



Growth and diffusion dynamics of tractor in Punjab

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Over the last few decades, India has seen an incessant increase of tractor use as well as expansion in its domestic tractor manufacturing business, regardless of comparatively slow wage growth and a slow decline in the employment proportion of the agricultural sector. If the present situation is to be accounted, arguably as much as 90% of the country's farm area may be prepared for cultivation (Seed bed preparation, harrowing, leveling) by tractors (CSAM 2014). India at present scenario is the major tractor market in the world and annual market size of tractors sold in India is more than US\$5 billion per year (Bhattarai *et al.* 2017). Despite this India still employs 40% or more of its workforce in the agricultural sector, and the average farm size remains low, at only slightly more than 1 ha. Such growth was not anticipated by many of the review studies done in India, and in South Asia in general, until the late 1980s (Binswanger 1978, 1986; Singh 2015). Information is still relatively scarce on the growth of mechanization, including tractors, such as data disaggregated by different phases in the past, data on the heterogeneity of adoption patterns across regions, and information on policy approaches that were more (or less) likely to have been influential on mechanization growth at different historical phases.

Tractor density in Punjab for last five years (2011-15) is almost constant and hovering around the value of 125. This suggests that tractor diffusion might have achieved its carrying capacity, therefore it becomes necessary to insight the real situation with appropriate statistical modelling. A large number of mathematical forecasting models have been postulated to explain the time pattern of diffusion technology (Gupta and Jain 2012). Monomolecular nonlinear growth model is one such model among which generally provides

a realistic description of technological innovation diffusion process (Transtrum *et al.* 2010). Hence, this study was taken up to visualize the real tractor diffusion scenario in Punjab and to identify its saturation time point if not yet achieved.

Numbers of tractors in Punjab were collected from (Bhalla and Singh 2011) and Ministry of Transport and Road Highways, Govt. of India. Net sown area was collected from Ministry of Agriculture and Farmers' Welfare, Govt. of India. The Compound growth rate of tractor density was calculated for three different periods, i.e. pre-liberalization (1982 to 1992), liberalization (1993 to 2003) and recent decade (2003 to 2015) to see the variation in growth rate over the time. Annual compound growth rate was worked out as under

$$Y_t = ab^t e_t \quad (i)$$

where Y_t is tractor density in time period t ; t is time element that takes the values 1, 2, 3, N ; a , Intercept or Constant; b , Regression or trend coefficient which equals to $1+r$; r , Compound growth rate; e_t , error term.

The compound growth rate was obtained as

$$r = [(Antilog \text{ of } b) - 1] \times 100$$

' t ' test was applied to test the significance of ' b ', i.e. regression coefficient, which is-

$$t = \frac{|\hat{b}|}{\text{S.E. of } \hat{b}}$$

Monomolecular model was employed to study the gradual growth of tractor density over the period of time. It assumes a carrying capacity of K , i.e. the maximum level of tractor density (Number of tractor per thousand ha of net sown area). The rate of growth at any time is proportional to the resources yet to be achieved. If $N(t)$ denotes the tractor density at time t and r is the intrinsic growth rate, then the rate of growth of tractor density is given by

$$dN/dt = r(K-N),$$

where K is the carrying capacity.

Integrating and substituting the value of constant of integration, we get the final form of the model given by:

$$N(t) = K - (K - N_0) \exp(-rt)$$

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Hence the growth rate is proportional to the difference between the carrying capacity and the actual size.

As in linear regression, in non-linear case also, parameter estimates can be obtained by the 'Method of least squares'. However, minimization of residual sum of squares yield normal equations which are nonlinear in the parameters (Seber and Wild 2003). Since it is not possible to solve non-linear equations exactly, the next alternative is to obtain approximate analytic solutions by employing iterative procedures (Hawkins and Khan 2009). Four main methods of this kind are Linearization (or Taylor Series) Method, Steepest Descent Method, Gauss-Newton Method, and Levenberg-Marquardt's Method (LM) (Ma and Jiang 2007). Among the four, the LM method is the most powerful. Further, detailed analysis of the residuals is strongly recommended to decide about the suitability of a model. Three important assumptions made in the model are Errors are independent, Errors are normally distributed, and Error variances are constant (Homoscedasticity). These assumptions can be verified by examining the residuals. If the fitted model is correct, the residuals should exhibit tendencies that tend to confirm or at least should not exhibit a denial of the assumptions.

Time-series datasets, viz. tractor density of Punjab, India from 1982 to 2015 is considered. Punjab is chosen as it is one of the most mechanized states in India and accounts for the major tractor bought in India. It was found that CAGR was 4.58 during overall period under study (1982-2015) for Punjab but varies over different period as in early stage (pre-liberalization) of tractorization, growth rate was higher than recent decade and we can conclude that most of the potential tractor market has been achieved in Punjab as growth rate in very low but statistically significant. Though, India as a whole still has booming market potential as compound growth rate was less compared to earlier periods but still at par and statistically significant.

Therefore, it becomes valid and justified reason to find out ceiling point of tractor density for Punjab by choosing appropriate diffusion model.

The available data was fitted using SAS software 9.4 available at ICAR-IASRI using PROC NLIN statement. For estimation of the parameters we made use of the Levenberg-Marquardt's method. The fitted model and ANOVA table

Table 1 Compound annual growth rate of Tractor density

State	1982– 1992	1993– 2003	2004– 2015	Overall (1982– 2015)
Punjab	9.55	3.58	1.47	4.58
India	10.19	8.34	7.15	7.95

Table 2 Estimated parameters of the Monomolecular model

Parameter	Estimate	Approx Std Error	Approximate 95% Confidence Limits	
N_0	4.9700	1.7969	1.3141	8.6259
r	0.0440	0.00345	0.0370	0.0510
K	162.9	6.2562	150.2	175.7

is given below:

Further, from the estimated value of carrying capacity, K , as 163, we can infer that Punjab state will reach 90% of carrying capacity in the year 2032. The forecast values of the tractor density from 2016-2025 are approximately 131, 132, 133, 135, 136, 137, 138, 139, 140, and 141. The computed values of Cox Stuart and Mann-Kendall rank test statistics are 11 and -0.8445 with p-values as 0.4807 and 0.3984 respectively, which implies that the residuals are random and there is nothing more in the data which is not explained by the model under consideration. Further, the computed Shapiro Wilk statistic of 0.98 implies normality of the residuals. We also can infer about the homoscedasticity of errors from Breusch-Pagan test. Taking all this into consideration, we can infer that the fitted monomolecular model is appropriate for the data under consideration.

This study conducted a simple assessment of growth and diffusion of tractor in Punjab state of India. Our assessment suggests that potential of tractor market in Punjab will be achieved 90 per cent of carrying capacity in the year 2032. The estimated value of carrying capacity approximately 163 tractors in per 1000 hectare of net sown area.

SUMMARY

Over the last few decades, India has seen an incessant increase of tractor use as well as expansion in its domestic tractor manufacturing industry, in spite of comparatively slow wage growth and a slow decline in the employment share of the agricultural sector. If the present situation is to be accounted, arguably as much as 90% of the country's farm area may be prepared by tractors. Monomolecular nonlinear growth model methodology was applied to Punjab's tractor density time-series data to capture the diffusion of tractor. Levenberg-Marquardt iterative method was applied with the help of SAS by using PROC NLIN statement and the obtained results show that the model is a good fit for the data under consideration. Further, Compound annual growth rate (CAGR) of tractor density was also calculated to infer about the changes in tractor density over the time (1982–2015) and found that CAGR was high during 80s and 90s than 2000s. Despite of low growth in last decade, Punjab is expected to have more adopters of tractor in coming years. From this empirical study, we also infer that 90 per cent tractor penetration will be achieved by 2032 in Punjab.

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