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ANALYSIS OF TIME SERIES USING COMPLEX ECONOMIC-MATHEMATICAL METHODS

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Abstract: This article covers the stages of determining nonlinear trends in time series, mathematical modeling, finding trend equations using regression methods, and forecasting. In particular, taking into account the complex dynamics of economic processes, the advantages of exponential, logarithmic, and polynomial models are analyzed. The accuracy and error criteria of forecast results are considered through practical examples.
Keywords: time series, economic processes, trend, mathematical modeling, regression

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Time series are an important tool in modern economic analysis. Time series analysis is used to observe and analyze how most economic indicators change over time. Through this analysis, trends are identified and future predictions are made. In most cases, these trends are not linear, so it is necessary to use complex economic and mathematical methods. The trend of time series is not always linear. Many economic processes can have non-linear trends, that is, exponential, logarithmic, polynomial or other forms, for example:

a. Types of non-linear trends
b. Mathematical Modeling (With Table and Practical Examples)
c. Finding trend equations using regression methods
d. We will explain these steps in detail in nonlinear trend prediction and error analysis .

a. Types of non-linear trends

If the time series does not fit a precise linear model, one of the following nonlinear trend models is used:

a) Exponential trend

Some economic processes have a tendency to grow or decline rapidly and can be represented by an exponential equation:

$$Y_t = ae^{bt} \qquad (1.1)$$

where: a-initial value, b- rate of increase or decrease, t-time $e(2.718)$- base of natural logarithm

Application: It is used in the areas of population growth, inflation rate, and price growth model.

b) Logarithmic trend

If the time series grows rapidly and then stabilizes, then the logarithmic model is used:

$$Y_t = a + b\ln(t) \qquad (1.2)$$

where: $\ln(t)$- natural logarithm , a, b- parameters

Application: The relationship between income and consumption is applied in the areas of the

speed of adoption of new technologies [1].
c) Polynomial trend
If a time series has complex fluctuations, it can be expressed by an n-degree polynomial:
$Y_t = a + b_1 t + b_2 t^2 + b_3 t^3 + \cdots + b_n t^n$ (1.3)

Application: It is performed in the areas of stock indices, unemployment rate dynamics, economic growth forecasting, mathematical modeling, and tabulation [2].
Example: Monthly economic indicators show the changes in a certain variable over five months as shown in Table 1 below.
Table 1. Parameters of economic indicators change

Moon	t	**Sales volume** Y	$\ln(t)$	t^2	e^t
January	1	100	0.000	1	2.718
February	2	150	0.693	4	7.389
March	3	210	1.099	9	20,085
April	4	280	1.386	16	54,598
May	5	360	1.609	25	148,413

Using the table above, the parameters of the equations corresponding to each trend model are shown in Figure 2.

No.	True Y	Exponential Y	Logarithmic Y	Polynomial Y
1	100	111.583706006351	72.42242261034382	100.0
2	150	150.212935735225	179.2560081050147	150.0
3	210	202.215241541712	241.7496494369848	210.0
4	280	272.220256608607	286.0095935996854	280.0
5	360	366.4603495912352	320.4823262479711	360.0

The application of nonlinear trend models based on the parameters of economic indicator

changes is illustrated in Figure 1.

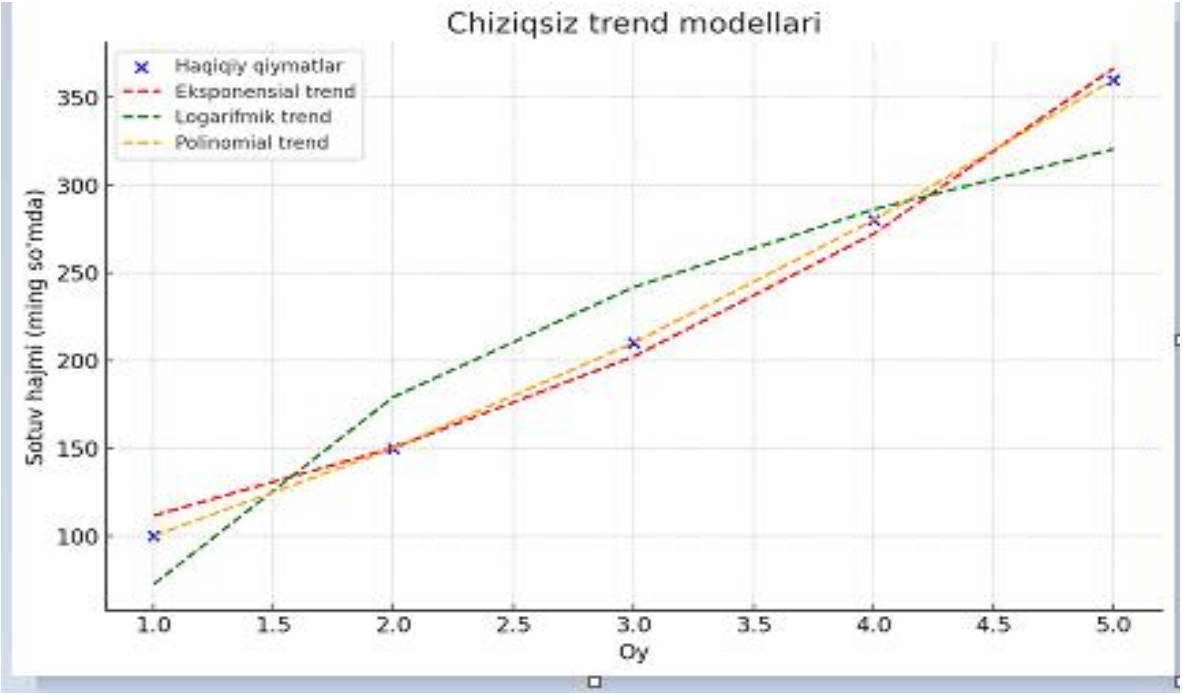

Figure 1. Nonlinear trend models of economic indicators change parameters

Based on the table and graph above, the following results can be obtained:

1. Blue dots are real time series values (sales volume).

2. Red line (exponential model) - used when the data has exponential growth.

3. The green line (logarithmic model) represents a process that initially grows rapidly and then slows down.

4. The yellow line (polynomial model) - identifies the complex dynamics of the time series.

You can check which of these models fits better by evaluating the error. If you need to compare by MSE (Mean Squared Error) or other evaluation criteria, you can say [3].
Time series smoothing is a technique used to reduce random variations in time series and to more clearly see the underlying trends. Smoothing methods are divided into the following:

a. Moving Average (MA)

b. Exponential smoothing (Exponential Smoothing, ES)

c. Holt-Winters model

d. Moving Average

In this method, the average value for each point in the time series is taken over a certain interval. The formula for a simple 3-period moving average is:

$$Y_t' = \frac{Y_{t-1}+Y_t+Y_{t+1}}{3} \qquad (1.4)$$

Figure 2 below shows a time series smoothing scheme:

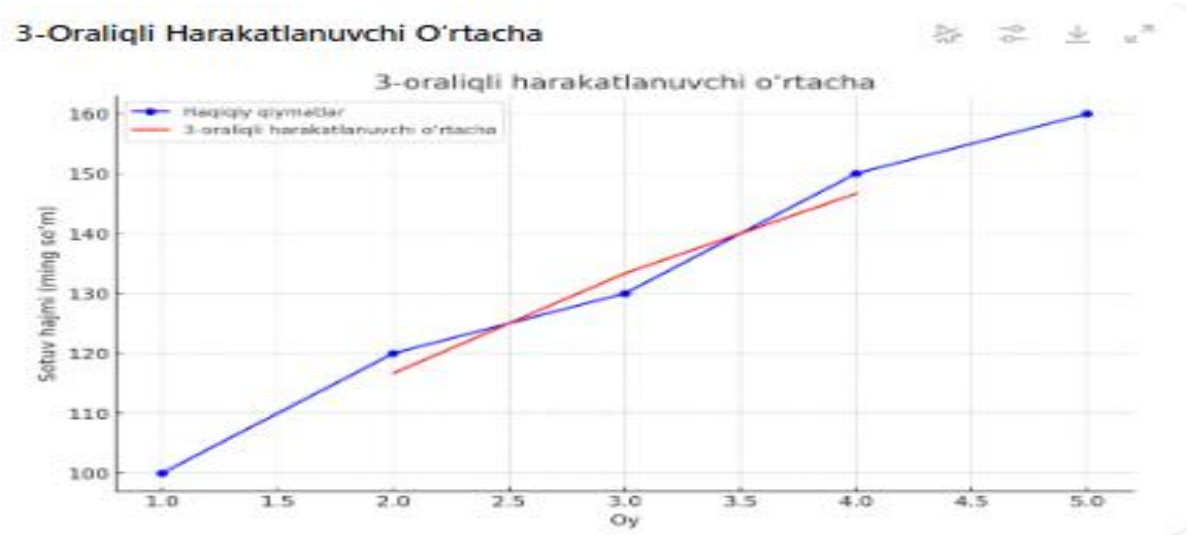

Figure 2. Moving average when smoothing time series

As can be seen, the time series is smoothed and the volatility is reduced with the help of the moving average. Now it is possible to apply the exponential smoothing method [4].

Simple Exponential Smoothing

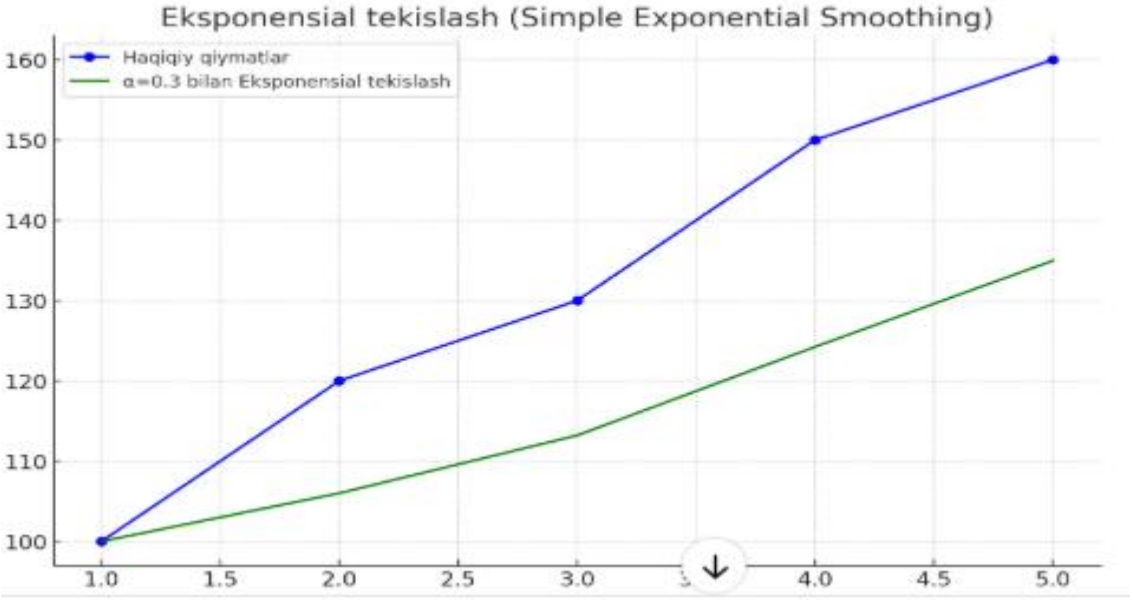

Figure 3. Time series smoothing scheme

Based on the exponential smoothing in the table and graph above, the following results can be obtained:

1. Blue dots and line - real time series (sales volume).

2. the results obtained using exponential smoothing .($\alpha = 0.3$)

Exponential smoothing adapts to new data faster than a moving average.

Conclusion

Nonlinear time series analysis provides a deeper analysis of economic processes. Since each economic indicator has its own trend, it is important to choose an appropriate trend model. These

processes are accurately represented using exponential, logarithmic or polynomial regression models. Using the equations determined by regression, it is possible to make reliable predictions and make decisions.

Literature

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