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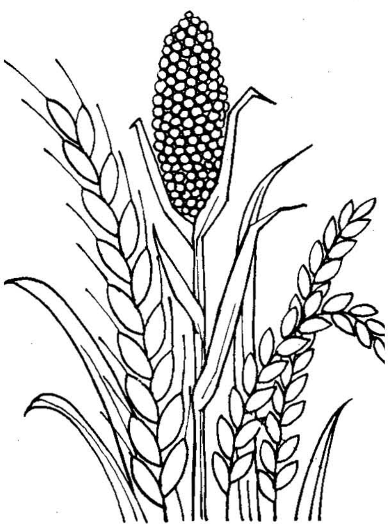

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SUPPLY RESPONSE OF FARMERS WITH HETEROGENEOUS LAND

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and

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INTRODUCTION

Much recent work in the estimation of farmer's responsiveness to price has been based upon the model developed by Nerlove.[1] A standard version of this model is :

$$(1) \quad A^*_t = b_1 + b_2 P^*_t + b_3 y_t + b_4 R_t + b_5 T + u_t$$

$$(2) \quad P^*_t - P^*_{t-1} = b_6 (P_{t-1} - P^*_{t-1})$$

$$(3) \quad A_t - A_{t-1} = b_7 (A^*_t - A_{t-1})$$

where

A^*_t = desired acreage in time t;
A_t = actual acreage;
P^*_t = expected relative price;
P_t = actual relative price;
y_t = actual yield per acre;
R_t = rainfall (average) or some other weather index; and
T = trend variable.

Equation (1) relates the factors influencing desired area. Equation (2) is the price expectation equation and equation (3) represents a partial area adjustment mechanism. This model has been adapted to estimate the supply response for a variety of crops. However, it would appear that in a desired acreage equation such as (1), the appropriate variable is *expected* yield rather than actual yield. That is, the farmer does not *a priori* know y_t, but rather makes some independent estimate of what the yield is likely to be. In this paper, we explore the concept of expected yield and empirical difference it might make in estimating the standard Nerlove model.

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1. Marc Nerlove : The Dynamics of Supply : Estimation of Farmers' Response, Johns Hopkins Press, Baltimore, 1958. For a detailed discussion of these studies refer to the authors': Farmer's Responsiveness to Price : A Survey of the Econometric Evidence, Praeger Publishers, New York (forthcoming).

METHODOLOGY

Yield at any time t depends upon past yields and any changes in other relevant factors between period (t—1) and t. Specifically, we may postulate that :

$$(4) \quad y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 \Delta A_t + \alpha_3 \Delta I_t + \alpha_4 \Delta R_t$$

where

I_t = inputs other than land at time t,

R_t = weather index at time t.

Thus, current yield is first of all a function of past yield.[2] Secondly, since land quality is not homogeneous, the use of additional land (or a reduction in planted acreage) can affect average yield; for instance, if inferior land is employed to expand acreage, then average yield is likely to decrease. Thirdly, shifts in the use of non-land inputs such as fertilizers, machinery and irrigation facilities as well as changes in rainfall should affect yield.[3]

We postulate then that the farmer has some notion of the effects of his planting decisions on yield and that such a relationship must be considered in addition to the three basic equations of the Nerlove model.[4] By estimating equation (4), we can produce an estimated (predicted) yield series. This generated series can then be used in equation (1) instead of actual yield figures.

The use of this method should have two principal results. First, we can determine from the estimate of α_2 quality is uniform in a particular region.[5] Second, by comparing estimates from the Nerlove model using both measures of actual yield and these generated figures, we can see if and in what manner the farmer takes into account the effect of differences in land quality in his acreage decisions.

A reduced form of equation (1) to (3) is used to estimate supply response. However, ordinary least squares techniques cannot be employed with this resulting equation; if they are, certain difficulties are encountered :

2. A simpler version of equation (4) would represent yield as well in first-difference terms; α_1 would then be equal to unity. However, in order to obtain more general results, we have not made this restriction. In a majority of the regressions performed on (4), α_1 was in fact found to be significantly different from both zero and one. For example, α_1 need not equal one if, *ceteris paribus*, land becomes less productive over time due to loss of soil nutrients.

3. Obviously if a weather index is included in equation (4), it would be omitted from equation (1).

4. The resulting four equation model should be estimated simultaneously, inasmuch as desired acreage depends on expected yield which in turn depends upon desired acreage. However, the reduced form of equation (1) to (4) cannot be readily estimated, and thus a two-step approach was in fact employed.

5. The Nerlove model [equations (1) to (3)] assumes uniform land quality.

1. Estimates will be inefficient as the disturbance terms in the reduced form will probably be serially correlated, irrespective of the degree of correlation found among the original disturbance terms;

2. The simple least squares estimates will be inconsistent inasmuch as the equation contains lagged values of the dependent variable; and

3. The equaton is over-identified, and the structural parameters cannot be uniquely recovered from the estimated parameters of the reduced form.

One way to approach this problem of efficiency and consistency is to maximize the likelihood function of the observation with respect to the b's. Under the assumption that the disturbance terms (W) are distributed $N(0, \sigma^2, I)$, the following can be written as the likelihood function:

$$(5) \quad L(\underline{A}\underline{X}, b, \sigma^2) = -\left(\frac{I}{2}\right) \log (2\pi) - \left(\frac{I}{2}\right) \log \sigma^2 - (1/2\sigma^2) (\underline{A} - \underline{X}\underline{B})' (\underline{A} - \underline{X}\underline{B})$$

The likelihood function is maximized when the sum of the squared residuals is minimized, and the estimated parameters are obtained by solving :

$$(6) \quad \partial W'W / \partial b_i = 0$$

These estimates are consistent, asymptotically unbiased and efficient.

RESULTS

We first estimated equation (4), using data from a number of Indian States for a variety of cereal and cash crops,[6] but omitting any measure of non-land inputs, for which no suitable data could be found. This circumstance introduced an element of confusion into the resulting analysis. In postulating the original hypothesis expressed in equation (4), it was anticipated that if land was, on the margin, more or less homogeneous regarding the cultivation of a particular crop, then the estimated coefficient $\hat{\alpha}_2$ would show little or no statistical significance. Should $\hat{\alpha}_2$ be both negative and significant, evidence for declining returns to land of heterogeneous quality would be indicated, while significant positive estimates would be consistent with increasing returns. If changes in non-land inputs are in the same direction and of the same proportion as changes in acreage, then omission of the former from the estimation would not prohibit assessment of the direction and degree of the influence of acreage changes on yield. But otherwise, the estimating procedure could attribute, at least in part, to the acreage effect the missing influence of non-land inputs which would not in fact be similar.

6. All crops and regions were not analysed due to the excessive requirements of computer time.

The fact is that in the period in question (various intervals in the 1950's and 1960's), there was a considerable secular increase in non-land inputs, particularly irrigation facilities, improved seed and agricultural implements, and to some extent, fertilizers. Should acreage changes also be secular and positive, then this "over-riding" problem would enter the estimation procedure. Such a possibility is actually remote for the major crops; in most such cases, acreage fluctuates from year to year, and any secular trend in the first-difference formulation ($\triangle A_t$) would be unlikely.

On the other hand, for a minor crop, particularly one increasing in importance, such behaviour would not be startling. Simultaneously, positive returns to land might well be possible—for example, as farmers become familiar with the crop, they might increasingly assign it better, as well as more, acreage, especially if it were a rather profitable cash crop. In such a case, analysis of equation (4) without a measure of non-land inputs would not be able to distinguish the two effects on yield—that of heterogeneous land could not be isolated from the influence of changes in non-land inputs.

In Table I, estimates of the area change coefficient α_2 are shown. If we first examine those for India's principal food crops, we find for wheat, the dominant cereal in the climatically more temperate States, definite indications of declining returns to land. Negative coefficients were found in four of the six States for which data were available,[7] and the only significant exception was in the small and under-developed Himachal Pradesh.

For rice, the major cereal in the rest of the country, the effects on yield of marginal changes in acreage are apparently not very great. Again Himachal Pradesh is an exception; the positive coefficients indicated here for both cereals might be indicative of recent adoption of more progressive agricultural techniques in an area which before Independence had been in large part an isolated collection of petty feudal States. Tamil Nadu, a major producing region, also shows a positive link between yield and changes in acreage; a possible explanation might be found in the post-war development of irrigation facilities in a State and for a crop where the results of "spreading" the benefits of monsoon rains across the growing season would be particularly effective.

The third cereal included in our test, barley, is quite different from the other two. First, it is of relatively minor importance in almost all regions in which it is grown. Secondly, it is considered by most cultivators a somewhat inferior crop and its production a less desirable endeavour than that of wheat, its chief competitor. Thirdly, two recent comprehensive studies of supply response for north Indian cereals[8] found a notably greater degree of positive and statistically significant market influence (as measured by output elasticities with respect to price) for barley than for either rice or wheat.

7. Limitations ruled out estimates for two States, Uttar Pradesh and Madhya Pradesh, which together with Punjab and Rajasthan comprise the bulk of India's wheat belt.

8. Vahid Nowshirvani : Agricultural Supply in India : Some Theoretical and Empirical Studies, M.I.T. Ph.D. Thesis, 1968, and John Thomas Cummings : Supply Response in Peasant Agriculture : Price and Non-Price Factors, Tufts University Ph.D. Dissertation, 1973.

TABLE I—YIELD EQUATION COEFFICIENTS

Crop	Region	Area coefficient A_1	R^2	Region	Area coefficient A_1	R^2
Rice ..	Himachal Pradesh	+ 46.97d (3.06)	0.59	Andhra Pradesh	— 0.049 (0.87)	0.55
	Maharashtra	+ 0.157 (0.53)	0.14	Assam	— 0.159 (1.04)	0.20
	Mysore	+ 0.280a (1.19)	0.50	Gujarat	— 0.360 (0.51)	0.59
	Punjab	+ 0.359 (0.93)	0.75	Kerala	— 0.141 (0.49)	0.70
	Tamil Nadu	+ 0.083d (3.20)	0.94	Tripura	— 0.210 (0.45)	0.11
Wheat ..	Delhi	+ 7.941 (0.98)	0.69	Mysore	— 0.923c (2.59)	0.43
	Himachal Pradesh	+ 4.265c (2.48)	0.46	Punjab	— 0.029 (0.55)	0.58
				Rajasthan	— 0.053b (1.73)	0.51
				West Bengal	— 1.922c (2.10)	0.43
Barley ..	Punjab	+ 0.754c (2.48)	0.35	Delhi	— 9.296d (2.91)	0.50
	Rajasthan	+ 0.062 (0.93)	0.17	Himachal Pradesh	— 5.337 (0.76)	0.45
	Pakistan	+ 0.540 (0.58)	0.41			
Cotton ..	Assam	+ 5.105c (2.34)	0.76	Andhra Pradesh	— 0.0003 (0.02)	0.35
	Mysore	+ 0.062 (0.16)	0.41	Tamil Nadu	— 0.013 (0.41)	0.85
	Tripura	+ 1.768 (0.50)	0.18			
Groundnuts	Maharashtra	+ 0.256a (1.10)	0.18	Andhra Pradesh	— 0.128b (1.92)	0.29
	Punjab	+ 2.745d (4.27)	0.84	Mysore	— 0.099 (0.72)	0.14
	Rajasthan	+ 0.449 (0.98)	0.11	Tamil Nadu	—22.59a (1.70)	0.52
Tobacco ..	Bihar	+ 0.384 (0.07)	0.16	Andhra Pradesh	— 0.182b (1.81)	0.58
	Maharashtra	+ 2.249a (1.34)	0.44	Assam	— 7.244a (1.10)	0.50
	Mysore	+ 1.334 (0.65)	0.27	Gujarat	— 3.115b (1.87)	0.50
				Tamil Nadu	— 2.746c (2.60)	0.82
Jute ..	Bihar	+ 0.414a (1.20)	0.16	Bangladesh	— 0.301c (2.54)	0.47
	Tripura	+ 4.777b (1.95)	0.27			
	Uttar Pradesh	+ 1.941 (0.85)	0.74			
	West Bengal	+ 0.311c (2.33)	0.41			

Notes : Figures in parentheses are t-values.
a = 30 per cent significance level.
b = 10 per cent significance level.
c = 5 per cent significance level.
d = 1 per cent significance level.

As can be seen from Table I, positive estimates were found for the influence of changes in acreage on yield for both major barley States tested in India, Punjab and Rajasthan, as well as for Pakistan where climate and soil conditions are similar, while negative links are indicated only for the minor regions, Delhi and Himachal Pradesh. While not much statistical significance was found, regressions were also run for the dozen largest barley districts in Punjab and Rajasthan, and positive coefficients were indicated in all but two cases.[9]

When these indications are taken together with the evidence of barley's greater (positive) responsiveness to prices, the economically rational behaviour of the cultivators of this less desirable crop is apparent. Acreage responds to prices; when the latter are low, barley planting shrinks and tends to be confined to less fertile soil. When prices rise, barley is not only planted more widely, but on more productive acreage.[10]

If we now turn to cash crops, marginal area changes seem to affect cotton yields little, while signs of declining returns to land are found for both groundnuts and tobacco.

Of the cotton States studied, only for Assam is the estimated coefficient statistically significant. In this State, the crop is of minor importance (it accounts for less than 0.5 per cent of the State's acreage and Assam for only about 0.2 per cent of India's cotton). Cotton has seen a small growth in popularity among Assamese cultivators since World War II; rising market demand may also have prompted its production on better soil. Regressions were also run for ten major producing districts[11] from Punjab to Tamil Nadu; without exception the results were the same as for the major States—no statistical significance for $\hat{\alpha}_2$ at even the 30 per cent level.

The principal groundnut regions are in Andhra Pradesh, Mysore and Tamil Nadu—ten per cent or more of each State's acreage is devoted to the crop and together they account for about 40 per cent of the nation's output. For all three, negative estimates for α_2 (if not strong statistical significance) and declining returns are indicated. Positive values were found for Maharashtra, Rajasthan and Punjab. In the latter two, the cultivation of groundnuts has increased rapidly in the past two decades, but the crop remains of minor consequence, claiming only about one per cent of each State's acreage.

Tobacco, though the smallest in terms of acreage of the crops included herein, is also perhaps the most valuable (on a returns-per-acre basis) annual

9. Positive for Ferozepore, Hissar, Ajmer, Bhilwara, Ganganagar, Jaipur, Pali, Sawai Madhopur, Tonk and Udaipur ; negative for Gurgaon and Alwar.

10. Greater quantities of non-land inputs are also likely to be employed.

11. Ferozepore in Punjab, Ahmedabad, Baroda and Broach in Gujarat, Anantapur and Kurnool in Andhra Pradesh, Bijapur and Dharwar in Mysore, and Ramanathapuram and Tirunelveli in Tamil Nadu.

cultivated in India. Unlike the situation prevailing for the other crops, there is no "tobacco-belt," rather, it is grown in several distinct areas where the soil and climate conditions appropriate for its successful production are found. About 40 and 25 per cent of India's tobacco is grown respectively in the two major producing States, Andhra Pradesh and Gujarat. Negative and generally significant estimates of α_2 were found for the major tobacco States; only for Maharashtra is there an exception noted. Supplementary regressions for the dozen most important districts also indicate declining returns in all but three cases.[12]

Jute, exported in various semi- and fully processed forms, is India's most important agricultural foreign exchange earner. Though it has long been a major crop, most of the important Jute-growing region went to the then East Pakistan, now Bangladesh, following partition. However, the bulk of the jute processing facilities remained with India, particularly in West Bengal State. This fact coupled with strong world demand in the years following Independence, led to a rapid growth in jute acreage within India, with planting more than doubling in Bihar and Assam and about tripling in West Bengal between 1947 and 1956.

Several researchers[13] have noted considerable differences in the post-Independence market responsiveness of cultivators in "old" as opposed to "new" jute areas (*i.e.*, in Bangladesh and India respectively). Rabbani and Cummings found much higher price elasticities in the latter than in the former, while Rabbani, together with Parikh, Hussain and Cummings, offer comparative evidence of a post-Independence *increase* in elasticity in the "new" and a *decrease* in the "old" districts.

Such contrast is borne out in the results shown in Table I—positive and generally significant coefficients for the four Indian States included and for the eight major jute districts[14] on which regressions were run, negative and also generally significant estimates for Bangladesh as a whole and for all seven major producing districts.[15] If declining returns to land were clearly indicated for the latter, it would nevertheless be rash to conclude that Indian regions show increasing return on the basis of these results. As was mentioned previously, lack of data precluded testing for the effect on yield of

12. Negative coefficients for Krishna, Guntur, Khammam, Warangal and West Godavari districts in Andhra Pradesh, Baroda and Kaira districts in Gujarat, and Belgaum and Kolhapur districts in Mysore; positive coefficients in East Godavari, Sangli and Mysore districts in Andhra Pradesh, Maharashtra and Mysore respectively.

13. A. K. M. Ghulam Rabbani, "Economic Determinants of Jute Production in India and Pakistan," *The Pakistan Development Review*, Vol. V, No. 2, Summer 1965 ; John Thomas Cummings : *op. cit.* ; A. Parikh, "Market Responsiveness of Peasant Cultivators : Some Evidence from Pre-War India," *Journal of Development Studies*, Vol. 8, No. 2, January, 1972 ; Sayed Mushtaq Hussain, "The Effect of the Growing Constraint of Subsistence Farming on Farmer Response to Price : A Case Study of Jute in Pakistan," *The Pakistan Development Review*, Vol. IX, No. 3, Autumn 1969.

14. Cooch-Behar, Hooghly, Jalpaiguri, Murshidabad, Nadia and 24-Parganas districts in West Bengal, and Goalpara and Saharsa districts in Assam and Bihar respectively.

15. Dacca, Faridpur, Mymensingh, Pabna, Ratshahi, Rangpur and Typpera districts.

changes in non-land inputs, and the possibility cannot be ignored that, in the case of a crop showing a more or less secular increase in acreage (as does jute) during a period when these other inputs probably saw similar growth, regression analysis might attribute at least part of the effects of the latter on yield to the former.

On the whole, it seems likely that as Indian farmers became more acclimated to jute cultivation during the post-Independence period, it tended to appropriate more suitable land, as well as benefit from better utilization of the acreage in question through application of yield-enhancing techniques. If the effects on yield of more and better land and non-land inputs cannot be distinguished in this case, nevertheless the contrast between Indian and Bangladesh jute is striking and confirms the distinctions between the two regions noted in earlier research.

Before moving to a discussion of our supply model results, a few words are in order regarding the general performance of equation (4). Though the absence of data for critical non-land inputs tended to rule out in advance a high degree of explanation of changes in yield by the remaining area and rainfall variables, R^2 was 0.5 or higher in about half the cases. The value of the F-statistic was significant at the 10 per cent level or better in more than three quarters of the regressions.

If equation (4) serves as a reasonable mechanism for predicting crop yield, then inclusion of its results to represent expected yield in the basic supply model should improve the performance of the latter. As a test of this premise, two different estimating equations were applied to supply data of several crop regions. These were of the form :

$$(7a) \quad A_t = \delta_0 + \delta_1 P_{t-1} + \delta_2 X_t + \delta_3 T + \delta_4 A_{t-1}$$

$$(7b) \quad A_t = \varepsilon_0 + \varepsilon_1 P_{t-1} + \varepsilon_2 Y_t + \varepsilon_3 R_t + \varepsilon_4 T + \varepsilon_5 A_{t-1}$$

where

P = average annual producer price (deflated);

X = the predicted yield resulting from regressions run with equation (4);

Y = a measure of actual yield;

R = a measure of rainfall in the sowing period;

T = a trend variable.

In evaluating the performance of one version of the model against the other, we should consider several criteria. For example, the values of the coefficients of determination (R^2) can be compared or, more suitably in this case where the degrees of freedom are different for the two equations, those of the F-statistic. Secondly, the degree of statistical significance indicated for the coefficient estimates is of obvious importance, particularly for those associated with the alternate formulations of the yield variable. Finally, and most importantly, the results of the regressions, singly and in toto, must be subject to the scrutiny of economic rationality.

Judged by these criteria, the results obtained from equation (7a) are markedly better, we believe, than those from (7b).[16] But whether R^2 or F-statistic values are used as guides, those regressions using predicted or "expected" yield (X) are superior more than half the time. In most other cases, not much difference between the two versions was found; in only two or three cases did the actual yield model seem to perform notably better.

As regards statistical significance attached to the yield coefficient estimates, about half the time, *both* versions indicate significance at the 30 per cent level or better, but the expected yield coefficient shows such significance in all but four cases, while for actual yield, nine such exceptions were found.

As regards economic behaviour underlying the indicated signs of the estimated yield coefficients, a positive relationship between yield and the dependent variable is consistent with rational or "normal" market reactions—higher yields encourage more planting and, hence, higher farm incomes. A negative sign for the yield coefficient, on the other hand, is reasonable for a crop grown primarily for family consumption—higher yields allow satisfaction of subsistence needs with less planting and hence more acreage available for other crops. In fact, though three or four crops are food crops and two of these are basic items in the diets of peasants in north-western (wheat) and southern and eastern (rice) India, in most cases herein considered, these cereals are also grown in large part for the market.

Negative yield coefficients are also possible for crops whose sale is important to the cultivators and where anticipated yield, for whatever reason, is declining. Should such a decline be secular, alternative market crops might gradually replace those which are faltering, but even if such a switch is possible, it would likely be gradual, especially if the present crop is of major importance to the region.

Negative yield coefficients were found in every case for which negative area difference coefficients were indicated in the yield regressions (Table I). On the other hand, positive signs for yield occurred in nearly every situation

16. The table of results is available from the authors.

where a similar relationship was indicated for $\triangle A$ (Table I). Not surprisingly, the increasing returns to land, the latter situation might indicate, seem to increase the popularity of a crop with its cultivators.

CONCLUSION

As was mentioned at the beginning, anticipated yield seems logically to be important in planting decisions ; yet only measures of yield which ignore the cultivator's experience with land of variable quality have been used in earlier formulations of the Nerlove supply model. Our premise that an implicit assumption of heterogeneity of land productivity might be invalid in many cases was borne out at least for some crops in the regressions conducted using equation (4). The likelihood that cultivators *are* aware of these relationships between marginal changes in acreage and crop yield and, furthermore, that they take such factors into consideration in planting decisions is strengthened by the indicated performance of the yield measure predicted by equation (4) in the supply model.

However, the value of such evidence is somewhat mitigated by any measure of changes in non-land inputs in the yield regressions. If such a measure could be derived and incorporated, it seems reasonable to assume that the explanatory power of equation (4) would improve. Furthermore, if cultivators are as cognizant of non-land changes as they are of land and weather shifts in forming their yield expectations, then a yield series predicted by an equation, including such factors should improve the performance of our anticipated yield measure. These results also indicate an obvious policy, for increasing agricultural acreage and output beyond price incentives, namely, measures which increase crop yield.