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Fitting of Non-Linear Regression Models to India exports to Basmati and Non-Basmati Rice

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India is the top exporter of Basmati and Non-Basmati Rice to the world. Nonlinear statistical growth models play a very important role in understanding the dynamics of an agricultural system. The present study attempted to develop nonlinear statistical growth models to describe export trends of Basmati Rice and Non-Basmati Rice from India, by using 36 years of data i.e., from 1987-2023. Here, different statistical growth models viz., Exponential, Logarithmic, Power, Quadratic, and Cubic models were applied and a comparative study was made for selecting the best-fitted models. By this study, the Cubic model was found to be quite successful in describing the growth pattern of Basmati and Non-Basmati Rice exports, based on selected diagnostic criteria and assumptions of residuals. Projection of Basmati and Non-Basmati Rice exports were found to be 5035.88 (‘000) MT, and 29269.82 (‘000) MT by 2026 respectively.
Keywords: Export, nonlinear, normality and randomness.

1. Introduction

“Basmati” is unique long-grain aromatic rice, which was majorly produced by the states of Haryana followed by Uttar Pradesh, Punjab, Rajasthan and Jammu & Kashmir. Haryana ranks first in Basmati Rice production with a share of 60%. The country has exported 4.55 million metric tonnes of Basmati Rice to the world for the worth of Rs. 38.52 thousand Crores (4787.50 US$ Mill.) during the year 2022-23. India accounts for over 70% of the world's basmati rice production and is the largest growing country globally. India is the leading exporter of Basmati Rice to the global market. (https://apeda.gov.in/).

The Non-Basmati Rice varieties are long and slender, some are short and thick, some are like beads, and some may be round. None have the same characteristics as basmati rice. Some names of non-basmati rice are shaped like basmati rice and PR, 104 IR8, IR 64, Masuri. (https://riceofindia.com/). It has been reported that there are 10000 varieties of rice and out of which the maximum number are in India. The country has exported 17.78 million metric tonnes of Non-Basmati rice to the world for the worth of Rs. 51.08 thousand Crores (6,355.74 USD Millions) during the year 2022-23. (https://apeda.gov.in/).

A similar kind of work done by Reddy et al. (2021), reported that the Cubic model was an appropriate model to fit the Prices and Arrivals of Turmeric in Duggirala Market. As per the report of Rankja et al. (2019), Logistic model for area under groundnut crop was found to be the best fitted model. Mishra et al. (2015), conducted a study on trend Analysis on wheat in India also revealed that cubic model was the best fitted model to forecast Production and yield of Wheat. Similar kind of report was obtained by Vulandari (2020), that the cubic model was appropriate to forecast rice yield in Wonogiri Regency in Central Java. The study of Abid et al. (2018), showed that the exponential model outperformed other models in predicting the potato area and production in Pakistan. Greeshma et al. (2017), studied on area and production of sugarcane in Coastal Andhra region of Andhra Pradesh, which revealed that the quadratic function was the best fitted model. As per the report of Kalaiselvi (2019), the Exponential model was found to be appropriate to forecast both area and production of Onion in Karnataka state. By keeping economic importance, present study had formulated to forecast exports of Basmatic and Non-basmati Rice through nonlinear regression models.

2. MATERIALS AND METHODS

Data pertaining to export of Basmati and Non-Basmati Rice in India was collected for period of 35 years as during 1987-2023, from secondary sources (APEDA website). With a view to identify the best pattern of export, the following statistical growth models were employed.

Where, Yt is the export (quantity) observed during the time t; a, b, c, d, are the parameters, and e is the error term. As in linear regression, non-linear regression (NLR) case also, parameter estimates can be obtained by the 'Method of least squares. However, the minimization of the residual sum of squares yields normal equations that are nonlinear in the parameters. Since it is not possible to solve nonlinear equations exactly, the next alternative is to obtain approximate analytic solutions by employing iterative procedures. (i) Linearization, (ii) Steepest decent method, (iii) Levenberg Marquardt technique. These methods are useful to obtain estimates of the unknown parameters of a non-linear regression model as reported by Pal and Mazumdar (2015).

Levenberg Marquardt (LM): Method is widely used for computing non-linear least squares. This method represents a compromise between the other two methods and combines successfully the best features of both, as in the sense that it almost always converges and does not 'slow down' at the latter part of the iterative process. Almost all the standard statistical packages have built-in programmes for estimating non-linear parameter estimates. The present statistical analysis was carried out by using the LM procedure available in SPSS software, which have NLR option to achieve the above task.

The LM iterative method requires specification of the initial estimates of each parameter of the models. Initial value specification is one of the toughest problems encountered in estimating parameters of nonlinear models. Inappropriate initial values will result in greater execution time, longer iteration and nonconvergence of the iteration. So, to start the iterative procedure by taking many sets of initial values to ensure global convergence. The Iterative procedure is stopped when the reduction between successive residual sums of squares is found to be negligibly low as per the report of Venugopalan and Shamasundaran (2003).

In this present study, the best model is identified by diagnostic criterion: Co-efficient of Determination-R2, Root Mean Squared Error-RMSE, Mean Absolute Error MAE and Mean Absolute Percentage Error-MAPE (Narnic et al. (2010)).

Furthermore, the main assumptions of randomness and normality of residuals are examined for each set of data by using the 'Run test 'and 'Shapiro wilk test' respectively (D'agostiono and Stephens (1986)).

3. RESULTS AND DISCUSSION

The average export of Basmati Rice in India during the study period was 1083.972 ('000) MT. Firstly, all selected models were tried to fit for Basmati Rice and their estimated parameters were depicted in Table-1. From this, it was observed that parameters were significant at 95 per cent asymptotic confidence interval. The main residual assumptions 'independence' and 'normality' of each selected model were examined by using the 'Run-test' and 'Shapiro-Wilk test', respectively and their probability values of test statistic were presented in Tables-1. It was revealed that the number of runs was found to be significant (p-value <0.05), in case of all models. Where, Shapiro-Wilk statistic was also non-significant (p-value > 0.05) for Quadratic and Cubic models. Hence, the assumptions of normal distribution and randomness nature of residuals were satisfied for these two models. Based on performance of model fit and assumptions of residuals, the cubic model was identified as suitable models for exports of Basmati Rice. Then goodness of fit for the fitted model viz., R2, RMSE, MAPE and MAE were computed to all models as shown in Table-1. From this, Cubic model was identified as better than Quadratic and exponential due to highest values of R2 and minimum values of remaining selected criterion. Hence, Cubic function was chosen for exports of Basmati Rice and forecasted for future as showed in Figure-1. From this, it was identified that actual and forecasted were very closely related and these exports will be going to rise in future which was projected as 5035.88 ('000) MT by 2026.

Table-1 Fitting of nonlinear regression models to India exports of basmati rice and Non-Basmati Rice

Exports of Basmati Rice										
		Goodness of Fit			**Tests for assumptions of Residual**			**Parameter Estimates**		
	R^2	**RMSE**	**MAE**	**MAPE**	**Shapiro Wilk test**	**Run test**	**a**	**B**	**c**	**d**
Exponential	0.952	588.61	362.7	18.68	<0.01	0.04	213.38*	0.097*		
Logarithmi	0.58	1035.8	940.24	107.9	0.007	<0.0	-1884.74*	1440.15*		

c	3					1				
Power	0.77	858.03	671.49	42.18	<0.010	<0.01	80.089*	1.035*		
Quadratic	0.939	396.45	289.65	19.88	0.502	0.006	185.578*	-6.683*	4.322*	
Cubic	**0.958**	**330.50**	**281.63**	**29.5**	**0.151**	**<0.01**	**873.411***	**-221.012***	**18.998***	**-0.27***
Exports of Non-Basmati										
Exponential	0.534	3234.7	1709.04	57.7	0.093	0.006	162.78*	0.13*		
Logarithmic	0.398	3059.75	2869.66	306.08	0.002	0.087	-4495.93*	3337.684*		
Power	0.63	1536.08	1231.65	76.55	<0.01	0.04	20.461*	1.678*		
Quadratic	0.737	3369.39	2384	144.21	0.689	0.001	1975.584*	-291.203*	17.738*	
Cubic	**0.819**	**3683.95**	**2511.15**	**183.23**	**0.094**	**0.087**	**-2066.09***	**968.188***	**-68.5***	**1.597***

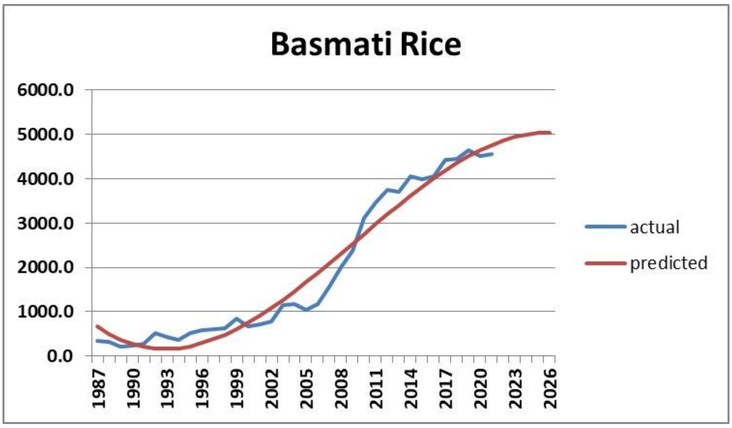

Figure-1: Graph of fitted Cubic model along with observed for Basmati Rice.

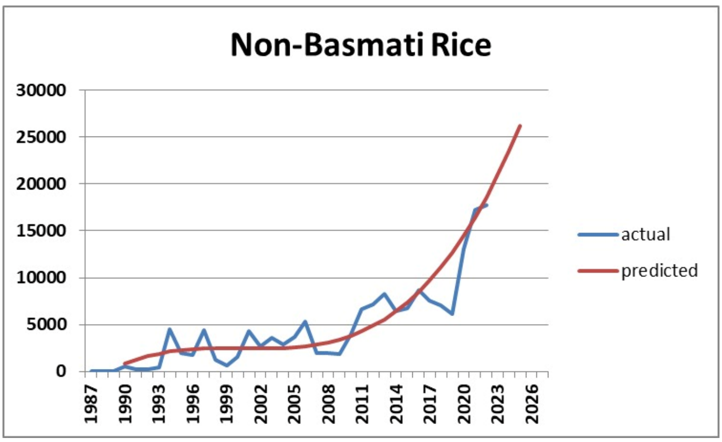

Figure-2: Graph of fitted Cubic model along with observed for Non-Basmati Rice.

The average export of Non-Basmati Rice from India during the study period was 716.535 ('000) MT. From Table-1, it was revealed that the number of runs was found to be significant (p-value <0.05) except for Logarithmic and Cubic models. Where, Shapiro-Wilk statistic was also non-significant (p-value > 0.05) for Exponential, Quadratic and Cubic models. The majority of statistics of goodness of fit showed that Cubic fit was faired and slightly better compared to Quadratic and Exponential fit. Actual and predicted exports of non-Basmati Rice was made by Cubic fit as showed in Figure-2 (Ramesh et al. 2015).

It was evident from the analysis that non-Basmati Rice was fluctuating more and fitting it to a non-linear form resulted in having higher deviations as compared to that of Basmati Rice. On the whole, it could be summarized that Cubic fit was better non-linear fits for non-Basmati Rice. So, Projection of non-Basmati Rice export was made by cubic function and it was found to be 29269.82 ('000) MT by 2026.

4. CONCLUSIONS:

The present investigation has been undertaken for export scenario of Basmati Rice and non-Basmati from India to evaluate the growth rates during the study period of 1987-2022. From this study, it was observed that Cubic model is found to be appropriate for describing trends in both Basmati Rice and Non-Basmati Rice. Finally, it has been concluded that in a few coming years, both of these exports will be going to increase. Timely management practices and effective extension systems are needed to create awareness among the farmers, regarding improved production technologies, various marketing and export channels to attain this quantity of export.

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