results for a drift attractor:

(a) TS "oil" from 21.12.12 to 21.12.17; (b) TS "wheat" from 1956 to 2015

Define the drift parameters [7] to remove the non-linear trend from the time series. Using an interactive procedure, the authors determined the parameters of the affine transformation: compression along the axis $\mathrm{OX} - kx$, axial compression $OY - ky$, angle of rotation – α, carry on $\mathrm{OX} - dx$ and by $OY - dy$. The obtained values allow us to calculate the estimates of the drift parameters of the attractor (linear displacement velocity, compression velocity, and rotation rate) [7]. The numerical values of the parameters are presented in table 1:

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Table 1: Parameters of the affine transformation of the drifting attractor of the TS under study

Affine transformation parameters	TS "wheat"	TS "oil"
Dx	0	−9
Dy	1,5	−10,2
Kx	0,56	0,67
Ky	0,62	0,7
α	−22,4	1,6

Step 4. Gilmore test [1, 6] (in accordance with Figure 4), which allows to detect signs of chaotic behavior. In graphs 6a (the result of Gilmore's test for TS "oil" from 12/21/12 to 12/21/17), we observe the presence of empty areas characteristic of the interval joker [3, 2], which allows us to put forward an assumption about the possibility of using these series using a class of models such as dynamic systems with a joker. In Figure 4b, empty areas and bands are expressed implicitly and are not actually observed, that is, It is impossible to conclude that there is a joker for TS "wheat" from 1956 to 2015.

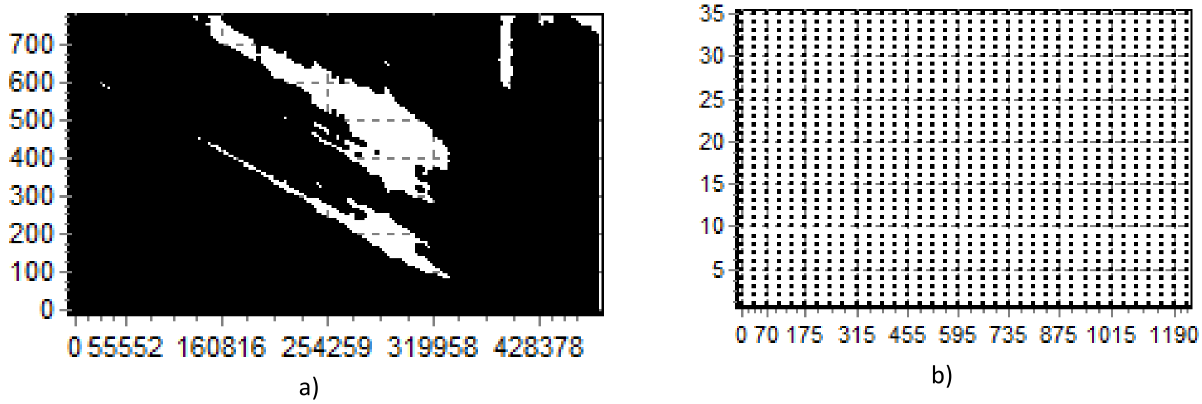

Figure 4: Gilmore test results for:

(a) TS "oil" from 21.12.12 to 21.12.17; (b) TS "wheat" from 1956 to 2015

CONCLUSION

Thus, as a result of the first stage of the analysis performed, time series were obtained, cleared of a linear trend. The calculated drift estimates allow us to clear the time series from the nonlinear trend and prepare them for further analysis (the second stage), which calculates metric characteristics (estimation of the correlation dimension; estimate of the maximum Lyapunov index; Kolmogorov K-entropy estimate; test Kherst H; test Brock's remnants; carrying out a shuffling diagnosis), allowing to diagnose the type of dynamics and accordingly select the most appropriate forecast models

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