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DYNAMIC SUPPLY AND DEMAND MODELS FOR BETTER ESTIMATIONS AND PROJECTIONS : AN ECONOMETRIC STUDY FOR MAJOR FOODGRAINS IN THE PUNJAB REGION†

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Accurate projection of supply of and demand for commodities is a vital pre-requisite for any effective policy. This necessity is reflected in continued endeavour by researchers to improve the analytical tools used in the projection process. It is recognized that the estimates of supply and demand elasticities are crucial, and a projection is only as good as these estimates are.

This paper concentrates on the elasticity estimates. Recent advances in the theory of economic behaviour incorporating dynamic elements and the corresponding econometric applications suggest that better estimates of the relevant parameters emanate from this rather than the 'conventional' static approach. The dynamic models of supply and demand used in this paper are based on the generally accepted notion that current decisions are influenced by experience relating to past decisions or past behaviour. The precise econometric specification of this influence, spelled out in detail subsequently, is based on different variants of the theory of distributed lags. It is also argued that the use of short run estimates for long run projections results in a built-in inconsistency. This paper presents some results obtained through the dynamic models for demand and supply elasticity estimates for wheat, maize and rice in Punjab.

A. SUPPLY

THE DYNAMIC SUPPLY RELATION

Supply decisions in agriculture are expected to be made on knowledge relating to technical coefficients, prices of inputs and prices of products. All these three components needed for decision making are not known with certainty. Additional uncertainty arises out of variations in such exogenous variables like weather and government policies, etc. A common assumption underlying all dynamic supply response models, including those referred to in this paper, is that farm-firms seek to maximize expected profits.¹ The difference between dynamic supply models arises in giving different measures to aggregate price expectation. These models assume that the entrepreneur's utility is a linear function of income. From this assumption follows the certainty-equivalence notion which implies that for every certain income there corresponds a probability distribution of uncertain incomes having the same actuarial value and yielding the same total utility. One commonly used certainty-equivalence model in supply response analysis, based on time-series data is the adaptive expectations (or distributed lags) model developed by Marc Nerlove.²

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1. The farm-firms acting under uncertainty either maximize expected profits or minimize expected losses.

2. Marc Nerlove : Dynamics of Supply, John Hopkins Press, Baltimore, U.S.A., 1958.

The choice between different distributed lag models depends on whether postulated lags are formalisations of technological-institutional setting or the expectational behaviour of the sector concerned. In the distributed lag model based on price expectation, the assumption made is that past price experience influences the formation of expected price which in turn influences the acreage decision. In the adjustment lag model, acreage adjustment is supposed to be based on institutional-technological constraints. Simultaneous considerations of both types of lags presents serious problems for econometric estimation. For the purposes of this paper the adjustment lag model has been used which in the simplest form, is based on the relation :

$$A_t^* = a + bP_{t-1} + u_t \quad (1)$$

$$A_t - A_{t-1} = B(A_t^* - A_{t-1}) : 0 < B < 1 \quad (2)$$

and the reduced form is given by

$$A_t = A_0 + A_1P_{t-1} + A_2A_{t-1} + V_t \quad (3)$$

where $A_0 = aB$, $A_1 = bB$, $A_2 = (1-B)$, $V_t = Bu_t$

Additional variables like lagged yield, rainfall, etc., can be easily considered in the structural equation.

Although the rationality of risk aversion on the part of farmers has been hypothesized, until recently no attempt was made to explicitly incorporate farmers' risk aversion in the estimation of supply responses. Behrman, in a recently published study, which represents a major econometric advance in dynamic supply response analysis, includes these factors.³ Farmers' rational conduct, following the risk aversion hypothesis would imply that, given the subjective price and yield probability distributions, farmers would seek to maximize expected utility, that is, maximize the expected return for a given level of variance in the expected return, which is a measure of risk. Thus, for example, a crop for which the subjective price and yield probability distributions provide smaller expected value but also smaller variance may be preferred to another crop yielding larger expected value but at the same time larger variance. The farmer in this case attaches larger expected utility to the first crop compared to the second.

A crude representation for price and yield variances can be incorporated in the supply response relation. The ratio of the actual standard deviation of the price of the crop concerned to the standard deviation of the price of alternative crops (σP_i), and the actual standard deviation of yields (σY_i) over the three preceding production periods, for example, may be considered to serve as proxies for the variances in the subjective probability distributions. This dynamic specification, which Behrman calls the 'modified' Nerlovian dynamic supply response model, incorporating the risk aversion hypothesis, is based on three structural equations:

3. J. R. Behrman : Supply Response in Underdeveloped Agriculture—Contributions to Economic Analysis, North-Holland Publishing Co., Amsterdam, 1968, Chapter I, pp. 1-20.

$$A_t^* = a_0 + a_1 P_t^* + a_2 \sigma P_t + u_t \quad (1)$$

$$(A_t - A_{t-1}) = b_0 + b_1 (A_t^* - A_{t-1}^*) + e_t \quad (2)$$

$$P_t^* - P_{t-1}^* = c_0 + c_1 (P_{t-1} - P_{t-1}^*) + v_t \quad (3)$$

The parameters of the reduced form for this system of equations are estimated by appropriate non-linear estimation procedures.

In this study, however, this model has not been used, but an attempt has been made to incorporate the σP_t variable in the Nerlovian adjustment lag model with a view to obtaining some idea regarding farmers' response to the variations in prices.

Data

In this paper, some results of the acreage response functions for three crops, namely, wheat, maize and rice have been presented. Data on area, production, prices, for wheat, maize, rice and their competing crops, rainfall, etc., were obtained from published sources for the period 1948-49 to 1965-66. The basic functional relation considered was :

$$A_t = f (P_{t-1}, Y_{t-1}, Z_{t-1}, T_t)$$

where A_t was defined as standard irrigated area for maize and rice and as irrigated area only for wheat. For all the three crops, both absolute and relative harvest prices (P_{t-1}) were considered.⁴ Y_{t-1} indicated yield of the crop in question relative to the yield of competing crops. Total irrigated area in the season concerned was defined as Z_t and T_t represented a trend variable.

RESULTS AND INTERPRETATION

I. Wheat

Acreage Response Equations :

| | | | |
|--------------|--|--|---|
| Equation (1) | $\text{Log } A_t = 0.0945 + 0.1086$ (0.1263) | $\text{Log } P_{t-1} + 0.9786^{***}$ (0.0786) | $\text{Log } A_{t-1}$ $R^2 = 0.9319$ |
| Equation (2) | $\text{Log } A_t = 0.7977 + 0.5398^*$ (0.2777) | $\text{Log } \bar{P}_{t-1} + 0.4723^@$ (0.2747) $+ 0.1381^@ \text{Log } T_t$ (0.0886) | $\text{Log } A_{t-1}$ $R^2 = 0.9439$ |
| Equation (3) | $\text{Log } A_t = 1.9022 + 0.6692^{**}$ (0.2257) | $\text{Log } \bar{P}_{t-1} + 0.0026$ (0.2611) $+ 0.4093^{***} \text{Log } T_t$ (0.1095) $- 0.0098$ (0.0205) | $\text{Log } A_{t-1}$ $R^2 = 0.9669$ |

@ Significant at 20 per cent.

* Significant at 10 per cent.

** Significant at 5 per cent.

*** Significant at 1 per cent.

4. For maize and rice, the relative price was in terms of weighted prices of six alternative *kharif* crops and for wheat, in terms of weighted prices of three competing *rabi* crops. In the equations presented subsequently, P_{t-1} indicates relative price, \bar{P}_{t-1} the absolute price of the crop in question and \hat{P}_{t-1} the prices of substitute crops.

The response functions for wheat indicate that relative prices do not exercise a significant influence on acreage, though the coefficient bears the correct sign. Absolute prices, however, prove to be significant. The inclusion of standard deviation of prices over the last three preceding production periods, as measure of price risk, seemingly does not improve the explanatory power of the hypothesized relation, and the relevant coefficient is not statistically significant. But the magnitude as well as the significance of the price coefficient increases and the σP_{t-1} coefficient bears the correct sign suggesting an inverse relation between acreage and price variability. It is also interesting to note that incorporation of this variable led to a substantial decline in the coefficient of lagged acreage.

The estimates of short and long run elasticities with respect to price and σP_{t-1} have been presented in Table I. The short run elasticity with respect to relative price is low and in keeping with the estimates of Raj Krishna⁵ and Kaul⁶ but the long run elasticities are much higher. With respect to absolute prices, however,

TABLE I—ESTIMATES OF SHORT AND LONG RUN ELASTICITIES

| Crop equation number | | Coefficient of adjustment | Elasticity with respect to price | | Elasticity with respect to price variability | |
|----------------------------|-----|---------------------------------|-------------------------------------|----------|---|----------|
| | | | Short run | Long run | Short run | Long run |
| <i>I. Wheat</i> | | | | | | |
| (1) | ... | 0.0214 | 0.1086 | 0.5075 | | |
| (2)† | .. | 0.5277 | 0.5398* | 1.0229 | | |
| (3)† | .. | 0.9974 | 0.6692** | 0.6709 | —0.0098 | —0.0098 |
| <i>II. Maize</i> | | | | | | |
| (1) | .. | 0.8455 | 0.5617** | 0.6643 | | |
| (2) | .. | 0.8199 | 0.2839@ | 0.3462 | 0.0027 | —0.0033 |
| (3)† | .. | 0.9108 | 0.4935 | 0.5418 | —0.2492*** | —0.2736 |
| <i>III. Rice</i> | | | | | | |
| (1) | .. | | 0.4939@ | | | |
| (2) | .. | 0.4656 | 0.1815 | 0.3898 | | |
| (3) | .. | 0.8661 | 0.3254 | 0.3757 | —0.0094 | —0.0108 |
| (4)† | .. | 0.2230 | 0.1498 | 0.6718 | | |
| (5)† | .. | 0.2002 | 0.1131 | 0.5649 | —0.0010 | —0.0049 |

† These relate to absolute prices.

@ Significant at 20 per cent.

* Significant at 10 per cent.

** Significant at 5 per cent.

*** Significant at 1 per cent.

5. Raj Krishna, "Farm Supply Response in India-Pakistan : A Case Study of the Punjab Region," *The Economic Journal*, Vol. LXXIII, No. 291, September, 1963, pp. 477-487.

6. J. L. Kaul, "A Study of Supply Response to Price of Punjab Crops," *Indian Journal of Economics*, Vol. 48, No. 188, July, 1967, pp. 25-40.

the elasticities are significant and high. Sud and Kahlon⁷ obtained even higher own price elasticity (0.8982) in the static model in which substitute crop price was also explicitly included. A similar specification in the Nerlovian frame gave a corresponding short run elasticity estimate of 1.0348 in this study also,⁸ but the deletion of insignificant variables gave Equation (2) presented above. This clearly indicates that the precise or best specification of price expectation needs more detailed evaluation. This point is also borne out by the instability of the coefficient of adjustment through Equations (1) and (3).

The elasticity with respect to σP_{t-1} indicates the influence of this variable on acreage. While the estimates are not statistically significant, the negative sign does indicate that large variations in prices do have an adverse impact on acreage.

II. Maize

Acreage Response Equations :

$$\text{Equation (1)} \quad \text{Log } A_t = 2.9864 + 0.5617^{**} \text{ Log } P_{t-1} + 0.1545^{**} \text{ Log } A_{t-1} \\ (0.2266) \quad (0.0690) \\ + 0.3887^{***} \text{ Log } T_t \quad R^2 = 0.7790 \\ (0.0624)$$

$$\text{Equation (2)} \quad \text{Log } A_t = 2.8335 + 0.2839^@ \text{ Log } P_{t-1} + 0.1801^{***} \text{ Log } A_{t-1} \\ (0.1897) \quad (0.0547) \\ + 0.5341^{***} \text{ Log } T_t - 0.0027 \text{ Log } \sigma P_{t-1} \quad R^2 = 0.8920 \\ (0.0682) \quad (0.0130)$$

$$\text{Equation (3)} \quad \text{Log } A_t = 1.8505 + 0.4935 \text{ Log } \bar{P}_{t-1} + 0.0892 \text{ Log } A_{t-1} \\ (0.5519) \quad (0.2203) \\ - 0.2492 \text{ Log } \bar{\sigma P}_{t-1} \quad R^2 = 0.5439 \\ (0.0170)$$

The response functions for maize show that relative prices did exercise a significant influence on acreage and the price coefficients in the first two equations are significant. Absolute prices did not emerge significant in this case. Interestingly enough, the inclusion of σP_{t-1} resulted in a decline in the magnitude and level of significance of the relative price variable. With absolute prices, its coefficient was found to be highly significant. The elasticity estimates presented in Table I suggest the positive influence of price but the magnitude of the estimates are again not stable. The long run elasticity for this crop is below unity in all cases. The coefficients of adjustment obtained from the three equations are fairly close and

7. Lalita Sud and A. S. Kahlon, "Estimation of Acreage Response to Price of Selected Crops in Punjab State," *Indian Journal of Agricultural Economics*, Vol. XXIV, No. 3, July-September, 1969, pp. 46-50.

8. The estimated equation was

$$\text{Log } A_t = 0.6370 + 1.0348^{***} \text{ Log } \bar{P}_{t-1} - 0.2141 \text{ Log } \bar{P}_{t-1} + 0.0863 \text{ Log } Y_{t-1} \\ (0.4037) \quad (0.2200) \quad (0.1668) \\ + 0.3064 \text{ Log } Z_{t-1} + 0.0468 \text{ Log } A_{t-1} + 0.1896^* \text{ Log } T_t \quad R^2 = 0.9596 \\ (0.8928) \quad (0.9385) \quad (0.0911)$$

their high values suggest the general absence of rigidities which inhibit speedy adjustment in the long run. One would again notice a similarity in the short run elasticity estimate from Equation (2) with Raj Krishna's estimate of 0.23. But primarily because of high rate of adjustment the long run elasticity for the estimated equation is lower.

III. Rice

Acreage Response Equations:

$$\begin{aligned} \text{Equation (1)} \quad \text{Log } A_t = & 0.7991 + 0.4939^{\textcircled{a}} \text{Log } P_{t-1} + 0.6004^* \text{Log } Y_{t-1} \\ & (0.3617) \qquad (0.3233) \\ & + 0.7560^{***} \text{Log } Z_{t-1} \qquad R^2 = 0.7991 \\ & (0.1112) \end{aligned}$$

$$\begin{aligned} \text{Equation (2)} \quad \text{Log } A_t = & 0.3090 + 0.1815 \text{Log } P_{t-1} + 0.2712 \text{Log } Y_{t-1} \\ & (0.4751) \qquad (0.4583) \\ & + 0.2685 \text{Log } Z_{t-1} + 0.5344 \text{Log } A_{t-1} \qquad R^2 = 0.8122 \\ & (0.4940) \qquad (0.5277) \end{aligned}$$

$$\begin{aligned} \text{Equation (3)} \quad \text{Log } A_t = & 2.0088 + 0.3254 \text{Log } P_{t-1} + 0.1339 \text{Log } A_{t-1} \\ & (0.4790) \qquad (0.5661) \\ & + 0.4128 \text{Log } T_t - 0.0094 \text{Log } \sigma P_{t-1} \qquad R^2 = 0.7587 \\ & (0.3698) \qquad (0.0762) \end{aligned}$$

$$\begin{aligned} \text{Equation (4)} \quad \text{Log } A_t = & 2.0343 + 0.1498 \text{Log } \bar{P}_{t-1} - 1.1479^{***} \text{Log } \hat{P}_{t-1} \\ & (0.2673) \qquad (0.4705) \\ & + 0.7770 \text{Log } A_{t-1} + 0.3575^{**} \text{Log } T_t \qquad R^2 = 0.8885 \\ & (0.3145) \qquad (0.1436) \end{aligned}$$

$$\begin{aligned} \text{Equation (5)} \quad \text{Log } A_t = & 0.7727 + 0.1131 \text{Log } \bar{P}_{t-1} - 0.1892 \text{Log } \hat{P}_{t-1} \\ & (0.5956) \qquad (0.7751) \\ & + 0.7998^{\textcircled{a}} \text{Log } A_{t-1} - 0.0010 \text{Log } \sigma \bar{P}_{t-1} \\ & (0.5045) \qquad (0.0944) \\ & - 0.1224 \text{Log } \sigma \hat{P}_{t-1} \qquad R^2 = 0.8055 \\ & (0.1084) \end{aligned}$$

In the rice equation, the relative price coefficient was significant in the static model only. The Nerlovian adjustment lag form resulted not only in a decline in the magnitude and significance of the price but also of the lagged relative yield and irrigated area variables.

When absolute prices of rice and its competing crops were explicitly included, the coefficients for the latter were found to be significant, though the own price

coefficient remained insignificant and comparable in magnitude to the Nerlovian relative price coefficient [Equation (2)]. The risk measuring variable (σP_{t-1}) did not emerge significant in either the relative or absolute price equations but it carried the correct sign.

Highest short run elasticity estimate with respect to relative price was obtained in the static model. The dynamic model yields lower and insignificant elasticity estimates for both relative and absolute prices. These do not correspond to the significant values obtained by Raj Krishna. The influence of price variability on acreage was found to be inverse, though insignificant. In the relative price equation, the inclusion of price variability-risk yields a price elasticity estimate [Equation (3)] comparable to Raj Krishna's estimate of 0.31. The long run elasticities remained below unity.

The dynamic model specification for estimating acreage response indicated that a proper appraisal of the price expectation behaviour of the farmers is important. The fact that relative price emerged significant in some cases and absolute prices in others should not be accepted *prima facie*. It would be apparently inconsistent to assume, except perhaps in the case of very highly remunerative crops, that farmers base their expectation on relative price for one crop and on absolute prices for others. A meaningful empirical work on acreage response must be based on more concrete information on this aspect.

The incorporation of price risk measures directly into the model, though not very successful, does indicate that this may be another fruitful avenue for future exploration. The three years' standard deviation in prices, crude as it is, may be substituted by more appropriate measures depending upon the nature of distribution of the price variable. Again, in this study the risk elements were considered in the Nerlovian framework and not in the modified version as developed by Behrman. A more rigorous estimation procedure might result in more conclusive evidence on this aspect.

Estimates of Acreage Elasticity and Supply Projections

Given a stable production technology, the acreage response functions may be used for projection of acreage and supply. But, in times of changing technology, the acreage elasticity estimates based upon time-series may be widely different from the actual current estimates. This problem would be all the more acute if the technological change is one of 'land-saving' type. It could be argued, with valid reasons, that in such situations the price elasticity of output rather than acreage should be more meaningful. It is basically this difficulty, and the fact that price elasticity of output is not easily measurable with accuracy, which has led to the use of 'budgeting' type of approach to supply projections in recent work in this country. This approach attempts first to project the level of input use, and by using appropriate yardsticks, arrives at projected supply estimates. The assumption implicit in this case is that prices will generally be favourable to the attainment of these projections. Clearly this assumption cannot be satisfied unless some reliable price elasticity of output estimates are available and on their basis the price structure is manipulated. This takes us back to the starting point. The answer that suggests itself from this line of reasoning is that the two approaches supplement each other.

B. DEMAND

THE DYNAMIC DEMAND RELATION

Developments in the theory of consumer demand have been followed by important improvements in econometric methods in estimating the effects of factors affecting demand. The contributions of Schultz, Wold, Stone, Duesenberry and Friedman represent some important steps in this direction. The approach to the analysis of consumer demand followed in our work is the one developed by Houthakker and Taylor in a recent contribution.⁹ In this approach greater attention is paid to the dynamic character of demand and the econometric estimation procedure takes full cognizance of the quantitative importance of the dynamic effects.

The standard approach in demand analysis involves the estimation of the following type of demand equation.

$$q_t = f(x_t, P_t, z_{1t}, z_{2t}, \dots, z_{nt}, u_t)$$

where: q_t is per capita consumption of the commodity in year t ,

x_t is a measure of per capita income,

P_t is the deflated price of the commodity,

$z_{1t}, z_{2t}, \dots, z_{nt}$ represent prices of substitutes or complements, and other pre-determined or exogenous variables.

Some of the difficulties inherent in the static specification of the demand equation are:

(a) The income and price variables may not be exogenous. For example, the income of the farm family producing foodgrains not only depends on what it produces but on how much it sells; this in turn is related to how much it consumes. Marketed sales and consumption are related to the price of the commodity as well as prices of substitutes.

(b) The static character of the model is not appreciably changed by the arbitrary inclusion of a lagged variable.

It is the purpose of the dynamic model to represent more accurately the behavioural decisions of the consumers.

The current decisions in the Houthakker-Taylor dynamic demand model are assumed to be influenced by past behavioural decisions. One representation of past decision is the current level of inventories. Past decision can also be represented by other "state variables." These state variables themselves are changed by current decisions. The dynamic demand model in this sense is of the distributed lag type where current decisions depend on past values of pre-determined variables. To illustrate, let q_t be the demand for clothing over interval time t ,

9. H. S. Houthakker and Lester D. Taylor: *Consumer Demand in the United States 1929-1970: Analysis and Projection*, Harvard University Press, Cambridge, Mass., U.S.A., 1966, pp. 1-214.

x_t the income during that period and s_t the level of inventory at time t , and p_t the relative price of the commodity, such that

$$q_t = a + b s_t + c x_t + e p_t + u_t \quad \dots \quad (1)$$

where a, b, c, e are the parameters of the structural equation (1). The per capita demand for clothing, the model suggests, depends not only on per capita income and price of clothing but also on the level of clothing inventory. We should expect, for an individual with given tastes and income, that his demand for clothing would be inversely related to the level of his inventory holding. The inventory coefficient, b , should, therefore, have a negative sign. The state variable, s_t , can also have an alternative interpretation. The above model can be made to represent not only the inventory adjustment behaviour just explained but also habit formation or inertia behaviour. According to this interpretation, the consumer's current consumption level will be affected by the level of his habit formation (psychological stock) and hence, b , will be positive, given the consumer's taste and income. However, we are confronted with the problem of measuring an unobservable psychological stock—habit formation variable. The difficulty of measurement is not limited to the unobservable nature of habit formation; it is also encountered in grouping heterogeneous categories of commodity—inventory. A further problem is encountered in specifying the relevant rate of depreciation of inventories or in choosing the rate at which the habit (psychological stock) wears off. An ingenious suggestion has been made by Houthakker and Taylor, who assume, because of the difficulties mentioned, that the state variable is really unobservable but its influence on consumer demand can be estimated by reference to the following accounting identity

$$\dot{s}_t = q_t - d s_t, \quad \dots \quad (2)$$

where \dot{s}_t indicates the rate of change of the state variable with respect to time t and d is a constant depreciation rate. For commodities subject to habit formation d measures the speed at which the habit wears off.

By using a finite approximation to continuous time (this is appropriate since our observations are annual), Equations (1) and (2) can be combined to give the final estimating equation.

$$q_t = A_0 + A_1 q_{t-1} + A_2 \Delta x_t + A_3 x_{t-1} + A_4 \Delta P_t + A_5 P_{t-1} + v_t \quad \dots \quad (3)$$

$$\begin{aligned} \text{where } A_0 &= \frac{ad}{1 - \frac{1}{2}(b-d)}, \quad A_1 = \frac{1 + \frac{1}{2}(b-d)}{1 - \frac{1}{2}(b-d)}, \quad A_2 = \frac{c(1 + \frac{1}{2}d)}{1 - \frac{1}{2}(b-d)} \\ A_3 &= \frac{cd}{1 - \frac{1}{2}(b-d)}, \quad A_4 = \frac{e(1 + \frac{1}{2}d)}{1 - \frac{1}{2}(b-d)}, \quad A_5 = \frac{ed}{1 - \frac{1}{2}(b-d)} \text{ and} \\ v_t &= (\text{the residual term}) = \frac{(1 + \frac{1}{2}d)u_t - (1 - \frac{1}{2}d)u_{t-1}}{1 - \frac{1}{2}(b-d)} \end{aligned}$$

We can compute the values of the structural parameters a, b, c, e and the value of d , the depreciation rate, from the known values of the parameters of the

estimating equation given above.¹⁰ It is important to note that over-identification of d following the inclusion of both income and price as predictors in the structural equation can be overcome by the method of constrained least squares and the process of iteration. In this study we present two sets of results. The first set is obtained without overcoming the problem of over-identification of d . It may be seen that in the estimated equation for wheat none of the price coefficients is statistically significant. We have, therefore, taken $d=d_1$ which is computed from the income coefficients since income appeared to have significant influence on consumption of wheat. In case of equations estimated for rice and maize, it is price (and not income) which is found to be significantly related to consumption. In these two cases, we have, therefore, used $d=d_2$ as the relevant depreciation rate.

The second set of results presented in this paper is obtained by refitting the estimating equation for all the commodities (wheat, rice and maize) after deleting the non-significant variables from the model. This approach, though based on purely statistical logic, automatically solves the problem of over-identification of d .

For any given value of the state variable c and e in Equation (1) denote the 'short run' income and price derivatives respectively. In the long run when stocks are permitted to adjust, so that

$\dot{s}_t=0$, we obtain from Equations (1) and (2)

$$\hat{q} = \frac{ad}{d-b} + \frac{cd}{d-b} \hat{x} + \frac{ed}{d-b} \hat{p}$$

where the long-term levels of q , x and p are denoted by \hat{q} , \hat{x} , and \hat{p} . The 'long run' derivatives¹¹ are given by $c' = \frac{cd}{d-b}$, and $e' = \frac{ed}{d-b}$.

The dynamic demand model referred to above and employed in this paper is of the stock-flow variety. Houthakker, Taylor¹² and Tendulkar¹³ have subjected this model to empirical testing.

$$\begin{aligned} 10. \quad d &= \frac{A_3}{A_2 - \frac{1}{2}A_3} \text{ or } \frac{A_5}{A_4 - \frac{1}{2}A_5}, \quad a = \frac{2A_0(A_2 - \frac{1}{2}A_3)}{A_3(A_1 + 1)} \text{ or } \frac{2A_0(A_4 - \frac{1}{2}A_5)}{A_5(A_1 + 1)} \\ b &= \frac{2(A_1 - 1)}{A_1 + 1} + \frac{A_3}{A_2 - \frac{1}{2}A_3} \text{ or } \frac{2(A_1 - 1)}{A_1 + 1} + \frac{A_5}{A_4 - \frac{1}{2}A_5} \\ c &= \frac{2(A_2 - \frac{1}{2}A_3)}{A_1 + 1}, \quad e = \frac{2(A_4 - \frac{1}{2}A_5)}{A_1 + 1} \end{aligned}$$

11. In case of inventory adjustment where $b < e$ it may be verified that for $|d| > |b|$, $c' < c$ indicating a change in income has larger effect in the short run than in the long run. On the contrary, in case of habit formation when $b > 0$, $c' > c$ implying that the long run effect of income change will be greater than the short run effect because habit is characterized by inertia. Similar interpretation may be made for e' and e .

12. See H. S. Houthakker and Lester D. Taylor : *op. cit.*

13. Suresh D. Tendulkar, "Econometric Study of Monthly Consumption Expenditures in Rural Uttar Pradesh," *American Journal of Agricultural Economics*, Vol. 51, No. 2, February, 1969, pp. 119-137.

Two special cases of the above dynamic model need to be mentioned. (a) One of the special cases arises when the difference $/A_2 - A_3/$ and $/A_4 - A_5/$ is not statistically significant implying $d=2$. This necessarily reduces Equation (3) to $q_t = A_0 + A_1 q_{t-1} + A_2 x_t + A_3 P_t$ which resembles in form the Koyck distributed lag equation. (b) The intercept, x_{t-1} , and P_{t-1} terms disappear from equation (3) when the value of d is equal or close to zero and consequently the long run nature of the model breaks down.

Since our dynamic model [Equation (3)] is a first order difference equation, the projection procedure will be different from that usually used for a static model. In order to arrive at projections of per capita consumption, either one of the following two procedures, which in principle are the same, may be followed: (a) Given some initial values of the predictors, projection can be made year by year; (b) alternatively, the first order difference equation can be obtained and projections made from the solved equation. The latter procedure involves larger rounding errors and hence the first approach though laborious is advisable.¹⁴ In this study year by year projections of per capita consumption from 1964-65 through 1968-69, have been made for wheat with the average per capita income as the initial value. The mean per capita consumption and relative price have been taken to illustrate how projections can be built up from the dynamic model used in this paper.¹⁵

Data and Variables

Time-series data of a changing cross-section of 46 households covering the period 1949-50 to 1963-64 were obtained from the reports published by the Board of Economic Inquiry, Punjab. Annual data on consumption, income, prices of wheat, rice and maize (including other cereals) were used and the methodology described above adopted for estimating the relevant price and income elasticities.

Symbols and notations used in this section are given below:

q_t = per capita consumption of the concerned commodity in year t (in quintals).
 x_t = per capita income in year t in constant rupee (1949 = 100).
 P_t = relative price per quintal in year t (1949 = 100).

$$\Delta q_t = q_t - q_{t-1}$$

d_1 = depreciation rate calculated from income coefficients.

$$\Delta x_t = x_t - x_{t-1}$$

d_2 = depreciation rate calculated from price coefficients.

$$\Delta P_t = P_t - P_{t-1}$$

a = intercept.

e = the short run price coefficient.

b = stock coefficient.

c' = the long run income coefficient.

c = the short run income coefficient.

e' = the long run price coefficient.

d = depreciation rate.

n = the short run income elasticity.

14. Houthakker and Taylor : *ibid.*

15. It should have been better to use actual per capita income for the initial year, 1963-64 and the per capita consumption and relative price for the same year instead of considering their means.

| | |
|--|--|
| n' = the long run income elasticity. | ***Significant at 1 per cent level. |
| s = the short run price elasticity. | **Significant at 5 per cent level. |
| s' = the long run price elasticity. | *Significant at 10 per cent level. |
| | R^2 = Coefficient of multiple determination. |

INTERPRETATION OF THE RESULTS

Ordinary least squares procedure was used to estimate equation (3) for data relating to wheat, rice and maize (including other cereals).

I. *Wheat*

$$q_t = -2.52604 + 1.60461^{***} q_{t-1} + 0.00493^{***} \Delta x_t + 0.00329^{***} x_{t-1} \\ (0.15162) \quad (0.00046) \quad (0.00045) \\ - 6.46554 \Delta p_t - 0.26971 p_{t-1} \\ (6.33339) \quad (8.15415)$$

$$R^2 = 0.77, \quad a = -1.93932, \quad b = 1.46426, \quad c = 0.00253,$$

$$e = -4.86114, \quad d_1 = 1.00000, \quad c' = -.00545, \quad e' = 10.47073,$$

$$n = 0.65894, \quad n' = -1.41946, \quad s = -2.79557, \quad s' = 6.02157.$$

The above results suggest that the relative price of wheat does not significantly influence the consumption of wheat. The consumption of wheat is dependent on lagged consumption of wheat and income. A positive b value indicates that wheat consumption is subject to habit formation ($b > 0$) although the habit wears off rapidly as evidenced by the rather large value of d . The positive value of b is consistent with the non-durable nature of the commodity. The long run coefficients of income and price and the corresponding elasticities have inappropriate signs. This difficulty is not experienced when the non-significant price variables are deleted from the model and the estimating equation refitted.

The estimating equation for wheat after deleting price terms becomes

$$q_t = -1.80017 + 0.47241^{***} q_{t-1} + 0.00497^{***} \Delta x_t + 0.00569 x_{t-1} \\ (0.12292) \quad (0.00053) \quad (0.00045)$$

$$R^2 = 0.68, \quad a = -9.1137, \quad b = 1.96647, \quad c = 0.00288,$$

$$c' = 0.01079, \quad n = 0.7511, \quad n' = 2.81027, \quad d = 2.68308.$$

A static demand model using the same data yielded the following result :

$$q_t = -.89859 - 2.70377 p_t + .00637^{***} x_t - .00475^{***} k_{t-1} \quad R^2 = 0.81 \\ (5.6217) \quad (0.00019) \quad (0.00040)$$

where q_t has the same interpretation as in the dynamic model, P_t = relative price per quintal in constant rupees (1949 = 100), x_t = per capita income in 1949 rupees and k_{t-1} = per capita savings lagged by one year in constant rupees

1949 = 100. The income elasticity calculated by using the static model is 1.6741 which is relatively higher than the corresponding dynamic model estimate. The static model also supports the result obtained in the dynamic model that price does not play a decisive role in consumption of wheat whereas income and savings do.

Table II gives the values of the predictors and the level of per capita consumption in 1963-64, the initial year for projection.

TABLE II—VALUES OF THE PREDICTORS AND THE LEVEL OF PER CAPITA CONSUMPTION OF WHEAT

| Predictors | 1963-64 | Assumed growth rate | 1964-65 | Assumed growth rate | 1965-66 | Assumed growth rate |
|-------------------------|---------|---------------------|---------|---------------------|---------|---------------------|
| Relative price | 1.1329 | 0 | 1.1329 | 0 | 1.1329 | 0 |
| Per capita income (Rs.) | 513.09 | 3% | 528.48 | 3% | 544.33 | 3% |

| Predictors | 1966-67 | Assumed growth rate | 1967-68 | Assumed growth rate | 1968-69 |
|-------------------------|---------|---------------------|---------|---------------------|---------|
| Relative price | 1.1329 | 0 | 1.1329 | 0 | 1.1329 |
| Per capita income (Rs.) | 560.66 | 3% | 577.44 | 3% | 594.76 |

A projection with the estimates obtained from our dynamic model without price variables is given below :

| | 1963-64 level | 1964-65 | 1965-66 | 1966-67 | 1967-68 | 1968-69 |
|-----------------------------------|---------------|---------|---------|---------|---------|---------|
| Per capita consumption in quintal | 1.97 | 2.13 | 2.29 | 2.46 | 2.64 | 2.82 |

II. Rice

$$q_t = 0.09734 + 0.78604^{***} q_{t-1} - 0.00001 \Delta x_t - 0.00004 x_{t-1} \\
\begin{matrix} (0.04134) & (0.00004) & (0.00004) \end{matrix} \\
- 0.68077^{***} \Delta p_t - 0.30271^* p_{t-1} \\
\begin{matrix} (0.15151) & (0.17791) \end{matrix}$$

$$R^2 = 0.65, \quad a = 0.19063, \quad b = 0.33220, \quad c = .00001,$$

$$e = -0.59284, \quad d_2 = 0.57178, \quad c' = .00002 \quad e' = -1.41479,$$

$$n = 0.02772 \quad n' = 0.05542 \quad s = -5.78456 \quad s' = -13.80457.$$

The coefficients of Δx_t and x_{t-1} have unacceptable negative signs and none of them is statistically significant. An interpretation of the result suggests that variation in income would not significantly influence variation in rice consumption. The price variable, however, has a significant influence on the consumption of rice. As in the case of wheat, the consumption of rice is subject to habit for-

mation (since the value of b is positive) and does not appear to depend on inventory adjustment. The habit, however, wears off rather rapidly. The short run price elasticity is as high as 5.7845 and the long run elasticity is still higher (13.8045). The results obtained after omission of income variable are presented below.

$$q_t = 0.08034 + \underset{(0.04117)}{0.78264^{***}} q_{t-1} - \underset{(0.15101)}{0.68886^{***}} \Delta p_t - \underset{(0.17683)}{0.32191^*} p_{t-1}$$

$$R^2 = 0.65, \quad a=0.14754, \quad b=0.36592, \quad e=-0.59227,$$

$$e' = -1.48097, \quad s=-5.77896, \quad s'=-14.45030, \quad d=0.60978.$$

The static demand model for rice yielded poor fit and hence is not referred here.

III. Maize¹⁶ (including Other Cereals)

$$q_t = 0.707443^{***} + \underset{(0.04850)}{0.44979^{***}} q_{t-1} - \underset{(0.00009)}{0.00004} \Delta x_t - \underset{(0.00007)}{0.00009} x_{t-1} \\ - \underset{(1.36991)}{3.74062^{***}} \Delta p_t - \underset{(1.83137)}{3.43287^*} p_{t-1}$$

$$R^2 = 0.34, \quad a=0.57545, \quad b=0.93690, \quad c=0.000007, \quad e=-2.79230,$$

$$d_2=1.69593, \quad c'=0.000015, \quad e'=-6.23920, \quad n=0.0049, \quad n'=0.1137, \\ s=-3.5557, \quad s'=-7.9448.$$

Like wheat and rice, maize consumption is also subject to habit formation ($b > 0$) which wears off very rapidly as evidenced by a large value of d (1.6959). As in the case of rice, income did not influence maize consumption. No static model could be selected for this commodity because of very low R^2 value of the fitted equation.

The equation fitted without the non-significant income terms and the structural parameters and elasticities obtained from the estimated coefficients are given below:

$$q_t = 0.66259 + \underset{(0.04840)}{0.45150^{***}} q_{t-1} - \underset{(1.36912)}{3.73075^{***}} \Delta p_t - \underset{(1.82942)}{3.45796^*} p_{t-1}$$

$$R^2 = 0.31, \quad a=0.52850, \quad b=0.97170, \quad e=-2.75820,$$

$$e' = -6.30453, \quad s=-3.51222, \quad s'=-8.02805, \quad d=1.72745.$$

The results presented in the preceding sections suggest the need for more comprehensive econometric work on estimation of supply and demand elasticities. The supply estimates indicate the importance of more appropriate specification of price expectation and incorporation of risk elements in the model. The price and income elasticities derived from the dynamic demand model represent qualitatively better estimates because the model outlines a more realistic representation of consumer behaviour.

16. The equation was selected for estimation of elasticities although it did not give good fit.