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Seminar on
DEMAND AND SUPPLY
PROJECTIONS FOR
AGRICULTURAL
COMMODITIES

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ECONOMICS, BOMBAY

Seminar on

DEMAND AND SUPPLY
PROJECTIONS
FOR AGRICULTURAL
COMMODITIES



THE INDIAN SOCIETY OF AGRICULTURAL ECONOMICS

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ALTERNATIVE MODELS OF LONG RUN SUPPLY
AND DEMAND PROJECTIONS IN AGRICULTURE

R. C. Agrawal*

Introduction

Man has always been curious to learn about what the future has in store for him. Agricultural economists are no exception to this. The theme of our seminar regarding demand and supply projections in agriculture is one such attempt to peep into the future. The deliberations are both timely and relevant, specially in the context of the "NEW" technology in Indian Agriculture. A study of the supply and demand projections of agricultural commodities is extremely useful to the economists, the State, the administrators, and the individual. The utility of these studies to us lies in the fact that they provide us with a ground to test various theories, hypotheses and models, and accept, modify or discard them accordingly.

Forecasting has never been easy. The peculiar nature of agricultural production makes the job all the more challenging. Disturbances in technology, weather conditions, prices, State policies (domestic as well as foreign), population, introduction of new crops and replacement of the old all makes accurate projections all the more difficult. The problem may be further complicated by other considerations relating to the nature, reliability and adequacy of the available information.

A number of tools are available to the economists to make these projections. The selection of a suitable approach is a function of several variables such as the objectives

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and scope of the study, type and nature of the information required, kind, adequacy and reliability of data available for analysis, and the like. It is not the sophistication of the model which is all important. The selection of an appropriate model and relevant interpretations of the results of analysis for use by policy makers are equally important if the study is to be meaningful.

The objective of this paper is to briefly discuss some of the models that have been (or could be) used to make supply and demand projections in agriculture. The paper does not attempt the stupendous task of dealing with all types of models used in demand and supply projections. Nothing has been said in the paper about the desirability or otherwise of using the macro or the micro approach in making these projections. The pros and cons of both are too well-known to be mentioned here. The approaches discussed here could be used in both cases.

Unless stated otherwise, we have assumed the following in this paper:

1. Perfect competition in the input market
2. Perfect competition in the output market
3. The objective of the farm firm is to maximize profits
4. Closed Economy.

Supply Projections in Agriculture

In agriculture, the supply of a commodity depends on, among other things, its price and price of other competitive and complementary products, the level of technology of its production, and the prices of inputs used. Basically,

$$S_{yt} = S(P_{yt}, P_{at}, P_{bt}, P_{xt}, T_t, U_t)$$

where,

S_{yt} is the supply of product Y in time t.

P_{yt} is the price per unit of product (y) in time (t).

P_{at} is the price index of other competitive commodities in time t.

P_{bt} is the price index of other complementary commodities in time t.

P_{xt} is the price of input used in the production of Y_t .

T_t is the level of technology used in the production of Y_t , and

U_t includes everything else (portmanteau) such as weather, etc.

Anything that affects these independent variables would also affect the level of supply. The greater the accuracy in the incorporation in a given model of the changes in these variables, the more precise are the projections of supply. The following approaches have been discussed in this paper in connection with the supply projections of agricultural commodities.

1. Production Functions Approach
2. Programming Approach
 - i) Linear Programming
 - ii) Recursive Programming
3. Regression Analysis Approach
4. Simultaneous Equations Approach

1. Production Functions Approach:

Production function is a mathematical expression of the input-output relationship. It is a single-valued, continuous function and embodies in it the available technology at its maximum efficiency. It is a versatile expression and can be used to derive several meaningful quantities. The derivation of the supply of output and demand for input are two cases in point. Here we shall

use this approach to derive the supply function of a commodity.

$$\text{Let } Y_t = f_t(x_1, x_2, \dots, x_i, \dots, x_n) \text{ ----- (1)}$$

where

Y_t is the expected quantity of output in time t , and

x_i is the quantity of the i th variable factor.

For simplicity let us assume that only x_i is variable and the rest are fixed, i.e.,

$$Y_t = f_t(x_i) \text{ ----- (1a)}$$

We could then write x_i as a function of Y_t as in (2)

$$x_i = f_t^{-1}(Y_t) \text{ ----- (2)}$$

$$\frac{dx_i}{dY_t} = \frac{df_t^{-1}(Y_t)}{dY_t} \text{ ----- (3)}$$

Putting the expression in (3) equal to P_{yt}/P_{xit} (under the assumption of perfect competition in both the product and the resource markets and also that the objective of the farmer is to maximize his profits) and solving for Y_t gives us the supply function of Y for different prices of Y and x_i (i.e. P_{yt} and P_{xit}) that are likely to prevail in time t . Consider the Cobb-Douglas type of production function in (4) with two variable inputs x and z

$$Y_t = a_t x_t^{b_t} z_t^{c_t} \text{ ----- (4)}$$

where

Y_t is again the expected quantity of output in time t , x_t and z_t are quantities of inputs x and z likely to be used to produce Y_t ,

b_t and c_t are elasticities of production of Y with respect to x and z .

a_t is interpreted to reflect technology and is sometimes referred to as the index of the total factor productivity.

If we assume the technological change to be neutral i.e., b and c are constants, it can be shown that the supply of Y , as a function of technology (as reflected in a , b and c in the production function), its own price and the price of variable inputs x and z , would be as given in (5).

$$SY = (a) \left(\frac{1}{1-b-c} \right) \left(\frac{b}{1-b-c} \right) \left(\frac{c}{1-b-c} \right) \left(\frac{b+c}{1-b-c} \right) \left(P_y \right) \text{-----(5)}$$

A cursory glance at (5) would reveal that the supply of Y is inversely related to the price of factors and directly to its own price. Under constant or increasing returns to scale of production (i.e., $b+c = 1$ or $b+c > 1$), if it is at all profitable to produce (supply some quantity of output, it will always pay the farmer to produce (and also supply) any quantity of output, and the value of S_{yt} would be indeterminate.

Under the assumption of 'neutral' change in technology and constant returns to scale such that $b > 0$, $c > 0$,

$$\frac{\dot{Y}}{Y} = \frac{\dot{a}}{a} + b \left(\frac{\dot{x}}{x} \right) + \frac{\dot{z}}{z} \text{-----(6)}$$

where $\dot{}$ represents derivative with respect to time.

The term on the left hand side of (6) represents the relative rate of growth of output which is a sum total of relative rate of growth in technology, i.e., $\frac{\dot{a}}{a}$ and relative rates of growth of factors multiplied by their

respective elasticities of production. Therefore, for relative rates of growth of factors, relative rate of growth of output and, therefore, of supply could be found and supply computed at a given point in time.

Production functions of the CES type (constant elasticity of substitution production functions), have also been used to make growth projections. As the name (CES) indicates, the elasticity of substitution between factors, is constant but not necessarily unitary. It would perhaps be interesting to examine the use of this type of functions in making projections first assuming 'neutral' technological change and then relaxing this assumption.

(a) Neutral Change in Technology

Let us take the model in (4), b and c need not be constants but

$$\frac{db}{d\left(\frac{x}{z}\right)} = \frac{-dc}{d\left(\frac{x}{z}\right)} \quad . \quad \text{If } b+c = 1, \text{ then } \frac{db}{dt} = (b)(c)\left(\frac{e-1}{e}\right)$$

$$\left(\frac{\dot{x}}{x} - \frac{\dot{z}}{z}\right) = -\frac{dc}{dt} \quad \text{-----}(7)$$

where

e is the elasticity of substitution and is defined

$$\text{as } d \log \left(\frac{f_x}{f_z} \right) \\ \frac{\quad}{d \log \left(\frac{x}{z} \right)}$$

f_x and f_z being the partial derivatives of Y with respect to x and z respectively.

(a) If $e = 1$, then $\frac{db}{dt} = 0$ and b and c stay the same.

(b) If $e < 1$ and rate of growth of x is less than rate

of growth of z then $\frac{db}{dt} > 0$ and b goes up, and c decreases.

(c) If $e > 1$ and $\left(\frac{\dot{x}}{x} - \frac{\dot{z}}{z}\right) > 0$, then again $\frac{db}{dt} > 0$ and b increases while c decreases.

(d) If $e < 1$ and $\frac{\dot{x}}{x} - \frac{\dot{z}}{z} > 0$ or vice versa, then $\frac{db}{dt} < 0$ and b goes down, while c increases. If $\frac{\dot{a}}{a}$, $\frac{\dot{x}}{x}$ and $\frac{\dot{z}}{z}$ stay the same, whether $\frac{\dot{y}}{y}$ will fall or rise will depend on the magnitude of change in b and c or in other words on the value of c and the nature of difference between $\frac{\dot{x}}{x}$ and $\frac{\dot{z}}{z}$.

General speaking, under the assumption of given and constant rates of growth of x and z ,

$$\frac{d}{dt} \left(\frac{\dot{y}}{y} \right) = \frac{db}{dt} \left(\frac{\dot{x}}{x} - \frac{\dot{z}}{z} \right) = - \frac{dc}{dt} \left(\frac{\dot{z}}{z} - \frac{\dot{x}}{x} \right) \text{-----}(8)$$

(b) 'Non-Neutral' Technological Change

Now let us relax the assumption of 'neutral' change in technology. Suppose b_t becomes b_{t+1} and c_t becomes c_{t+1} in

time $t+1$. The rate of technological change could then be

expressed as $\frac{b_{t+1} - b_t}{b_t}$ in respect of factor x and

$\frac{c_{t+1} - c_t}{c_t}$ in respect of factor z and, therefore,

equation (7) would take the form in (9)

$$\frac{db_t}{dt} = b_t (c_t) \left(\frac{\dot{x}_t}{x_t} - \frac{\dot{z}_t}{z_t} \right) \frac{e-1}{e} + (b_t) (c_t) \left(\frac{b_{t+1} - b_t}{b_t} - \frac{c_{t+1} - c_t}{c_t} \right) \text{-----}(9)$$

Clearly if the change is 'neutral' $\frac{c_{t+1} - c_t}{c_t} = \frac{b_{t+1} - b_t}{b_t}$

and therefore, the last term on the right hand side of (9) would become zero and equation (9) would be reduced to the same old familiar form in (7).

In this case, the rate of change in the growth of output would be

$$\frac{d}{dt} \left(\frac{Y}{Y} \right) = \frac{db}{dt} \left(\frac{\dot{x}}{x} - \frac{\dot{z}}{z} + \frac{b_{t+1} - b_t}{b_t} - \frac{c_{t+1} - c_t}{c_t} \right) \text{-----(10)}$$

In the foregoing analysis, an attempt has been made to demonstrate the use of production functions to project growth of production (and indirectly that of the supply). These projections of supply, made on the basis of production function, at best, would be only as good as out projections of input and output prices, likely technology and the goodness of fit of the production function that is used for projection purposes.

2. Programming Approach to Supply Projections:

We have so far looked at the procedure of projecting the output (and, thereby the supply) of agricultural commodities by using the 'Production Functions Approach.' Unfortunately, the derivation of production functions in itself is subject to several limitations. There may be multicollinearity among the 'independent' variables; we may not be able to identify all the relevant variables, there may be difficulty in precisely pinpointing the contribution of different known variables to the output and supply, adequate information in the desired form may not be available; and so on. Though production function approach

cannot be completely neglected (and it would be a great folly on our part to even think of it), some of the above difficulties can be obviated by using the 'Programming' approach in the estimation of 'normative' supply function. Here we propose to refer to the use of linear and recursive programming techniques in the projection of supply of agricultural commodities.

Linear Programming Approach:

The general format of a maximization linear programming problem (under the usual assumptions of additivity, linearity divisibility, finiteness of resources and activities, etc.) is given in (11)

$$\begin{array}{ll} \text{Maximize} & c'Y \\ \text{Subject to} & AY \leq b \\ & Y \geq 0 \end{array} \quad \left. \begin{array}{l}) \\) \\) \end{array} \right\} \text{-----(11)}$$

If we consider it a problem of farm planning with an objective of profit maximization, then c would be the profit vector, Y the activity vector (product vector either in terms of acreage, quantity of output or some other suitable unit), A the input-output matrix (also referred to as the technology matrix), and b the resource vector. The prices of inputs used in the production process, price of output, the level of production, all these are reflected in the c vector. Matrix A represents the technology used by the farmer in raising the activities from the set of resources available with him as represented by b . Thus any change in the prices of inputs or output, or both would, generally, change the c vector. For a given level of technology and price of resources, a change in output prices would change the components of c vector. Likewise any change in technology would be reflected in the yields and A matrix, whereas

a change in resources would change the b vector, Any change in A , b or c may change the supply.

In order to derive the supply functions of the i th commodity, the linear programming problem is first solved with one set of prices of various commodities that the farmer may raise (i.e., feasible activities). Then the price of the i th commodity is changed with others left constant. Thus for a given level of technology and prices of resources and other feasible activities, only the i th component of c vector would change; all other components would stay the same. The problem is solved again with the new c vector. This is called variable price programming and through this, one can derive (a) the optimal levels of supply of the commodity that should be forthcoming on the farm at different product prices and, (b) such price levels of the i th commodity where its supply function takes a step. Similarly, a change in the price or quantity of available resources of the farmer or changes in technology can be taken care of through sensitivity analysis either individually or simultaneously. Thus if we could have an idea of the likely prices of different inputs used in the production of commodities raised on the farm, technology or resource availability to a farmer in some future period t , we could find the optimum levels of different commodities that he would grow and the most desirable allocation of his resources. An obvious merit of this approach is that we could examine the likely effects of changes in the prices of a commodity on the supply of not only that commodity but all other commodities (raised on the farm) as well.

The linear programming approach considers only those resources which are limited. If a resource is not fixed, its contribution to supply is not reflected in the supply function derived by using this tool.

(E) Recursive Programming Approach to Supply Projections:

One technique that incorporates time series analysis in linear programming framework has been developed by Day [1] for making supply projections. In this method, called 'Recursive Programming', we start with a linear programming problem, the point of start being $t = 0$. The solution to this problem yields constraints for the next period and so on. A new 'c' vector may be used for each period, depending on the price and yield expectations during that period. The model makes use of the concept of 'Flexibility Constraints.' First introduced by J.M. Henderson [2], the concept assumes that the change in production (or acreage) of an agricultural commodity during a given period has some lower and upper bounds, thereby implying that the production (or acreage) of that commodity in time t varies within the two limits and is some function of the production (or acreage) in time $t-1$ which, in turn, depends on the production (or acreage) of that commodity in time $t-2$.

Suppose a farmer has $A(t)$ acres of land available in period t on which he can grow two crops G_1 and G_2 . Further, let the acreage under these two crops be $A_1(t)$ and $A_2(t)$ respectively. K_1 and K_2 are flexibility co-efficients for G_1 and G_2 - \tilde{K}_1 and \tilde{K}_2 comprising the upper and \underline{K}_1 and \underline{K}_2 the lower bounds such that:

$$\begin{array}{rcl}
 A_1(t) \leq (1 + \tilde{K}_1) A_1(t-1) & \text{-----} & (12.a) \\
 A_1(t) \geq (1 + \underline{K}_1) A_1(t-1) & \text{-----} & (12.b) \\
 A_2(t) \leq (1 + \tilde{K}_2) A_2(t-1) & \text{-----} & (12.c) \\
 A_2(t) \geq (1 + \underline{K}_2) A_2(t-1) & \text{-----} & (12.d)
 \end{array}
 \left. \begin{array}{l}) \\) \\) \\) \end{array} \right) \text{---(12)}$$

The inequality in (12.a) means that the acreage under G_1 will at most be the acreage under that crop in the previous year plus \tilde{K}_1 (upper flexibility coefficient for G_1) times this acreage. This is the upper limit for $A_1(t)$. Likewise, the lower bound for acreage under G_1 is given by the right hand expression in (12.b) where \underline{K}_1 is the lower flexibility coefficient for $A_1(t)$. (12.c) and (12.d) specify the upper and lower limit respectively for $A_2(t)$ with \tilde{K}_2 and \underline{K}_2 being the upper and lower flexibility coefficients. These flexibility coefficients are largely determined by the future expectations of prices and yields. Clearly $\underline{K}_1 > -1$ and $\underline{K}_2 > -1$, because if $\underline{K}_1 \leq -1$ and $\underline{K}_2 \leq -1$, then according to (12.b) and (12.d), $A_1(t)$ and $A_2(t)$ could be less than zero which is not feasible as negative area under a crop does not make any sense.

The area under these two crops in a given year cannot exceed the total acreage available during that year i.e.

$$A_1(t) + A_2(t) \leq \bar{A}(t) \text{ ----- (13)}$$

(13) together with (12.a), (12.b), (12.c) and (12.d) makes up the restrictions to be included in the model. If the profits per acre of G_1 and G_2 in time t are $c_1(t)$ and $c_2(t)$ respectively, and if the objective of the farmer is to maximize his profits, the problem could be stated as follows:-

$$\text{Maximize } c_1(t) A_1(t) + c_2(t) A_2(t) \quad)$$

subject to

$$\begin{array}{r}
 A_1(t) \leq (1 + \tilde{K}_1) A_1(t-1) \\
 A_1(t) \geq (1 + K_1) A_1(t-1) \\
 A_2(t) \leq (1 + K_2) A_2(t-1) \\
 A_2(t) \geq (1 + \tilde{K}_2) A_2(t-1) \\
 A_1(t) + A_2(t) \leq \bar{A}(t) \\
 A_1(t) \geq 0, A_2(t) \geq 0
 \end{array}
 \left.
 \begin{array}{l}
) \\
) \\
) \\
) \\
) \\
) \\
)
 \end{array}
 \right\} \text{-----(14)}$$

The model in (14) is the familiar linear programming problem and could be solved for $A_1(t)$ and $A_2(t)$ in the usual manner. These solutions are then used for framing the problem to be solved for the next phase of the system. The whole time path of supply (or acreage) is composed of several phases. A phase is defined as a period of time during which the same equations govern the supply system. The number of such dynamic equations is exactly equal to the number of variables appearing in the solution. The direction and magnitude of changes would depend on the value of the \tilde{K}_1 , K_1 , \tilde{K}_2 , K_2 , $c_1(t)$, $c_2(t)$, $A_1(0)$ and $A_2(0)$.

With the introduction of demand structure, one could compute the price-movements for any phase. Further, technological changes could be incorporated in the model and their effects on investments and supply found out. The model could be generalized in a way that yearly re-evaluation of production and investment plans is possible. The technique, therefore, appears to be quite promising and versatile.

However, there are some difficulties in its use. For example, if $A_i(0) = 0$ for some i (i.e., if acreage

under any crop is zero in time zero) then the value of that $A_i(t)$ would always be zero in further solutions. Likewise if $K_i = -1$ for some i , then $A_i(t)$ would be zero in time t and in subsequent periods as well. Determination of K 's also presents quite a few problems in practice because they are governed by a multiplicity of forces that are difficult to be measured precisely.

3. Supply Projection With Regression Analysis:

The use of regression analysis in projecting supply of agricultural commodities has been extensive. These projections have been either in terms of acreage or output. Lagged models (15) emphasising cob web nature of agricultural supply where the producers respond to a change in price not instantaneously but with a time lag, as well as simple models where supply in time t is a function of its expected price during that time (16) have been developed.

$$S_{yt} = g(P_{yt-1}) \quad \text{-----} \quad (15)$$

$$S_{yt} = h(P_{yt}) \quad \text{-----} \quad (16)$$

There are several variants of (15) and (16). These could be linear as in (17.a and 17.b) or power functions or of some other types.

$$S_{yt} = a + b P_{yt-1} + c t \quad \text{-----} \quad (17.a)$$

$$S_{yt} = a + b P_{yt} + c t \quad \text{-----} \quad (17.b)$$

where

b is the slope of the regression line and c represents shift in supply over the period of study. Further refinements of (17.a) and (17.b) are possible through the introduction of the prices of other commodities,

expectations regarding the area under the commodity, or the assumption of non-linearity. One such model in terms of acreage [10,24] proposed by Nerlove is given in (17.c).

$$A_t = a + b_1 P_{yt-1} + b_2 A_{t-1} + v_t \text{ -----(17.c)}$$

where

A_t is the acreage under the crop in time t and v_t is a random term.

In this approach, projections (estimates) of yields per acre have also to be made in order to estimate the quantity of supply. A modification of this model [25] includes several other variables such as expected yields, risk factor, etc. Another lagged supply function of the form given in (18) has been used [3] for agricultural commodities:

$$S_{yt} = a + b \frac{P_{yt}}{P_{st}} + c \frac{P_{yt}}{P_{ct}} + S_{yt-1} \text{ ----- (18)}$$

where

P_{st} and P_{ct} are the prices of products that are respectively substitutes and complementary to Y .

Therefore, there are several forms of regressions models that have been or could be used for supply projections; the choice would depend on several factors such as length of the time series data available and their trend, variation explained by different variables, sampling error of the relevant coefficients in relation to their size, etc.

4 Simultaneous Equations Approach to Supply and Demand Projections

Simultaneous equations permit estimation of both the

demand for and supply of a product at the same time. In agriculture, several demand and supply studies have been made for as widely divergent commodities such as eggs [4] and onions [5]. A simple simultaneous equation model with demand as a function of current price and supply as a function of the price prevailing in the preceding period is given in (19).

$$\left. \begin{aligned} S_{yt} &= a + b P_{yt-1} + U_t && \text{----- (19.a) } \\ D_{yt} &= c + d P_{yt} + V_t && \text{----- (19.b) } \\ S_{yt} &= D_{yt} && \text{----- (19.c) } \end{aligned} \right\} \dots (19)$$

where

D_{yt} is the demand for Y in time t, a, b, c and d are constants and U_t and V_t are error terms. (19.c) gives the equilibrium condition of demand for a commodity in time t being equal to its supply in that period. Solving for P_y in terms of $P_y(0)$, we get

$$P_{yt} = (c-a) \left(\frac{1}{b} + \frac{d}{b^2} + \frac{d^2}{b^3} + \dots + \frac{d^{t-1}}{b^t} \right) + \frac{d^t}{b^t} P_y(0) + \frac{d^{t-1}}{b^t} (V_1 - U_1) + \frac{d^{t-2}}{b^{t-1}} (V_2 - U_2) + \dots + \frac{1}{b} (V_t - U_t) \quad (20)$$

The model would explode if $b < d$ and converge if $b > d$. For $b > d$, as t increases $\left(\frac{d}{b}\right)^t$ approaches zero. As t approaches infinity,

$$(c-a) \left(\frac{1}{b} + \frac{d}{b^2} + \frac{d^2}{b^3} + \dots + \frac{d^{t-1}}{b^t} \right)$$

approaches $\frac{(c-a)}{(b-d)}$

The time path of sequence, would, therefore, depend on the magnitude of (c-a) and (b-d).

Though least squares method is most commonly used in this approach, other approaches have also been tried. Feltner [6] used the two-stage least squares and limited information methods, in addition to the usual least squares method, to estimate demand for a supply of livestock products. Reduced forms were used to determine the demand elasticity of foodgrains and supply elasticity of livestock.

One of the merits, from the view point of statistical efficiency, of using P_{yt-1} for the supply equation (19.a) and P_{yt} for the demand equation (19.b) lies in the identification of the equations. A possible limitation of this model as pointed out by West [7] could be that the supply functions derived in this approach may be inadequate or improperly specified.

Demand Projections in Agriculture

The demand projections in agriculture can be broadly discussed under two broad heads, viz.,

- a. Demand projections of agricultural commodities, and
- b. Projections of demand for inputs in agriculture such as fertilizer, seed, pesticides and weedicides, tractors, pumping sets, etc.

1. Projections of Demand for Agricultural Commodities

The demand for a commodity is a function of the price of that commodity, the prices of its substitutes and complementary goods, income and tastes of the consumer, the population, etc.

$$D_{yt} = D (P_{yt}, P_{st}, P_{ct}, I_t, U_t) \text{ ----- (21)}$$

where

D_{yt} is the per capita demand for commodity Y in time t,
 P_{yt} is the price per unit of Y in time t,
 P_{st} is the price index of its competitive good in time t,
 P_{ct} is the price index of its complementary good in time t,
 I_t is the per capita income in time t, and
 U_t includes all other factors.

Regression and simultaneous equations models have been used to project demand for agricultural commodities. The latter approach is used in conjunction with the supply equation and was already been discussed earlier. We shall, therefore, confine our present discussions to the use of regression models in demand projections. The actual form of these models and the variables considered therein vary from study to study. For example, in his demand functions for wheat in the United States, Schultz [8] used simple regression analysis considering only price of the commodity and time. His basic model was

$$\log D_{yt} = a + b \log P_{yt} + ct + dt^2 \quad \text{-----} (22)$$

where

P_{yt} would be the deflated price of that commodity with some base year, and t is the time with the year of origin being designated as zero. The third and the fourth terms (having t and t^2) represent the shifts in demand for commodity Y the period of study.

The model presented in (22) does not take any cognizance of the changes in the income of the consumers. Other limitations of this model include assumptions with regard to

(i) independence of successive observations, and (ii) identification of the system.

Another approach to making demand projections of agricultural commodities is mainly based on coefficients of income elasticities, changes in per capita income and expected increase in population. One model [9] incorporating these is given in (23)

$$D_{yt} = D_{y0} \left(1 + \frac{I_t - I_0}{I_0} \right)^E \quad \text{----- (23)}$$

where

D_{yt} is the per capita quantity of commodity Y demanded in time t,

D_{y0} is the per capita quantity of Y demanded in the base period,

I_t is per capita income in the year of projection,

I_0 is the per capita income in the base year, and

E is the income elasticity of demand.

This model does not take into account the changes either in the relative prices of commodities or in the price elasticity. One formulation, in which both the price and income elasticities of demand could be taken into consideration is of the form given in (24) and was used by Wold and Jureen.

$$D_{yt} = a P_{yt}^{-\epsilon} I_t^E \quad \text{----- (24)}$$

where

D_{yt} , I_t and E are the same as in (23)

P_{yt} is the actual average price of the commodity at time t , and e is the price elasticity of demand. Equation (24) was written as (24a) and solved for e and E .

$$\log D_{yt} = \log a - e \log P_{yt} + E \log I_t + U_t \text{ ----- (24a)}$$

A significant correlation between the income and the price will render this model unsatisfactory. Wold and Jureen tried to overcome this by assuming that (a), $e > E$ and (b) $E = ke$ where k was a constant such that $k < 1$. Accordingly, relationship in (24) was rewritten as the one in (25) and estimates of e and E were obtained from (25) by using the least squares method.

$$\log D_{yt} = \log a - e (\log P_{yt} - k \log I_t) + U_t \text{ ----- (25)}$$

Distributed log models have also been used in demand analysis by Nerlove [10], Koyck [11] and Ladd and Martin [12], to mention a few. In these models, the present consumption, among others, a function of the lagged consumption. Due to a likelihood of the presence of auto-correlated errors, autoregressive least squares method has been found more satisfactory. These models appear to be specially useful for the short run (say monthly or quarterly) analysis of demand.

2. Projections of Demand for Agricultural Inputs

The demand for agricultural inputs could be derived by using either the regression models as in the case of any other agricultural commodity or the production function approach.

A. Regression Approach:

Both, time series and cross-section data have been used to derive demand functions and project demand for

agricultural inputs like fertilizers, irrigation, farm machinery and equipment, labour, etc. Of these, the emphasis has been on fertilizer studies (specially nitrogenous fertilizers). In deriving the demand for nitrogenous fertilizers in India, one study [13] treated the sale of these fertilizers as a function of acreage under important fertilizer consuming crops (such as rice, wheat, sugarcane, tobacco, cotton, potato, groundnut, etc.), and the irrigated area. The consumption of nitrogen in different States in time t was expressed as a function of the percentage of cultivated land irrigated during that period and the ratios of weighted average price of nitrogen in the State in time t to the weighted average price of crops in the State in time $t-1$. The Statewise demand projections for nitrogen were made for each crop by simply multiplying the expected acreage under that crop in a State in year t by the average rate of nitrogen application per acre. The price part was taken care of in the expected average rate of fertilizer application. There have been studies on the demand for other inputs and the actual model, its form and variables considered, depends, among other things, on the nature of input for which the demand functions are being derived. For example, in considering the demand for labour, we will have to consider the relative wage rates in agriculture and other industries, prices and availability of farm machinery, general level of agricultural prices, etc. The demand for agricultural equipment and machinery would depend on its relative profitability over human labour with respect to cost of fuel and oil, etc.

B. Production Functions Approach to the Derivation of Input Demand Function

While the projections made on the basis of the regression models (whether from time series or cross data)

are positive in nature, normative demand functions of inputs for various commodities could be derived from the production functions of the agricultural output. These are normative because they specify what 'ought to be' rather than 'what would be' the demand for inputs.

$$\text{Let } Y = f(F) \text{ ----- (26)}$$

where Y is the quantity of output and F is the quantity of fertilizer applied to obtain Y.

The demand for a factor to raise a product is then derived from the production function (of that product) by first taking the derivative of output with respect to the input and equating it to the inverse of the price ratios i.e., price of input divided by the price of output.

$$\frac{dy}{dF} = f'(F) \text{ ----- (27)}$$

Putting the expression in (27) equal to the inverse of the price ratios we get

$$f'(F) = \frac{P_F}{P_Y} \text{ ----- (28)}$$

The expression in (28) is then solved for F.

This approach assumes that the farmer does not have any other resource restriction and is using the profit maximizing quantity of fertilizer. The production functions approach, therefore, tends to give the upper bound of the demand for inputs.

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