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Analysis of Area Decision in the Supply Response Model of Indian Tea

The present concern in the Indian tea industry is to raise production in order to meet the domestic and export requirements. The internal consumption of tea has been rising so rapidly that it is expected to offset the supply by the turn of this century. During the period 1974-83, the domestic consumption of tea[1] had increased at an average rate of 5.41 per cent per annum (against 2.16 per cent per annum at international level) while the domestic production had increased by only 2.80 per cent per annum.

The rising domestic demand has not only caused a steep rise in domestic tea prices, the rate of growth of which had doubled from 6.12 per cent in 1964-74 to 11.64 per cent in 1974-84, but also reduced the share of exports in total production from 60 per cent to 40 per cent during 1960-80. Consequently, the exports had stagnated at around 200 thousand tonnes for the past two decades. This stagnation in exports had reduced India's share in world tea exports from 37 per cent in 1960 to 22 per cent in 1985. Looking at the London auction prices for Indian tea which had a growth rate of 16.88 per cent per annum, it appears that the main reason behind our stagnated exports is not lack of demand, but shortage of supply.

The rise in domestic and world tea prices for Indian tea though appears profitable in the light of short-run inelastic demand, may prove detrimental in the long run, where a switch over to other substitutes or other non-Indian teas cannot be ruled out.

To meet the domestic requirement and export targets for the year 2000 A.D., the country requires an estimated (Tea Board, 1983 *b*) increase in production of 27 million kg. of tea per annum. Given the slow growth in output and the existing supply conditions, it may be a herculean task.

Tea, being a perennial crop, takes at least three years after planting to start yielding. It takes another 10 to 15 years to reach the peak level yield. Then after a period of another 15 to 20 years of peak yields, the yields start declining around the age of 40 to 50 years.[2] At present, about 53 per cent of the total area consists of bushes with age above 40 years. As a result, the yield rates of Indian tea (1,300 to 1,600 kg./hectare) are low compared to those of other countries like Kenya, Japan and U.S.S.R. with more than 1,700 kg./hectare. Inadequate infilling or low density of bushes per hectare is another reason for the low yield per hectare.

The large number of old bushes indicates that replanting has been neglected. Replanting has indeed been declining at 1.51 per cent per annum during the last two decades while the stipulated rate is around 2 per cent. In 1984, only 0.6 per cent of the total area was replanted.

The low replanting rates are as much due to the producer's desire to reap the short-run profits, as due to their financial constraints. By uprooting the old but still productive bushes the producer incurs a loss which cannot be recovered until the next 10 to 15 years. Besides the long gestation periods, augmentation of funds for replanting investment is also a problem. The motivational limitations accentuated by financial constraints have impaired the growth of production. The rise of incidence of sick gardens in recent times signifies the outcome of these constraints.

The adoption of new, high-yielding, short duration varieties and providing loans and subsidies[3] to reduce the financial burdens, would go a long way in encouraging replanting.

Nevertheless, the ultimate success of such measures depends on the producer's awareness, capacity to generate internal funds and finally and more importantly, on his perception of the present and future market conditions. The supply response studies, which help in identifying the factors responsible for output changes, have been a powerful instrument in formulating and evaluating output promotion policies.

In the Indian context, there are a few such studies which have mainly concentrated on 'total area' (including all components) and yield responses (Rajagopalan *et al.*, 1971; Mitra, 1987). Total area response involves aggregation of its components, and hence the total area response impede the analysis of core problems. More importantly, the long-run determinants of output, *viz.*, new planting and replanting decisions, need to be analysed separately in order to identify the factors influencing them. Ram and Chowdhury (1978) did estimate the responses of these plantings to changes in prices. However, further analysis was aborted due to the negative and statistically not significant price coefficients in the results. The recent study of Misra (1986) analyses the aggregate responses of all plantings which obscure their individual responses.

With this background, the present study attempts to estimate the response surfaces for new plantings, replantings, replacement plantings, 'total area' and yield per hectare. For this purpose, time-series data on these variables for all-India for the period 1960-82 are collected from "Tea Statistics" published by the Tea Board, Calcutta. The estimation of expected prices and risk due to prices is based on the average Indian auction prices published in Tea Statistics (J. Thomas and Co. Ltd., 1984).

AREA RESPONSE SURFACE

The total area that a producer desires to hold in a year depends mainly on his future price (proxy for profits) expectations, the expected yield rates and the risk due to prices. Thus the desired 'total area' (A_t^d) is specified as a function of expected prices (P_t^e), expected yield rate (Y_t^e) and the risk factor (R_t) as:

$$A_t^d = \alpha_0 + \alpha_1 P_t^e + \alpha_2 Y_t^e + \alpha_3 R_t + U_t \qquad \text{.... (1)}$$

Using the Nerlovian adjustment lag model, equation (1) is transformed as:

$$A_t = \alpha_0' + \alpha_1' P_t^e + \alpha_2' Y_t^e + \alpha_3' R_t + \alpha_4' A_{t-1} + U_t \qquad \text{.... (2)}$$

where $\alpha_i' = \lambda \alpha_i$ for i = 0, 1, 2, 3

$\alpha_4' = 1 - \lambda$; λ = adjustment lag coefficient and $U_t' = \lambda U_t$.

YIELD RESPONSE SURFACES

The desired change in output could also be realised by changing the yield per hectare. Yield may be changed in the short run as well as in the long run. Thus two separate equations are specified for short-run and long-run yield responses.

The short-run equation is specified as a function of current and expected prices (P_t, P_t^e), risk due to prices (R_t) as well as a trend variable (T) to capture technology change as:

$$Y_t = \beta_0 + \beta_1 P_t + \beta_2 P_t^e + \beta_3 R_t + \beta_4 T + V_t \quad \text{.... (3)}$$

The long-run yield responses mainly depend on the changing age distribution which in turn depends on the new planting and replanting decisions. Thus the long-run yield is specified as a function of 'total area' in the preceding year (A_{t-1}), planned uprootings (using replacement plantings, as a proxy) (RPC_{t-1}) and 'total plantings' (includes new plantings, replanting and replacement planting areas: NRR) in the years (t-5) and (t-10) (to estimate the impact of age distribution), the lagged yield variable (Y_{t-1}) and the trend variable (T) (to measure the management factors). The equation is as follows:

$$Y_t = \gamma_0 + \gamma_1 T + \gamma_2 A_{t-1} + \gamma_3 RPC_{t-1} + \gamma_4 NRR_{t-5} + \gamma_5 NRR_{t-10}$$

$$+ \gamma_6 Y_{t-1} + \gamma_7 P_t^e + \gamma_8 R_t + W_t \quad \text{.... (4)}$$

RESPONSE SURFACES FOR DIFFERENT COMPONENTS OF 'TOTAL AREA'

New plantings, replantings and replacement plantings are the principal components determining the 'total area' as well as 'long-run yield rates'. Thus their analysis is crucial to the supply problem. The area newly planted (N_t) is specified as a function of expected prices (P_t^e), lagged 'total area' (A_{t-1}), lagged area newly planted (N_{t-1}), expected uprooting (RPC_{t-1}), expected yield rates (Y_t^e) and the risk due to prices (R_t) as:

$$N_t = \delta_0 + \delta_1 P_t^e + \delta_2 A_{t-1} + \delta_3 N_{t-1} + \delta_4 RPC_{t-1} + \delta_5 Y_t^e + \delta_6 R_t + Z_{1t} \quad \text{.... (5)}$$

Whereas the area replanted (RP_t) and area replacement planted (RPC_t) are specified as functions of lagged prices (P_t), lagged removals[4] (RM_{t-1}), expected yield rates (Y_t^e) and risk due to prices in the following forms:

$$RP_t = \varepsilon_0 + \varepsilon_1 P_{t-1} + \varepsilon_2 RM_{t-1} + \varepsilon_3 Y_t^e + \varepsilon_4 R_t + Z_{2t} \quad \text{.... (6)}$$

$$RPC_t = \phi_0 + \phi_1 P_{t-1} + \phi_2 RM_{t-1} + \phi_3 Y_t^e + \phi_4 R_t + Z_{3t} \quad \text{.... (7)}$$

The variable representing expected yield is measured by the average of preceding three years' yields per hectare. Expected price is measured as an average of preceding eight years' prices. This measure is adopted on the basis of preliminary analysis as described below. The function

$$A_t = a_i + b_i P_{t-i} + c_i A_{t-i} + U_{ti}$$

is estimated for each value of i = 1, 2,....10

These provide ten different estimates of price and area coefficients, for ten lags separately. In a single equation only one lagged variable each of P_t and A_t is included in order to exclude the possibility of multicollinearity.

The estimates thus obtained for P_{t-i} and A_{t-i} coefficients showed opposite trends in their magnitudes. While the coefficients of P_{t-i} increased with an increase in i, those of A_{t-i} declined. But after i = 8, the trends in coefficients reversed.

In order to test for the consistency of these results, instead of changing both the price and area lags simultaneously, the lag for area is fixed at '1'. By changing the lag value of P_{t-i}, the following function has been estimated ten times:

$$A_t = a_i + b_i P_{t-i} + c_i A_{t-i} + U_{ti},$$

each time using a different lag for prices. The results thus obtained were consistent with those of earlier analysis. Therefore, the relevant lag for prices, which is important in expectation formations, has been deduced to be eight years. By the same logic, risk due to prices has been measured as the 'standard deviation' as well as 'coefficent of variation' of preceding eight years' prices.[5]

THE SUPPLY RESPONSE OF TEA

The total supply response of tea can be divided into those of area and yield responses. The aggregate 'area' variable can be further studied in terms of responses of its components like area newly planted, replanted and replacement planted. This analysis utilises the popular econometric computer packages like RATS and MULREG. The results of response are important in understanding the long-run yield responses.

Total Area Response

Total area response function is estimated as:

$$A_t = \underset{(1.90)}{25148.5^{*}} + \underset{(19.95)}{0.91^{***}} A_{t-1} + \underset{(4.09)}{1572.49^{***}} P_t^{*} - \underset{(2.23)}{1399.79^{***}} \sigma P_t$$

$R^2 = 0.99$ $F = 844.59$ D-W = 1.596(NA)

Figures in parentheses are t-ratios.
* and *** denote levels of significance at 10 per cent and 1 per cent respectively.
NA = No auto-correlation.

The 'total area' is found to be significantly responsive to all variables included in the equation except the expected yield. In the case of tea production, when the variations in yield levels are small, the area decisions may not depend on the yield expectations, in which case the market factors like expected prices and risk due to prices play a major role. The short-run elasticity of total area at 3 per cent (to expected prices) and -0.4 per cent (to risk due to prices) is quite low compared to their long-run values at 34 per cent and 5 per cent respectively. The estimate of adjustment lag (given by the inverse of λ) is found to be 0.09, which implies that in one year only 9 per cent of the total desired change in 'area' is realised.[6] These responses of total area are only partial indicators of the output response. The other part of the output response could be in the form of yield responses.

Yield Responses

Short-run response surface is given by:

$$Y_t = \underset{(29.81)}{1026.32^{***}} + \underset{(8.12)}{23.04^{***}} T + \underset{(2.34)}{14.62^{**}} P_t - \underset{(4.28)}{35.80^{***}} P_t^{*} + \underset{(9.05)}{51.70^{***}} \sigma p_t$$

$R^2 = 0.97$ $F = 147.23$ D-W = 2.01 (NA).

Figures in parentheses are t-ratios.
** and *** denote levels of significance at 5 per cent and 1 per cent respectively.
NA = No auto-correlation.

The short-run yield responses to expected prices and the price risk (σp_t) are found to be in contrast to those of 'total area'. The short-run price (P_t) elasticity of yield at 12 per cent per annum is much higher than that of 'total area'. Table I presents the estimates of elasticities of area and yield to prices and risk. The short-run yield increases can be obtained by resorting to intensive (or coarse) plucking. When the prices are expected to rise, coarse plucking may have an adverse impact on future returns (by impairing the quality image or by actually reducing the future yields). Thus when the prices are expected to rise, short-run yield may fall and vice versa. Besides, these measures for increasing long-run output like uprooting the old bushes with a view to replant them, are undertaken in response to expected prices. These measures also affect the short-run yield responses adversely, in which case a positive long-run yield response to expected prices could be anticipated.

TABLE I. ESTIMATES OF ELASTICITIES OF AREA AND YIELD TO PRICES AND RISK

	Yield		Area	
Parameter (1)	Short run (2)	Long run (3)	Short run (4)	Long run (5)
Price	12	16	2.99	33.5
Risk	13	3	-0.004	-0.048

Long-Run Yield Responses

In addition to prices, risk and technology, the long-run yield is influenced by appropriate filling (total of new planting, replanting and replacement planting) and lagged replacement. The estimated regression equation is given by:

$$\begin{aligned} \ln Y = \; & -0.13^{***} \ln NRR_{t-5} \quad -0.27^{***} \ln NRR_{t-10} \quad -0.11^{***} \ln RPC_{t-1} \\ & \;\; (3.98) \qquad\qquad\qquad (9.15) \qquad\qquad\qquad (6.72) \\ & + 0.32^{***} \ln T \qquad + 0.16^{**} \ln P_t \qquad + 0.03^{***} \ln CVT_t \\ & \;\; (7.35) \qquad\qquad\qquad (2.64) \qquad\qquad\qquad (4.14) \end{aligned}$$

$R^2 = 0.99$ $\quad F = 158.77$ $\quad$ D-W = 1.266 (IC).

Figures in parentheses are t-ratios.
** and *** denote levels of significance at 5 per cent and 1 per cent respectively.
IC = Inconclusive.

As expected, the long-run yield has a high positive elasticity of 16 per cent to expected prices, indicating its significant importance. As in the case of short-run yield, the risk due to prices (CVP_t) is also found to have a positive impact on long-run yield. Thus the overall response of yield under price risk situations is found to be positive, implying that there is a level of variation in prices beyond and below which there will be a change in yield. There may be an increase in yield rates when price variation crosses that level and there may be a decline when it falls below the level. In effect, price variation over a particular level induces the producer to increase yield levels. But the capacity to increase the yield per hectare, without impairing the quality of tea, depends on the age distribution of the bushes, which in turn depends on various planting decisions.

Planting Decision Responses

The new planting equation is given by:

$$\ln N_t = \underset{(3.84)}{225.18^{***}} + \underset{(2.08)}{1.69^{**}} \ln P_t^e + \underset{(2.11)}{4.21^{*}} \ln Y_t + \underset{(0.96)}{0.18} \ln RPC_{t-1}$$

$$+ \underset{(1.92)}{0.37^{*}} \ln N_{t-1} - \underset{(3.72)}{19.92^{***}} \ln A_{t-1} - \underset{(2.06)}{0.35^{*}} \ln \sigma p_t$$

$R^2 = 0.63$ $F = 4.23$ $D\text{-}W = 1.329$ (IC).

Figures in parentheses are t-ratios.
*, ** and *** denote levels of significance at 10 per cent, 5 per cent and 1 per cent respectively.
IC = Inconclusive.

It is seen that the lagged total area has a high negative impact on the area extended or area newly planted. This is because, when there is already a large area under the crop, the need and desire for bringing new areas under the crop may be less. Besides, with increase in total area the availability of suitable land for extension gets limited, thus new plantings may be discouraged (Table II).

TABLE II. ESTIMATES OF ELASTICITIES OF NEW PLANTING AND REPLACEMENT PLANTING

Parameter (1)	New planting (2)	Replacement (3)	Replacement planting (4)
Price	169.0	-	33.6
Risk	-35.0	-	-
Removal	-	26.4	20.1

Like 'total area', area newly planted responds positively to expected price and negatively to risk due to prices. Both these elasticities are much higher at 169 per cent and 35 per cent respectively, compared to the corresponding ones for 'total area'. Thus it can be seen that area newly planted may be a better measure of output response than 'total area'. These responses of area newly planted coupled with those of area replanted or replacement planted provide better insights into the 'area' response.

Replanting and Replacement Planting Responses

The estimated values of regression coefficients for replanting and replacement planting decisions are given in Table III. Compared to new plantings, area replanted is found to be non-responsive to prices and risk due to prices. Its major determinant appears to be the lagged removals, though expected yield also has a negative and significant impact. Replacement planted area emerges to be relatively better responsive to price factors.

Not only lagged prices, but also lagged removals and expected yield are found to have a greater impact on replacement plantings than on replantings. Replacement plantings (in anticipation of uprootings) take place on virgin soils in contrast to replantings which are carried on soils from which old bushes are removed. Therefore, the former do not involve loss in output and hence may respond better to prices as well as expected yield levels. Though falling yield levels cause an increase in replantings and replacement plantings, their elasticities are not very high.

TABLE III. REGRESSION ANALYSIS OF REPLANTING AND REPLACEMENT PLANTING

Model (1)	Intercept (2)	P_{t-1} (3)	Y_t^* (4)	RM_{t-1} (5)	R^2 (6)	F (7)	D-W (8)
Replanting	853.94***	27.79	-0.678*	0.47***	0.43	4.26	1.46
	(2.92)	(1.69)	(1.96)	(2.94)			(IC)
Replacement planting	3507.68***	59.09*	-2.42***	0.135***	0.76	18.40	1.89
	(6.16)	(1.84)	(3.58)	(4.36)			(NA)

Figures in parentheses are t-ratios.
D-W = Durbin-Watson test of coefficient for auto-correlation.
IC = Inconclusive.
NA = No auto-correlation.
*, ** and *** denote levels of significance at 10 per cent, 5 per cent and 1 per cent respectively.

It is obvious from the analysis that all the three types of plantings not only differ in magnitudes of their responses to various factors but also in directions. The responses of these three components in turn differ greatly from those of 'total area'.

CONCLUSION

The present tea scenario in the country is serious enough to call for an appropriate development strategy. The paper has studied the supply response behaviour of tea in terms of the area and yield responses. Different components of 'total area' are analysed individually. The study empirically determines the appropriate lag for prices that is relevant in expectation formations. The analysis has clearly brought out the need for studying different types of area decisions separately. The results reveal that removals have an impact on replanting and replacement planting decisions only, whereas expected prices and risk due to prices are found to have significant impact on area newly planted. It is also clear from the analysis that the scope for extension is limited by the availability of suitable land for tea cultivation. Yield per hectare has revealed higher responses to expected prices and risk due to prices, as compared to 'total area'. Risk due to prices has a relatively small but a positive impact on yield per hectare, and has negative impact on 'total area' or 'area newly planted', thus indicating a less than favourable overall impact. The stability of prices emerges as a crucial factor for maintaining stable growth of tea production. The presence of a large number of very old bushes reduces the production in future. Therefore, in spite of hesitation by the planters due to loss of short-term profit, the new planting and replacement planting will contribute significantly in the long run.

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NOTES

1. Consumption figures estimated by the Indian Institute of Management, Calcutta are published in Tea Board (1987, p. 129).

2. The gestation period is fixed for a particular variety of tea plant, but may vary little among different varieties.

3. The Development Bank like the National Bank for Agriculture and Rural Development and its subsidiaries, provides loans for replanting purposes, with a view to share the financial burden whereas the subsidies are mainly to encourage planters to take up the desired steps.

4. Data on removals are not available, therefore, this variable is derived as a residual using the total area, area newly planted, replanted and replacement planted as:

$A_t = A_{t-1} + N_t + RP_t + RPC_t - RM_t$

5. Equations (2) to (7) are estimated using the two measures of risk, *viz.*, the standard deviation and the coefficient of variation separately. Both linear as well as curvilinear forms of these functions are estimated and the 'best' equation for each of the dependent variables, based on statistical criteria, is presented for discussion. The elasticities derived from the estimates are given in Table I.

6. λ is derived from α'_4, the coefficient of A_{t-1} as $\alpha'_4 = 1 - \lambda$, therefore $\lambda = 1 - \alpha'_4$.

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