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Least Squares Method for Time Series Analysis in Economics

Nand Kishor Kumar
Assistant Professor
Tri-Chandra Campus, Kathmandu, Nepal

Raj Kumar Shah
Assistant Professor
Ratna Rajya Laxmi Campus, Kathmandu, Nepal

Sudhir Kumar Rimal
Associate Professor
Baneshwor Multiple Campus, Kathmandu, Nepal

Correspondance email: rimalsudhir@gmail.com
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Abstract

Least squares approach of time series analysis of applications is observed in this paper with examples. A key technique for time series analysis in economics is the Least Squares Method. Its limitations require employment of more sophisticated econometric techniques for accurate analysis, despite the fact that it offers vital information on economic patterns and projections. Businesses, legislators, and economists can all make better decisions if they realise and use LSM suitably. The Least Squares Method can assist economists in developing policies and better managing budgets by drawing important conclusions from historical data.

Keywords: Least square method, time series analysis, trend, line of best-fit

Introduction

Time series analysis is a cherished technique in economics for measuring and forecasting long-term trends. The least squares method (LSM) is a vital tool for modelling economic data. This statistical method helps in fitting a trend line to a dataset, permitting economists to make informed judgments based on historical data.

Choosing a method is a challenge for economists to deal with time series data. Since time series data have special characteristics like trend and structural break, common tactics used to analyse other types of data might not be suitable for time series data analysis. The characteristics of time series data and popular data analysis techniques are

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discussed in this paper. The framework makes process of choosing suitable test methods easier. For an example, connection between pricing and money in Nepal is analysed. Test results generated with this scientific method are found to be more reliable and consistent (Shrestha & Bhatta, 2018). Using examples, this paper seeks to determine least squares approach for time series analysis.

Concept of Least Squares Method

A helpful statistical method for figuring out a regression or best-fit line for a particular outline is least-squares approach. An equation of particular parameters can be used to explain this tactic. Regression and evaluation both make considerable use of the least squares method. Regression analysis frequently uses this method to approximate sets of equations with more equations than unknowns. The method for reducing errors in each equation's output is providing by the least squares approach. Use the formula for sum of squares of errors to find the variance in the observed data.

The least-squares method is usually employed when fitting data. It is expected that best fit result will lower the sum of squared errors, also known as residuals, which are defined as the variations between the experimental or observed value and the matching fitted value provided by the model. There are two types of least-squares problems:

a. Ordinary or linear least squares

b. Nonlinear least squares

These rely on whether the residuals are linear or nonlinear. Regression analysis in statistics frequently encounters linear issues. Conversely, the iterative refinement approach typically uses non-linear issues, where each iteration brings the model closer to the linear one.

A mathematical method for curtailing sum of squared of disparities between observed and anticipated values is called the Least Squares Method. It offers the regression line, which is the best-fitting line for trend analysis of economic data.

Let and are two variables with a certain relationship between them. Let (x_1,y_1), (x_2,y_2), (x_3,y_3)......,(x_n,y_n) be points with, x_1, x_2,x_3,...,x_n are the values of x and y_1,y_2,y_3,…,y_n corresponding values of .

A line is to fit in the plane in view that the distance of each point on the plane from the corresponding point on the line to fit is least. The value of denoted by in each ordered pair is observed value and its corresponding in the line is estimated value and is denoted by . The difference is known as the error. The difference may be positive or negative according as or . In order to avoid the sign of the difference, we find the square of the difference so that it may not affect due to the sign. The line produced using this technique is referred to as the line of regression, trend line, or line of best fit. Knowing the value of one variable allows for the estimation of another using this line.

Time Series Analysis

A group of statistical data in chronological order is called a time series. It is described mathematically by the functional relationship

$$y = f(t). \qquad (1)$$

In this case, y denotes the phenomenon under consideration at time t. For example, the population (y) of Nepal in various years (t). If a phenomenon or variable at times t_1, t_2, ...,t_n are y_1 y_2, ...y_n

t : t_1, t_2, ...,t_n

y :y_1 y_2, ...y_n

denotes a time series. So, A bivariate distribution is produced invariantly by a time series, where time (t) and the phenomenon's value (y) at various time series points are the two variables. Annually, monthly, barely daily, or even hourly, and typically but not necessarily at equal intervals, value of t can be delivered.

Components of Time Series

Time series data contains the observations recorded over time at regular intervals. The important components assist in recognizing underlying patterns in data.

These components are:

1. **Trend (T)**
   (i) Represents long-term upward or downward movement in the data.
   (ii) It may be linear or nonlinear.
   (iii) Example: Increasing population over years or declining sales of DVDs.

Seasonal Component (S)
   (i) Recurring patterns or fluctuations within a fixed period (e.g., daily, monthly, yearly).
   (ii) Occurs due to external factors like weather, holidays, or business cycles.
   (iii) Example: Increased retail sales during December or higher electricity usage in summer.

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Cyclical Component

(i) Long-term oscillations or cycles that occur over periods longer than a season (e.g., economic cycles).

(ii) Unlike seasonal effects, cyclical patterns do not have a fixed duration.

Example: Economic recessions and booms.

Irregular or Random Component (R)

(i) Unpredictable variations caused by unforeseen factors like natural disasters or political events.

(ii) It does not follow a pattern and is usually considered noise in time series forecasting.

Example: A sudden stock market crash or unexpected spikes in demand due to a viral product.

Models of Time Series Composition

There are two primary ways to model time series data using these components:

Additive Model:

$$Y_t = T_t + S_t + C_t + R_t$$

i) Used when variations remain constant over time.

ii) Example: Sales figures showing steady seasonal fluctuations.

Multiplicative Model:

$$Y_t = T_t \times S_t \times C_t \times R_t$$

i) Used when variations increase or decrease proportionally to the trend.

ii) Example: Retail sales where seasonal peaks grow over time

Conceptualizing these components aids in decomposing time series data for analysis and forecasting.

Measurement of Trend Values

The equation of the trend line as

$y = a + bx$

This estimate provides value of dependent variable, given the known value of the independent variable. This values of y corresponding to given values of x are known as the trend values. The trend values thus obtained may or may not be equal to the corresponding actual values. But a trend value y_c for a given value of x is the dependent variable.

Least Square Method of Time Series Analysis

We should match trend of supplied time series using an analytical tool provided by the principle of least squares. Since the majority of data pertaining to business and economic time series follow a certain rule of development or decay, analytical trend fitting will be more accurate for forecasting and projections in these circumstances. Both linear and non-linear trends can be fitted using this method (Kumar, 2023, & 2024).

Fitting of Line of the Best Fit

Let x and y are independent and dependent variable respectively on trend line.

$$y = a + bx \qquad (2)$$

a and b are constants and known to be parameters, that to be evaluated.

For a given value of x, the estimated value of y obtained from equation (i) denoted by y_c is

$$y_c = a + bx \qquad (3)$$

where a = value of y at x = c
b = slope of the trend line
To fit trend line, values of a and b may evaluate from subsequent two equations

$$\Sigma y = na + b\Sigma x \qquad (4)$$

and

$$\Sigma xy = a\Sigma x + b\Sigma x^2 \qquad (5)$$

The equation (3) is obtained by summing up the terms of equation (1). Again, the equation (3) is also obtained by multiplying each term of (1) by x and then summing up the terms.

After solving,

$$b = \frac{n\Sigma xy - \Sigma x \cdot \Sigma y}{n\Sigma x^2 - (\Sigma x)^2} \text{ and } a = \frac{\Sigma y - b\Sigma x}{n}$$

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where n is the no. of observations.

The equation of the trend line, sometimes referred to as the line of best fit, may be obtained by changing values of a and b in (1).

The answer of the equations (3) and (4) can be made easier when the deviations of the independent variate values are taken from the middle of the independent variate value to make Σx=0.

Then the equation (3) and (iii) reduce to

$$\Sigma y = na \;\Rightarrow\; a = \frac{\Sigma y}{n}$$

$$\text{and } \Sigma xy = b\Sigma x^2 \;\Rightarrow\; b = \frac{\Sigma xy}{\Sigma x^2}$$

Substitution of values of a and b in (1) gives the trend line. While making Σx=0, we have the following two rules.

(i) When the no. of observations i.e. n is odd

Let the independent variable be denoted by X.
If n= no. of observations be odd, there is only one middle independent variate value.

$$x = \frac{X - \text{ middle of the variate value}}{\text{Difference of two consecutive values}}$$

(ii) When the no. of observations be even

When n= no. of observations be even, then there will be two middle independent variate values.

Here, we write

$$x = \frac{2(X - \text{ mean of two middle values })}{\text{Difference of two consucative middle values}}$$

In fitting the trend line equation y = a+bx using method of least square, we have two variables-x and y. If x be taken as time, then the series formed is said to be time series.

The method that is used to get the maximum information from the given data is analysis of time series. The commonly used method to get maximum information is the trend line equation y = a+bx in which we use method of least square.

Example 1:

The equation of line of best fit is determined using method of least squares for a given set of observations.

x	2	4	6	8	10
y	5	8	12	7	8

Then estimating the values of y when x=20.

x	y	x^2	xy
2	5	4	10
4	8	16	32
6	12	36	72
8	7	64	56
10	8	100	80
Σx=30	Σy=40	$\Sigma x^2=220$	Σxy=250

Let the equation is y=a+bx

Now, we find the values of a and b.

$$b = \frac{n\Sigma xy - \Sigma x \cdot \Sigma y}{n\Sigma x^2 - (\Sigma x)^2}$$
$$= \frac{5 \times 250 - 30 \times 40}{5 \times 220 - (30)^2} = \frac{50}{200}$$
$$= 0.25$$
$$a = \frac{\Sigma y - b\Sigma x}{n}$$
$$= \frac{40 - 0.25 \times 30}{5} = 6.5$$

Substituting the values of a and b in (1), we have the following equation of the line of best fit

y = 6.5 + 0.25x

When x=20 y=6.5+0.25×20=11.5.

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Example on Method of Least Squares

Calculate the straight-line trend by method of least square from the given data. Evaluate the trend values. Also, estimate the sales for 2022.

Year	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Sales of Mobiles (in 000)	12	13	14	15	22	26

Solution:

Year(X)	**Sales (y)**	**X = 2(X-2017.5)**	**x²**	**Xy**
2015	12	-5	25	-60
2016	13	-3	9	-39
2017	14	-1	1	-14
2018	15	1	1	15
20119	22	3	9	66
2020	26	5	25	130
	$\sum y = 102$	$\sum x = 0$	$\sum x^2 = 70$	$\sum xy = 98$

The trend line be y = a+bx

$$\text{Since } \sum x = 0, \text{ so } a = \frac{\sum y}{6} = \frac{102}{6} = 17$$

$$b = \frac{\sum xy}{\sum x^2} = \frac{98}{70} = 1.4$$

The required equation of trend line is

y = 17+1.4x

When x =- 5, y = 17-1.4 × 5 = 10

x = - 3, y = 17-1.4 × 3 = 12.8

x =- 1, y = 17-1.4 × 1 = 15.6

x = 1, y = 17+1.4 × 1 = 18.4

x = 3, y = 17+1.4 × 3 = 21.2

x = 5, y = 17+1.4 × 5 = 24

The trend values are 10, 12.8, 15.6,18.4, 21.2 and 24. For X = 2022, x = (X-2017.5) = 9

y_{2022} = 17+1.4 × 9 = 29.6

The estimated value of sales in 2022 = Rs. 29.6 thousand.

Application in Economic Time Series Analysis

The Least Squares Method is widely applied in economics for:

Trend Analysis: Identifying long-term patterns in GDP growth, inflation rates, or stock market movements.

Forecasting: Predicting future economic indicators based on historical data.

Business Cycles Analysis: Accepting cyclical fluctuations in employment, production, and demand.

Policy Evaluation: Measuring the impact of government interventions over time.

Strengths and Limitations

Strengths

i) Simple and easy to implement.

ii) Provides a clear mathematical relationship between time and the economic variable.

iii) Can be used for short-term forecasting.

Limitations

i) Assumes a linear relationship, which may not always be valid.

ii) Sensitive to outliers that can distort the trend line.

iii) Does not account for external economic shocks or structural breaks.

Conclusion

The Least Squares Analysis is a powerful model for economic time series analysis, offering insights into trends and future projections. While it has limitations, it serves as a fundamental technique for policymakers, economists, and analysts to make data-driven decisions. For more accurate forecasting, LSM can be complemented with advanced econometric models such as ARIMA or machine learning techniques.

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