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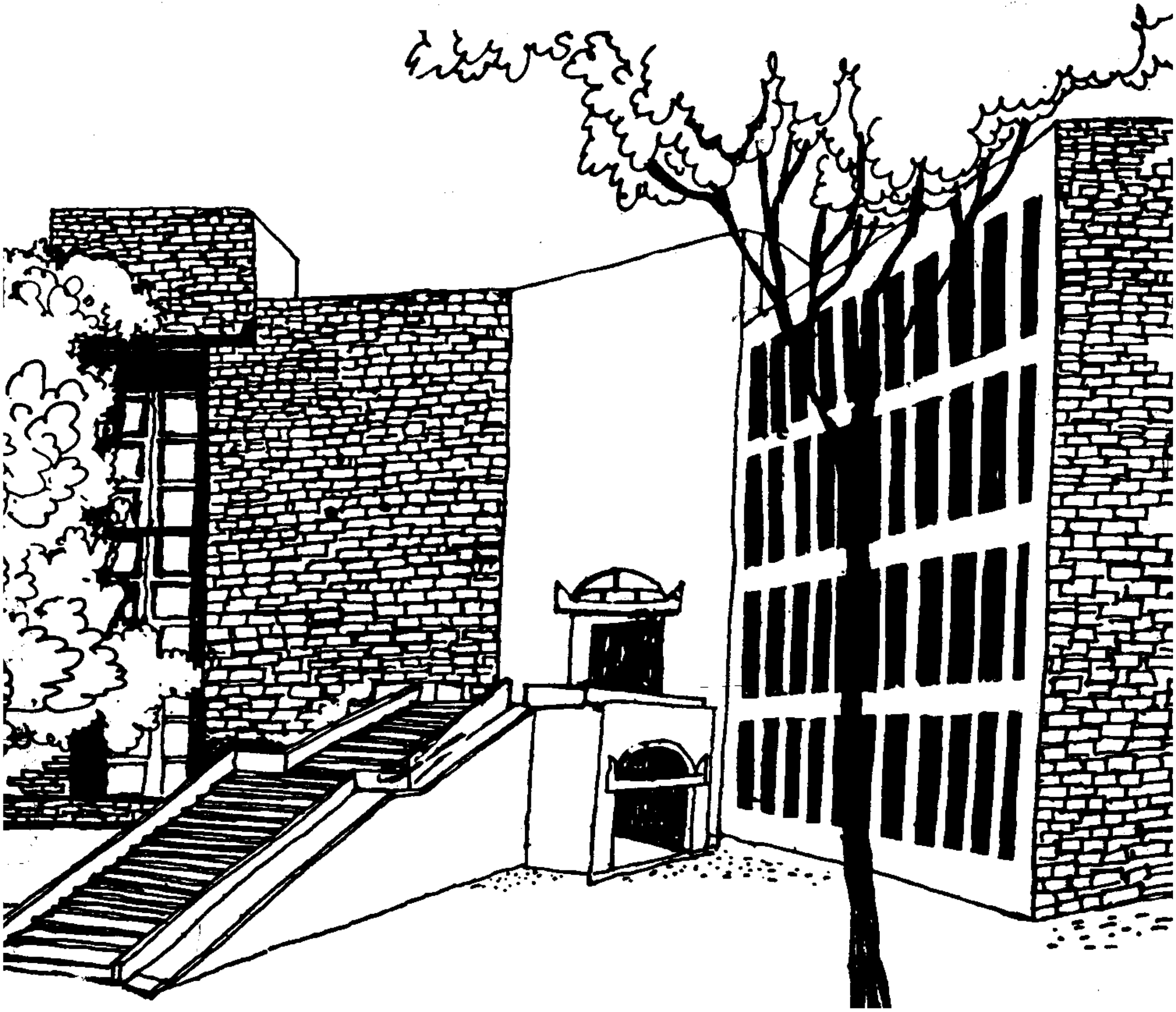

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DEMAND FOR FARM TRACTORS: TWO MODELS

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Abstract

Demand prediction for farm tractors is of interest to industry and government. Two different models were developed earlier. One termed a causal model, was similar to a model of a process driven by potential difference. The other was based on time series analysis. In this paper the performance of these is examined over a ten-year span, and their special merits discussed.

Introduction

Sharan and Kayastha[1] studied the pattern of growth of four-wheel tractors on Indian farms. That work was done in the context where prediction of future demand was desired by industry and government. But the procedures to predict, available then were mostly unsatisfactory. Some were based on regression[2] and some on other trend fitting approaches.[3] Sharan and Kayastha (SK) made a departure from these approaches and proposed a causal model.

That model, summarised below, is essentially driven by the potential, much as a diffusion process. To help those interested only in short term prediction of one or two years in advance (industry for instance), SK also proposed another model based on analysis of time series data of sales.

Both these works were done around the year, 1988. The aim of this paper is to compare the predictions from the two models with the actual data available now. The merits of the two approaches are briefly discussed. Since details of the two models are available elsewhere[1],[4], we shall give here only a brief outline.

Causal Model

Change in the stock of tractors in the country in a given interval of time occurs in two ways. New tractors are purchased by the farmers adding to the stock. Tractors reaching the end of their working life are salvaged, reducing the stock. Those salvaging, may buy a replacement. If it is assumed that the tractors salvaged are replaced **necessarily and without delay** (in practice it would mean within a year), the net change will consist only of those buying tractors for the first time, during that period.

The core of this model is the postulate that the rate at which first time buyers emerge is proportional to the number of farmers who do not yet own a tractor, i.e difference between the ultimate potential and the number of owners at present.

Let

t	time (year)
N(t)	tractors present at time t (no)
H	holdings of > 4 ha.(no.); it is visualised that these constitute the ultimate potential; assumed constant (10.4 million)
I(t)	proportion of cultivated area which is irrigated (fraction), values available from Statistical Abstract of India; here 0.6 has been used for the holdings of more than 4 ha.
M(t)	effective potential, equal to (H*I(t)) i.e. holdings of 4 ha. and above that are irrigated (no); in general it may vary with time but has been treated as constant here
s(t)	annual sales (no/year)
c(t)	credit allocation by banks (all commercial and cooperative) for farm mechanisation (Rs/year)
p(t)	weighted average price of tractors prevailing during the year (Rs/unit)
k	an empirical factor
L	working life of tractor (years)
f(t)	demand by first-time-buyers (no/year)

$r(t)$ demand by replacement buyers (no/year)

$j(t)$ obsolescence rate (no/year) equal to the number of tractor purchased 'L' years ago; Or equal to a realistic fixed proportion of $N(t)$, coefficient of proportionality can be based on average life

The rate of growth can be written as

$$\frac{dN(t)}{dt} = s(t) - j(t) \tag{1}$$

since $s(t) = f(t) + r(t)$, and $r(t) = j(t)$ under assumption of immediate and necessary replacement,

$$\frac{dN(t)}{dt} = f(t)$$

And $f(t)$ can be expressed as

$$f(t) = k * (M(t) - N(t)) .$$

That is, rate of emergence of new buyers is proportional to the unexhausted potential. Using this,

$$\frac{dN(t)}{dt} = k * (M(t) - N(t)) \tag{2}$$

With time interval of one year, this can be written in the form of a difference equation

$$N(t+1) = N(t) + k * (M(t) - N(t)) \tag{3}$$

Factor 'k' can be interpreted as a facilitating factor which determines the rate at which the unexhausted potential will diminish. It will be influenced positively by all those factors that facilitate diffusion. Most important among such factors will be the availability of credit from banks. There are also factors that will tend to reduce 'k'. Most important of these may be the price of tractors. Using the past data on price and credit, SK determined the following form for 'k'

$$k = 9.2*10^{-3} + 1.52*10^{-7} \frac{c(t)}{p(t)}$$

Accordingly,

$$N(t+1) = N(t) + \left[9.2*10^{-3} + 1.52*10^{-7} \frac{c(t)}{p(t)}\right] * (M(t) - N(t)) \quad \textbf{(4)}$$

the initial value of N, expected credit, c(t) and price, p(t) regime; and the estimate effective potential M, the growth trajectory can be predicted using equation-4. Demand by first time buyers, f(t), can be obtained by differencing the values of N(t). Total annual demand, s(t), can be obtained by adding to, f(t), the replacement, r(t), purchases. Latter, as indicated before, could either be a fraction of N(t) or equal to the sales of, L, periods ago as done here. Yearly predictions were made for the period, 1986-1995 using the following inputs.

M = 6 x 10^6 (constant); N (1985) = 624527
C (1985) = Rs.5191 million; growing @ 15% per year
p (1985) = Rs.78500; growing @ 7% per year

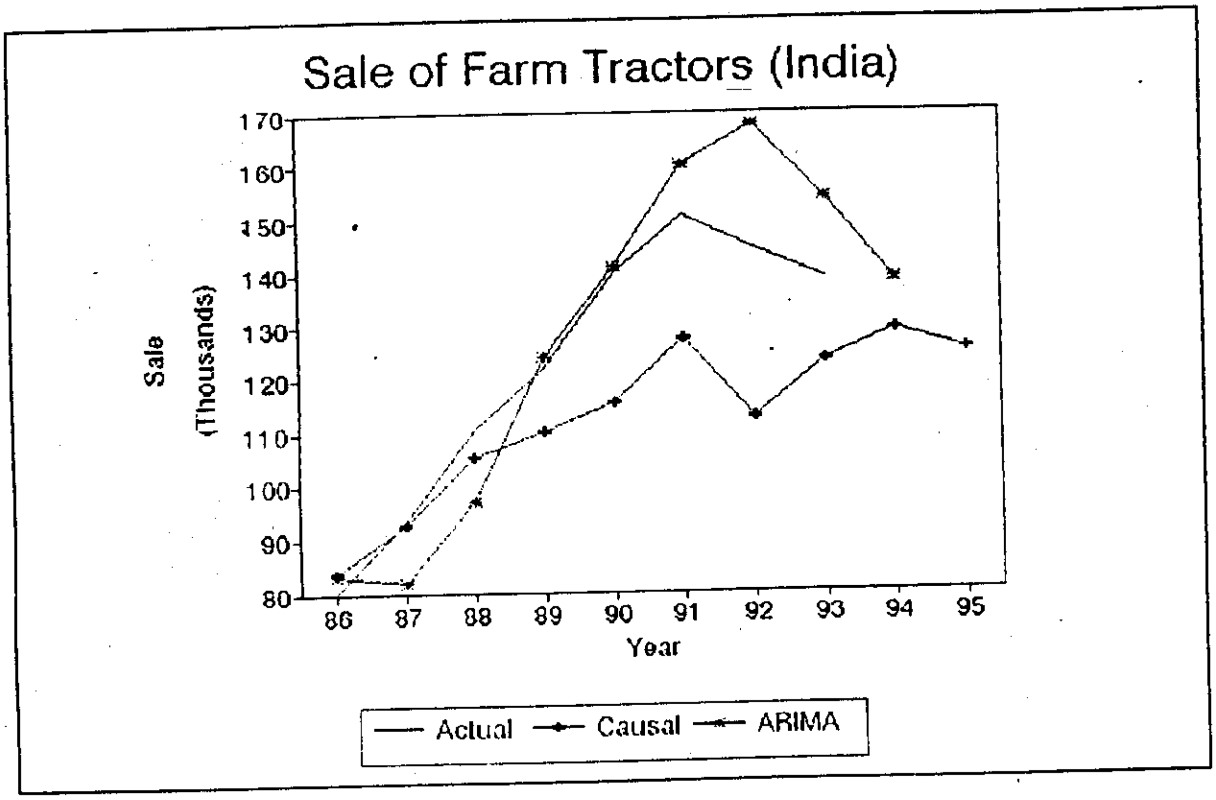
Data on credit allocation for farm mechanisation is not easily available. References[5],[6] give data on medium and long term loans to farm sector which includes credit for tractors. From 1985 to 1989 it has grown at the compound rate of 15% per year. The data for subsequent years is not available yet. We have therefore assumed that the 15% growth rate held for the entire span (1985-95). The weighted average price of tractor was found to have increased at the compound rate of 7% per year between 1985-95.

Year	Actual Sales (no)	Predicted		Deviation	
		Causal Model (no)	ARIMA Model (no)	Causal y (%)	ARIMA (%)
1986	80164	83758	82885	4	3
1987	93157	92590	81935	-1	-12
1988	110323	105392	97070	-5	-12
1989	122098	110202	124061	-11	2
1990	139831	115420	141041	-21	1
1991	150582	127242	159937	-18	6
1992	144330	112471	167592	-28	16
1993	138716	123261	153894	-13	11
1994		128810	138591		
1995		124933			

Source: Sales data from A E TODAY Vol. 18 (1&2), 1994; Sales data for 1982-85 are 63073, 74318, 80317, 76886.

Table-1 gives the annual sales as predicted by equation-4 and also the actual data. **Figure-1** shows the two graphically. It is interesting to note that even though the magnitudes differ, the general form of the two curves is similar. The predictions are close to the actual up to the year 1989, with deviations of less than 11 per cent. Deviations have increased after that.

Recall that we did not get the actual credit allocation data for the years after 1989. The possibility exists that credit allocations rose at a faster rate than assumed (15 per cent). We will have to await publication of credit data to confirm this. Alternately, the model may need to be modified.



Until further verification, it may be advisable to use the causal model for predictions of only about five-year span at a time.

Time Series Analysis

Lack of credit and price data in advance limits the utility of **equation-4**. It would be useful to have an alternative approach. SK analysed the time series of annual sales (1956-85) to determine the underlying structure. Time series models include auto-regressive (AR), moving average (MA), auto-regressive moving average (ARMA) and auto-regressive integrated moving average (ARIMA).

AR, MA and ARMA are suitable for stationary series. When mean is changing with time, ARIMA can be used. ARIMA removes stochastic trend from a non-stationary series by differencing. After removing non-stationarity the resultant series ~~is~~ analysed to identify suitable AR, MA or ARMA models.[7]

ARIMA model

$$B(O)^p V^d z(t) = B(V)^q a(t)$$

B	backshift operator
$B(O)^p$	backshift operator of AR process of order p
$B(V)^q$	backshift operator of MA process of order q
V	difference operator
d	degree of differencing
z(t)	estimated time series
a(t)	white noise (mean zero and variance one)
s(t)	series of actual sales data

When d=0, the model becomes ARMA (p,q) model. In addition if B(V)=1 the model is AR (p). If d=0 and B(O)=1 then model is MA(q).

Sequence of differences between sales of two consecutive years was plotted on a graph. Visual examination suggested that both mean and variance were changing (increasing) with time. Thus, the series appeared to be non-stationary. Original series, s(t), was then transformed.

$$z(t) = \ln s(t)$$

Visual examination of the plot of first differences of the transformed series suggested that it could be stationary. Treating it as such various models were checked for suitability. ARIMA (2,2,0) model was eventually found suitable and is given below.

$$Z(t) = 1.27\ Z(t-1) + 0.11\ Z(t-2) - 0.03\ Z(t-3) - 0.35\ Z(t-4) + a(t) \quad (5)$$

where a(t) is white noise

Estimated sales series is recovered by inversion

$$s(t) = \text{antilog}\ Z(t) \quad (6)$$

Yearly demand was predicted using **equations (5 & 6)** for the period, 1986-1995. These are shown in **Table-1**. Unlike in the causal model, the predictions using **equation-5** were made for just one year ahead at a time. Each new value used the previous four actual values. Thus, the predicted sales for 1986, used the actual values of 1982, 1983, 1984 and 1985 which are shown at the bottom of **Table-1**.

The predicted values are shown in **Figure-1**. Again the form of the predicted and the actual sales curves are broadly similar. In fact the deviations are smaller in this case than the causal model. ARIMA predicts that the demand in 1994-95 will be 139000 units, virtually the same as the previous year 1993-94. ARIMA model should be used only for one-year-ahead predictions, otherwise errors accumulate.

Conclusion

Industry usually desires short term predictions for use in its production planning. The ARIMA model appears to be satisfactory in making one-year-ahead forecast of demand.

Government on the other hand usually desires long term prediction in order to evolve broad policies related to industrial capacity, licensing etc. The causal model is more suited for long term predictions. The present model appears to be of right form. It predicts well for the period for which credit and price regime are known. Perhaps it should be used to predict for only about five years at a time. For, the credit and price regimes might undergo significant changes in longer spans.

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