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A study to compare the various growth models to assess the milk procurement of Delhi based milk enterprise

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Abstract
Dairy production and processing certainly appear to be the most important industry in terms of contributing to the global challenge of food security today and in the future. Milk is a common agricultural product produced by dairy animals in practically every country, and many people also survive on dairy farms via employment. Dairy is one of the largest agri-businesses in India and a significant contributor to the economy. In India, the largest milk producer in the world, production increased by 4.2 per cent to 192 MT. This study focuses on the growth modeling with various statistical models to find best curve of fit. To meet the objective of the study, various curves *viz.*, polynomial, logarithmic, inverse, compound, power, growth and exponential are fitted over the production of milk and milk products. In this study data from June 2015 to December 2020 was collected for milk procurement. With the highest adjusted R^2 value and lowest RMSE of cubic model, it was considered as best fit among all other growth models for milk procurement.

Keywords: Milk procurement, statistical models, growth curves, adjusted R^2 and RMSE

Introduction
It is the agricultural commodity with approximately 4 per cent share in the economy. Indian dairy industry has increased at about 12 per cent during last five years, with value added products driving market growth. It is a significant contributor to farmers income; dairy is the sole agriculture product in which around 70-80 per cent final market value is shared with farmers and it accounts for nearly one-third of rural household income in India. It serves a wide range of consumer needs like protein supplements and health foods to indulgence foods such as yoghurt and ice creams (Anon., 2021) [3]. The contribution of agriculture and allied sectors is decreasing year by year, but during the pandemic situation, it is the only sector that has sustained. The rest of the sectors collapsed due to the halt during the COVID-19 pandemic. The crops and livestock contribute to a major share of the agriculture sector, and this has helped the sector to sustain itself in this pandemic situation. To meet the public demand, there is necessity to study the milk industry with various statistical tools to analyze the growth of the industry and to manage the policies to uplift the production and to boost profit. Similar study was also done by Patil (2015) [7] to examine the trend of milk production in Karnataka based milk industry, where quadratic model was best fitted over the trend of milk production with Adj. R^2 of 0.89. Agatha (2015) [1] in Bucharest, Romania developed regression models for milk production from the period 2007-2014, linear model was best fit compared to quadratic one with low standard error.

Growth curve modeling is a statistical method for analyzing change over time using longitudinal data. Data collected from individuals at multiple time points is used to analyze trends over time and variation in changes over time among individuals.

Materials and Methods
Delhi Milk Scheme is a subordinate office of Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, Government of India. Delhi Milk Supply Scheme under India Council of Agricultural Research was underway after independence of India to provide milk in Delhi. It has network of over 1101 outlets (Including all day milk stalls). The milk booths are allotted to and manned by Ex-serviceman/ retired Govt. servants, physically handicapped, widow and unemployed persons. The DMS also supply milk to about 174 institutions such as hospitals, government canteens, hostels and defense units *etc.* At Present, DMS is supplying liquid pasteurized milk of different grades along with nutritious value-added dairy products like Ghee, Butter, Paneer, Butter milk and curd to the Delhi Market

(Anon. 2020) [2].

Delhi Milk Scheme (DMS) was purposively selected for the presented study, since it handles large quantity of milk and milk products and it was the only milk union under the government in the NCT of Delhi. The objective of the study to go detail of growth rate and the statistical evaluation of milk and milk products of Delhi Milk Scheme (DMS). The secondary data were collected from June, 2015 to December, 2020 of milk procurement on monthly basis from headquarter of DMS.

The brief explanation of various curve of fit discussed below.

Linear Function

Linear fit is given by the equation,

$$Y_t = a + bt$$

Where,

t is the time in months, independent variable,

Y_t is trend value of the dependent variable *i.e.*, procurement or production, a and b are constants or parameters.

The above equation is fitted by using the least squares method of estimation

Inverse function

Inverse curve shows a decreasing growth, it is given by the equation

$$Y_t = a + \frac{b}{t}$$

Where,

Y_t is the dependent variable *i.e.*, procurement or production, t is the independent variable, time in months,

'a' and 'b' are parameters.

The parameters can be estimated by the method of Ordinary Least Squares (OLS).

Quadratic function

This function is useful when there is a peak or a trough in the data of past periods. Quadratic fit is given by the equation

$$Y_t = a + bt + ct^2$$

Where,

Y_t is the dependent variable *i.e.*, procurement or production, t is the independent variable, time in months,

a, b and c are constants.

The constants can be calculated by applying the method of ordinary least squares approach.

Cubic function

This function is useful when there is or has been, two peaks or two troughs in the data of past periods. Cubic fit or third-degree curve is given by the equation:

$$Y_t = a + bt + ct^2 + dt^3$$

Where, Y_t is the dependent variable, procurement or production and t is the independent variable, time in months. a, b, c and d are parameters. The parameters are calculated by ordinary least squares technique.

Logarithmic function

This model shows very rapid growth, followed by slower growth, the mathematical equation is given by

$Y_t = a + b \ln(t)$ Where,

Y_t is the dependent variable *i.e.*, procurement or production, t is the time in months, independent variable,

'a' and 'b' are constants. The constants 'a' and 'b' are estimated by applying the Ordinary Least Squares approach.

S- Curve

S- Curve fit is given by

$$Y_t = \exp\left(a + \frac{b}{t}\right)$$

Where,

Y_t is the dependent variable,

t is the independent variable, time in months a and b are parameters or constants. Ordinary Least Squares (OLS) method can be applied to estimate the parameters of the model.

Growth function

The fit is given by, $Y_t = \exp(a + bt)$

Or, $\ln Y_t = a + bt$

Where,

Y_t is the dependent variable, procurement or production, t is the independent variable, time in months,a and b are parameters or constants.

The constants are obtained by ordinary least squares technique.

Power function

The fit is given by the equation

$$Y_t = a \exp(bt)$$

Where,

Y_t is the dependent variable, procurement or production, t is the independent variable, time in months,

a and b are parameters or constants, calculated by ordinary least square technique.

Exponential fit

If the values of t are arranged in an arithmetic series, the corresponding values of y form a geometric series, the relation is of the exponential type. The function of this fit given as

$$Y_t = at^b$$

Where,

Y_t is dependent variable, procurement or production, t is independent variable, time in months, a and b are constants.

The constants are calculated by ordinary least squares technique.

Criteria to find best fit trend equation

Root mean square error, RMSE

The root-mean-square deviation (RMSD) or root-mean-square error (RMSE) is a frequently used measure of the differences between values (sample or population values) predicted by a model or an estimator and the values observed. The RMSD represents the square root of the second sample moment of the differences between predicted values and observed values or the quadratic mean of these differences. These deviations are called residuals when the calculations are performed over the data sample that was used for estimation and are called errors (or prediction errors) when computed out-of-sample.

RMSE is always non-negative, and a value of 0 (Almost never achieved in practice) would indicate a perfect fit to the data. In general, a lower RMSE is better than a higher one. However, comparisons across different types of data would be invalid because the measure is dependent on the scale of the numbers used.

Formula for Root mean square error, RMSE is given by

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{N}(O_i - P_i)^2}{N}}$$

Where,

O_i = Observed value, P_i = Predicted value,

N = Number of data points.

It is also known as Root mean square deviation, RMSD.

Adjusted R^2

Adjusted R^2 also indicates how well data fit a curve or line, but adjusts for the number of terms in a model. If you add more and more useless variables to a model, adjusted r-squared will decrease. If you add more useful variables, adjusted r-squared will increase. Adjusted R^2 will always be less than or equal to R^2.

Both R^2 and the adjusted R^2 give you an idea of how many data points fall within the line of the regression equation. However, there is one main difference between R^2 and the adjusted R^2:

R^2 assumes that every single variable explains the variation in the dependent variable. The adjusted R^2 tells you the percentage of variation explained by only the independent variables that actually affect the dependent variable.

Formula for Adj. R^2 is given by

$$\text{Adj. } R^2 = \left[\frac{(1-R^2)(N-1)}{N-k-1}\right]$$

Where,

R^2 = Coefficient of determination, N = Number of data points,

k = Number of independent regressors or variables.

Results and Discussion

For the study of trend analysis, ten growth models *viz*., linear function, logarithmic function, inverse function, quadratic function, cubic function, compound function, sigmoid curve function, growth function, power function and exponential function fitted over the trend of milk procurement and production of the milk products. The estimates, adjusted R^2 and RMSE obtained by fitting of various growth models over the trend of milk procurement were displayed in Table 1. Adj.R^2 values for fitted models ranged from 0.097 to 0.712.

Among the fitted models, cubic function was obtained as best fit over the trend of milk procurement with significantly low RMSE and highest Adj. R^2. The fitting of cubic model over the procurement of milk is shown in Figure 1. The study of trend gives the idea about shift in a data set over a period of time, it allows the prediction of future with the study of past situation. The trend of milk procurement was presented for the period from 2015-16 to 2019-20.

Various types of models were tried to fit over the trend of milk procurement in this procedure of fitting growth models. In comparison to various growth models, the cubic growth model was shown to be the best of all, with a low RMSE and a high R^2 value. In the case of milk procurement, the cubic model achieved stability with RMSE and highest R^2 values of 67.256 and 0.712, respectively, implying that nearly 71% of the variation was explained in this model.

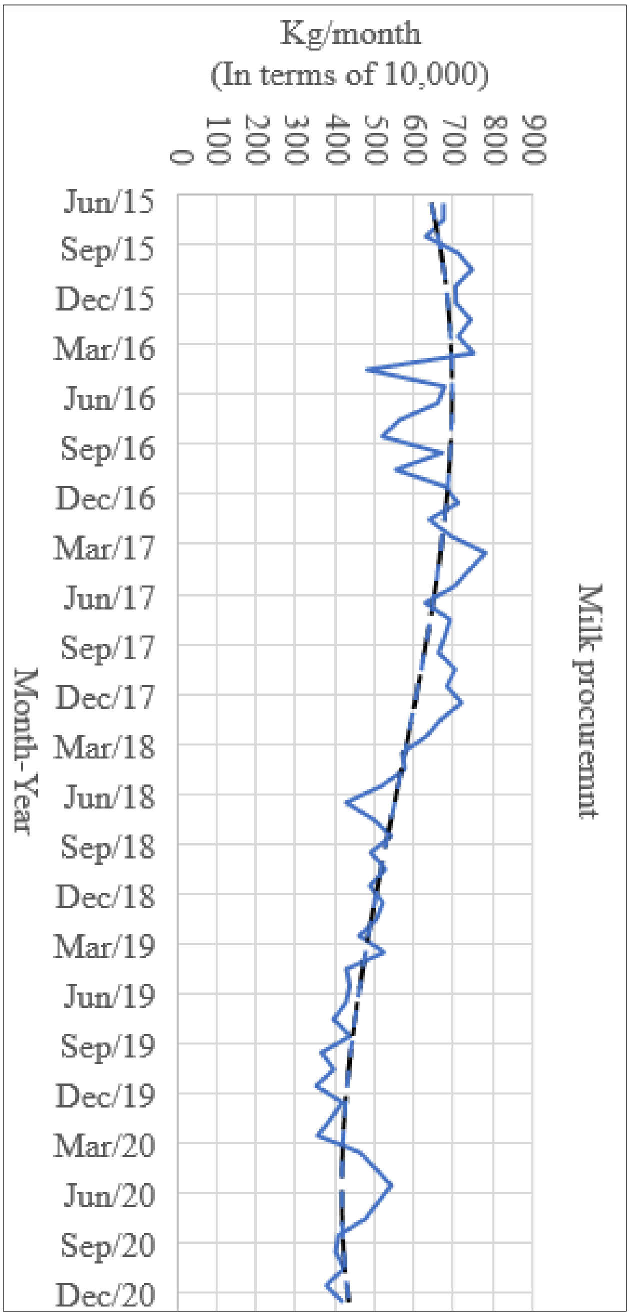

Fig 1: Cubic fit over the trend in milk procurement of DMS

Table 1: Analysis of various curve of fit for milk procurement

Fitted models	a	b	c	d	Adj. R^2	RMSE
Linear function	742.102	-5.244			0.659	73.226
Logarithmic function	866.401	-93.183			0.446	93.295
Inverse function	542.263	301.487			0.099	119.003
Quadratic function	714.978	-2.885	-0.35		0.663	72.835
Cubic function	632.409***	11.168*	-0.548***	0.005***	0.712	67.256**
Compound function	762.629	0.990			0.659	0.134
Power function	954.350	-0.170			0.439	0.173
Sigmoid function	15.480	0.549			0.097	0.219
Growth function	15.847	-0.010			0.659	0.134
Exponential function	762.629	-0.010			0.664	0.134

Note- *Significant at 5 per cent
**Significant at 1 per cent
***Significant at 0.01 per cent
a, b, c and d are parameters of regression model Adj. R^2 – Adjusted coefficient of determination RMSE – Root Mean Square Error

Conclusion

India has topped in milk producer countries in all over the globe with 192 mt. The path to achieve development will go through development of agriculture and its allied sectors as nearly 60-70 per cent of population serving in this sector. The impact of pandemic has been mostly disruptive in terms of economic scenario and human lives. All the sectors collapsing in this pandemic and lead to negative GDP growth, but agriculture sector emerged as a hope for economy as well as to curb the food insecurity. The dairy sector contributing around 25 per cent of the agriculture sector. Milk and related products are emerging day by day as major contributor in nation’s economy. To analyze the performance of the Delhi based milk industry, the trend of milk procurement fitted over the various growth models. The cubic model came up with the best fit because it obeys higher degree polynomial compared to linear and quadratic, thus it minimizes the chances of over fitting and under fitting.

By the approach of curve fitting over the trend of the milk procurement, policy makers get to know how the trend is fluctuating over the period of time and in which month, season they need to put more emphasis on their policies.

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