CHAPTER III
SUPPLY RESPONSE MODELS - A THEORETICAL FRAME - WORK

In chapter II, the important studies relating to the supply responses of agricultural commodities have been discussed. There had been several successful studies that used econometric models to estimate elasticities, estimators developed from ancient Nerlovian model. The important supply response models which form the basis of the selection of variables as well as the final form of the partial adaptive expectations model used in the present study are discussed here in this chapter.

Supply Response Functions

The supply curve shows the relationship between price and quantity supplied on the assumption that other determinants of supply are held constant. These other determinants are rainfall, fertilizer prices of competing crops, wages etc. When the 'ceteris paribus' assumption is not met then there will be shifts in the supply curve.

The statistical data used for correlating quantity supplied and price are of market transactions over a period of time. As such the 'ceteris paribus' assumption is not satisfied and the simple relationship extend to a multivariate one. Instead of having the supply equation:

\[ S_t = \alpha + \beta P_t + u_t \]  \hspace{1cm} (3.1)

where

\( S_t \) = quantity supplied in period \( t \)
\( P_t = \) price in period \( t \)  
\( u_t = \) Error in period \( t \)  
\( \alpha \) and \( \beta = \) Constant parameters  
The following type of relationship should form the basis for the analysis.  
\[ S_t = \alpha_0 + \alpha_1 P_t + \alpha_2 P_t + \alpha_3 R_t + \alpha_4 W_t + u_t \ldots (3.2) \]
where  
\( P_t = \) Index of prices of competing crops in period \( t \)  
\( W_t = \) the wage rate in period \( t \)  
\( R_t = \) Rainfall in period \( t \)  
\( \alpha_0, \alpha_1, \alpha_2, \alpha_3, \alpha_4 = \) Constant parameters  
\( S_t, P_t \) and \( u_t \) as previously defined  

The choice of the other determinants of supply depends on the characteristics of the production schedule of each crop or product. It is to be further noted that these characteristics may even change in the same country or locality over time. What therefore, needed is a comprehensive supply model which can incorporate the various alternative opportunities open to the farmer.

**Types of Supply Response**

Supply responses of primary producers vary considerably according to the choice of supply response models and the characteristics of the crops analysed.

The supply response of individual crops covers perennial and annual/seasonal crops. Annual/seasonal and perennial crops have different
characteristics and present different conceptual problems. Therefore, they require the use of different models.

Most of the econometric studies on supply responses have been carried out on annual/seasonal crops. These crops form the staple foods of most underdeveloped countries and as self-sufficiency in food became the overriding aim of most of the underdeveloped countries, emphasis was placed on such crops. Policies which could encourage greater production of these staple crops were required and formulation of these policies necessitated supply response studies on such crops. The crops considered in the present study takes account of these problems for primary producers in Kerala.

**Responsiveness of Annual Crops**

The underlying aim of all supply response studies is to find out how a farmer intends to react to movements in the price of the crop that he produces. When more than one crop is being cultivated the aim is to find out how the farmer intends to reallocate his efforts between the various crops in response to changes in the relative price levels. In attempts to quantify such price responsiveness, acreage planted and not actual output should be used as the dependent variable because in most agricultural activities actual output is not a good proxy for intended output. The acreage planted would give a better indication of the farmer's intention as he has greater control over this variable.

Six different models can be identified in the supply response studies of producers of annual crops. These are:
(i) the simple Koyck distribution lag model or the simple Nerlovian expectations model

(ii) the complex Nerlovian expectations model

(iii) the Koyck second order lag model

(iv) Nerlovian adjustment model

(v) the expectations adjustment model and

(vi) the simple model

(i) Simple Koyck Distribution Lag Model/simple Nerlovian Expectations model

Koyck believes that in a dynamic setting the current value of a variable, say Y, depends on many lagged values for another variable, such as \( x_{t-1} \), \( x_{t-2} \), \( x_{t-3} \), etc. A general distributed lag function is

\[
Y_t = f \left( x_{t-1}, x_{t-2}, x_{t-3}, \ldots, u_t \right) \tag{3.3}
\]

Assuming except for the first few coefficients, the coefficients of the distributed lag equation decline in geometric progression in successive periods because it is normally expected that more remote values would tend to have smaller influence than more recent ones. Koyck, solved the multicollinearity problem of estimation and obtained the equation, viz.

\[
A_t = \alpha + \alpha_1 P_{t-1} + \ldots + P_{t-k} + \alpha_k \theta P_{t-(k+1)} + \alpha_k^2 \theta^2 P_{t-(k+2)} + \ldots + u_t \tag{3.4}
\]

\( 0 < \theta < 1 \)

When the Koyck model is used in econometric studies, it is usually assumed that \( k \) is equal to zero in which case equation (3.4) becomes
\( \Delta t = \alpha + \alpha_1 P_{t-1} + \alpha_2 \theta P_{t-2} + \alpha_3 \theta^2 P_{t-3} + \ldots + u_t \ldots (3.5) \)

on algebraic manipulation, it can be stated as
\[ \Delta t = \alpha(1-\theta) + \alpha_1 P_{t-1} + \theta A_{t-1} + (u_t - \theta u_{t-1}) \ldots (3.6) \]

If all the coefficients of equation (3.6) are known or estimated then \( \alpha_i \) and \( \theta \) are known directly and \( \alpha \) can be calculated from the formula \(^1\)

\[ \frac{\alpha (1-\theta)}{(1-\theta)} \]

Nerlove's pioneering work on the production of cotton, wheat and maize in the United States for the period 1909-32 obtained the following interesting observations. (see Table 3.1)

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\(^1\) L.M. Koyck, Distributed Lags and Investment Analysis (Amsterdam, North-Holland Publishing Company, 1954)
Table 3.1

Elasticities of supply with respect to expected price of cotton, wheat and maize: 1909-32

<table>
<thead>
<tr>
<th>Crop and magnitude compared</th>
<th>Special case ((\beta = 1))</th>
<th>General case ((0 \leq \beta \leq 1))</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cotton</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price elasticity of supply</td>
<td>0.20</td>
<td>0.67</td>
</tr>
<tr>
<td>Coefficient of expectation ((\beta))</td>
<td>1.00</td>
<td>0.51((+).17)</td>
</tr>
<tr>
<td>Trend</td>
<td>0.48((+).10)</td>
<td>0.18((+).12)</td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.59</td>
<td>0.74</td>
</tr>
<tr>
<td>Durbin-watson statistic 2</td>
<td>n.a.</td>
<td>2.34</td>
</tr>
<tr>
<td><strong>Wheat</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price elasticity of supply</td>
<td>0.47</td>
<td>0.93</td>
</tr>
<tr>
<td>Coefficient of expectation ((\beta))</td>
<td>1.00</td>
<td>0.52((+).14)</td>
</tr>
<tr>
<td>Trend</td>
<td>1.03((+).17)</td>
<td>0.53((+).17)</td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.64</td>
<td>0.77</td>
</tr>
<tr>
<td>Durbin-Watson Statistic</td>
<td>n.a.</td>
<td>2.19</td>
</tr>
<tr>
<td><strong>Maize</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price elasticity of supply</td>
<td>0.09</td>
<td>0.18</td>
</tr>
<tr>
<td>Coefficient of expectation ((\beta))</td>
<td>1.00</td>
<td>0.54((+).24)</td>
</tr>
<tr>
<td>Trend</td>
<td>0.21((+).10)</td>
<td>0.16((+).11)</td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.22</td>
<td>0.35</td>
</tr>
<tr>
<td>Durbin-Watson Statistic</td>
<td>n.a.</td>
<td>2.04</td>
</tr>
</tbody>
</table>

1 Figures in parentheses are the standard errors of estimate
2 The durban-watson statistic for the special case is not available (n.a.)


This would be the traditional Koyck model as applied to supply response studies when there is only one independent variable. Nerlove has
interpreted the Koyck model in a slightly different way to produce on expectations model ²

The Nerlovian expectations model in linear form is given by

\[ A_t = a + bp_t^* + u_t \]  \hspace{1cm} ...(3.7)

where \( p_t^* \) is the expected price in period ‘t’. The assumption is that the rational farmer is more likely to respond to the price he expects rather than to the price of the previous period and the expected price will depend only to a limited extent on the actual price in the previous period.

Expressing the expected price in terms of directly observable variable

\[ p_t^* - p_{t-1}^* = \beta (p_{t-1} - p_{t-1}^*) \]  \hspace{1cm} ........(3.8)

\[ 0 < \beta < 1 \]

where \( \beta \) is the coefficient of expectations. The equation states that for each period the farmer revises the price he expects to prevail in the coming period in proportion to the mistake he made in predicting price this period. This hypothesis of the farmer’s price expectations is both plausible and reasonable.

On further mathematical treatment, the equation becomes

\[ A_t = a_0 + b_0 p_{t-1} + c_0 A_{t-1} + v_t \]  \hspace{1cm} ........(3.9)

where

\[ a_0 = a \beta \]

\[ b_0 = b\beta \]

² Marc Nerlove, “Estimates of the Elasticities of Supply of Selected Agricultural Commodities”, and Dynamics of Supply; Estimation of Farmer’s Response to Price.
\[ c_0 = t \beta \text{ and} \]
\[ V_t = u_t - (1-\beta) u_{t-1} \]

This estimating equation of the Nerlovian expectations model is identical with the estimating equation of the Koyck distributed-lag model (3.6) provided the parameters in the two equations are related in the following way:

\[ a \cdot (1 - \theta) = a_0 \]
\[ \alpha_1 = b_0 \]
\[ \theta = 1 - \beta \]

Equation (3.6) is a first order difference equation whose solution is given by:

\[ P_t = \beta P_{t-1} + (1-\beta) \beta P_{t-2} + (1-\beta)^2 \beta P_{t-3} + \ldots \quad (3.10) \]

\[ 0 < \beta < 1 \]

This shows that the importance of past prices declines in a geometric progression. This idea is basic to the Koyck distributed-lag model.

The present study uses an expectational approach employing Nerlovian formulation for supply responses of primary producers.

(ii) **Complex Nerlovian Expectations Model**

The complex Nerlovian Expectations Model \(^3\) that postulates different expectation lag coefficients for the expectational variables is more realistic. The expectations hypotheses can be written as:

\[ P_t^* - P_{t-1}^* = \beta (P_{t-1} - P_{t-1}^*), \quad 0 < \beta < 1 \quad \ldots \quad (3.11) \]

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\(^3\) Marc Nerlove, "Estimates of the Elasticities of Supply of Selected Agricultural Commodities", p.501.
Estimating equation whose expectational variables can be written as weighted averages of past values is obtained as:

\[ Y_t - Y_{t-1} = r (Y_{t-1} - Y_{t-1}) \leq r < 1 \]  

........ (3.12)

As a result of serious estimation problems, complex Nerlovian expectations model which assumes different expectation lag coefficients for expectational variables is seldom used. On the other hand, such model which assumes unrealistically identical expectation lag coefficients is often employed.

(iii) Koyck Second Order Lag Function.

This model assumes a second order lag function for the dependent variable and can be written as

\[ A_t = a P_{t-1} + b A_{t-1} + C A_{t-2} + u_t \]  

........ (3.15)

This is the simplest generalisation of the Koyck model. 4

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The use of a two-period lag for the dependent variable is based on the observation that peak response takes place after a time-lag of two periods. The farmer may be traditionally slow in responding or institutional factors may force him to delay his responses. The subsequent transformation of the two-period lag into a one-period lag is based on the assumption that once the process is started the farmer's resistance to change and the institutional constraints are progressively reduced.

The following conditions must be satisfied if the model is to be stable:
1. $0 < b < 2$
2. $-1 < c < 1$
3. $-1 - b - c > 0$
4. $b^2 > -4c$

The average lag can be calculated from the following formula:

$$\theta = \frac{b + 2c}{1 - b - c}$$

The average lag can be calculated from the following formula:

$$\theta = \frac{b + 2c}{1 - b - c}$$  \hspace{1cm} (3.16)

Because of serious estimation problems, the Koyck second-order lag model is seldom used in econometric studies on supply responses.

The study examined is one by Parikh who made use of the data presented in a non-statistical analysis by Narain of the supply responses of Indian producers of Cotton, Jute, Groundnut, Sugarcane, Rice and Wheat over

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the period 1900-39. Parikh fitted Koyck second-order lag function only to the data for wheat grown in four provinces in India - Berar, Bombay - Sind, united provinces and Punjab. The price variable was the retail price of wheat in the previous year deflated by a general price index and the weather variable, the rainfall at or preceding the sowing time. The average lag was calculated from the formula,

$$0 = \frac{b + 2c}{1 - b - c}$$

Where $b$ and $c$ are the estimated regression coefficients of $A_{t-1}$ and $A_{t-2}$. The adjustment coefficient was obtained by subtracting the sum of $b$ and $c$ from one. (See Table 3.2).
Table 3.2
Adjustment coefficient, average lag and short-run and long-run elasticities for wheat: 1900-39

<table>
<thead>
<tr>
<th></th>
<th>Average lag (years)</th>
<th>Price</th>
<th>Weather</th>
<th>Adjustment coefficient</th>
<th>Serial correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central</td>
<td>1.16</td>
<td>-4.68</td>
<td>0.22</td>
<td>0.56</td>
<td>Yes</td>
</tr>
<tr>
<td>Province-Berar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bombay-Sind</td>
<td>8.50</td>
<td>n.a.</td>
<td>n.a.</td>
<td>0.20</td>
<td>No</td>
</tr>
<tr>
<td>United Provinces</td>
<td>2.50</td>
<td>Negative price elasticity</td>
<td>n.a.</td>
<td>0.39</td>
<td>No</td>
</tr>
<tr>
<td>Punjab</td>
<td></td>
<td>Very low coefficient of determination</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Parikh, op.cit., p.70
Note: The figures in parentheses are the long-run price elasticities

(iv) Nerlovian Adjustment Model

In its simplest form, with one determinant and the assumption of a linear relationship, the model can be presented in the following way:

\[ A_t^* = a + b P_{t-1} + u_t \]  \quad \ldots (3.17)

\[ A_t - A_{t-1} = \beta (A_t^* - A_{t-1}) ; 0 \leq \beta < 1 \]  \quad \ldots (3.18)

\[ A_t^* \] is the acreage farmers would plant in period t if there were no difficulties of adjustment. As \( A_t^* \) is unobservable, equation (3.17) cannot be estimated. Therefore assuming that acreage actually planted in period t equals acreage actually planted in period t-1 plus a term that is proportional to the difference between the acreage farmers would like to plant now and the acreage actually planted in the preceeding period, hypothesis (3.18) is made.
Technological or institutional factors prevent the intended acreage from being realised during the period and the parameter $\beta$ is called the acreage adjustment coefficient. Expressing $A_t$, in terms of directly observable variables estimating equation is 7.

$$A_t = a_0 + b_0 P_{t-1} + c_0 A_{t-1} + u_t \quad \text{(3.19)}$$

where

- $a_0 = a \beta$
- $b_0 = b \beta$
- $c_0 = 1 - \beta$ and

$$V_t = \beta u_t$$

Additional determinants can be very easily incorporated into the estimating equation.

The Nerlovian adjustment model is supposed to reflect technological and/or institutional constraints which allow only a fraction of the intended acreage to be realised during the period $t$ while the Nerlovian expectations model is supposed to reflect the way in which past experience determines the expected prices and other expectational variables which in turn determine the acreage planted.

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7 Marc Nerlove, "Estimates of the Price Elasticities of Supply of Selected Agricultural Commodities", p. 503.
The study on the Punjab is the one carried out by Krishna which covered cotton, maize, sugarcane, paddy, bajra, jowar, wheat gram and barley over the period 1914-15 to 1945-46. The basic estimating equation used by Krishna is

\[ A_t = a_0 + b_0 P_{t-1} + c_0 Y_{t-1} + d_0 Z_{t-1} + e_0 W_t + g_0 A_{t-1} + V_t \]  

(3.20)

where,

- \( A_t \) = The standard irrigated acreage actually planted with the crop in the harvest year \( t \).
- \( P \) = The post-harvest price of the crop deflated by an index of the post-harvest prices of the competing crops.
- \( Y \) = The yield of the crop deflated by an index of the yields of the competing crops.
- \( Z \) = The total irrigated area in all crops of the season
- \( W \) = Rainfall
- \( V \) = The error term

The short-run price elasticity of supply is defined as

\[ - \frac{b_0 P_{t-1}}{A_t} \]

where,

- \( P_{t-1} \) and \( A_t \) are the mean price and acreage respectively.
- \( b_0 = b \beta \) where \( b \) is the regression coefficient of \( P_{t-1} \) in the original Nerlovian adjustment function, the short-run price elasticity of supply is

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The long run in which there are no more adjustment problems, price elasticity of supply is

$$\frac{b\beta \cdot \frac{P_{t-1}}{A_t}}{A_t}$$

This is obtained by dividing short run price elasticity of supply by $\beta$. The short run and the long run elasticities of supply with respect to the other determining variables are obtained in the same way.

The model by Krishna has close resemblance with the present study where the linear model were found to be best fit for area responses with slight differences in the variables selected.

The study on the Philippines is the one conducted by Mangahas, Recto and Ruttan\(^9\) on paddy and maize over the period 1910-11 to 1963-64. The basic estimating equation was

$$A_t = a_0 + b_0 \cdot P_{t-1} + c_0 \cdot C_{t-1} + d_0 \cdot F_t + e_0 \cdot Y_t + g_0 \cdot T + V_t \quad \quad \text{(3.21)}$$

Where

- $A =$ average yield or output of paddy or maize
- $P =$ harvest price of paddy or maize
- $C =$ index of the harvest prices of alternative crops

\( F = \) index of factor prices, measured by the wage rate for hired agricultural workers

\( Y = \) index for technological change, measured by the ratio of the yield of paddy or maize to the yield of the alternative crop or crops.

\( T = \) Trend

(V) Expectations - Adjustment Model.

Ideally a model of supply response should incorporate a separating lag coefficient for each expectational variable and a different adjustment lag coefficient.

\[
A_t = a \; P_t^* \\
\text{............(3.22)}
\]

\[
P_t^* - P_{t-1}^* = \beta_1 (P_{t-1}^* - P_{t-1}^*) \; ; \; 0 \leq \beta_1 < 1 \quad \text{............(3.23)}
\]

\[
A_t - A_{t-1} = \beta_2 (A_t^* - A_{t-1}) \; ; \; 0 \leq \beta_2 < 1, \beta_1 + \beta_2 = 1 \quad \text{......(3.24)}
\]

The solution to this three equation model will yield the following estimating equation.

\[
A_t = a \; \beta_1 \; \beta_2 \left( P_{t-1} + [(1-\beta_1) + (1-\beta_2)] \; P_{t-1} + [(1-\beta_1)^2 + (1-\beta_1) \; (1-\beta_2) + (1-\beta_2)^2]P_{t-3} + [(1-\beta_1)^3 + (1-\beta_1)^2 (1-\beta_2) + (1-\beta_1) (1-\beta_2)^2 + (1-\beta_2)^3]P_{t-4} + \ldots \right) \text{......(3.25)}
\]

This model of supply response is more realistic than one which assumes either only the expectational or the adjustment element. It is not possible to isolate \( \beta_1 \) and \( \beta_2 \) in equation (3.25) to isolate the effects of changes in
factors which bring about changes, firstly in the coefficient of expectation and, secondly, in the coefficient of adjustment. Nerlove\textsuperscript{10} has suggested a way of getting round this weakness and obtained the equation\textsuperscript{(3.26)}.

\[ A_t = a + b A_{t-1} + [(1 - \beta_1) + (1 - \beta_2)] A_{t-1} - (1 - \beta_1)(1 - \beta_2) A_{t-2} \ldots \ldots \text{(3.26)} \]

If either $\beta_1$ or $\beta_2$ is equal to one, the term $A_{t-2}$ can be eliminated from the estimating equation.

The study by Behrman on four major annual crops in Thailand over the period 1937-63 used the basic average response function as

\[ A_t = a + b P_t + c Y_t + d S P_t + e S Y_t + g N_t + h M_t + u_t \ldots \ldots \text{(3.27)} \]

Where

- $A_t$ = the desired planted area in the crop under study
- $P_t$ = the expected relative price of the crop
- $Y_t$ = the expected yield of the crop
- $SP$ = the standard deviation of the relative price of the crop over the last three preceding production periods.
- $SY$ = the standard deviation of the annual yields of the crop over the last three preceding periods.
- $N$ = the farm population in the geographical area of concern
- $M$ = the annual malaria death rate per 100,000 occupation in the area of concern

The Nerlovian adjustment model was used to express the dependent variable ($A_t^*$) in observable variables while $P_t^*$ for a slight variation of the

\textsuperscript{10} Marc Nerlove, Dynamics of Supply : Estimation of Farmer's Response to Price, p.64.
Nerlovian price expectations relationship was adopted. In order to express \( Y_t^* \) in observable variable the following procedure was adopted. The actual yield in the period \( t \) was given by
\[
Y_t = a_1 + \delta (R_t - \bar{R}_t) + b_1 T + c_1 T^2 + u_t; \ 0 \leq \delta \leq 1
\]  \hspace{1cm} (3.28)
where
- \( R_t \) = actual rainfall in period ‘t’
- \( \bar{R}_t \) = Mean annual rainfall
- \( T \) = Trend
- \( r \) = Proportionality parameter
- \( u \) = random term

For studying supply response of paddy and coconut the Nerlovian expectations - adjustment model as in Behrman’s model has been used in the present study, the differences being in the selection of variables.

(vi) Simple Model

This model has a dependent variable which does not have an adjustment lag and independent variables which do not have expectation lags. It attempts to take into consideration some of the slowly changing factors such as institutional or technological changes over time variable. A typical simple model of supply response can be written as:
\[
A_t = a + b P_{t-1} + C Y_{t-1} + d T + u_t
\]  \hspace{1cm} (3.29)
Where \( T \) is the trend variable. It is a one equation model, as the estimating equation is the same as the original supply function.
The study by Dean 11 on the production of Tobacco in Malawi used the supply function.

$$\log S_t = \log \alpha + \beta \log P_t + r \log W_t + \delta \log C_t$$

i.e.,

$$S_t = \alpha P_t^\beta W_t^r C_t^\delta$$

(3.30)

Where

- $S$ = sales of tobacco in pounds weight
- $P$ = Money price of tobacco
- $W$ = Weighted wage rate obtainable outside Malawi
- $C$ = Price index of cash goods purchased by tobacco growers

**RESPONSIVENESS OF PERENNIAL CROPS**

The time horizon involved for the producers of perennial crops is much longer than that for producers of annual crops. For perennial crops the response period is the production period plus the time it takes the information of price changes to filter down to producers. The basic producer output decisions are implemented primarily in the form of acres planted and removed.

A number of models have been put forward on the manner in which producers of perennial crops respond to various economic variables when deciding on the number of acres to be planted. Some of the models combining planting - decisions models with output - planting relationship in order to estimate the price responsiveness of producers are presented below.

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(i) The Bateman Model

The Bateman model specifically takes into account a comprehensive planting-output relationship. In his study of Ghanaian Cocoa taking five regions covering the period 1946-62 Bateman suggested a planting-output relationship.

\[ Q_{it} = b_1 \left( \sum_{i=k}^{s-1} X_{1,i} \right) + b_2 \left( \sum_{i=s}^{\infty} X_{1,i} \right) \] \tag{3.31}

Where

- \( k \) = the age at which trees first begin to bear
- \( S \) = the year in which the second phase of rapid increase in yield occurs
- \( b_1 \) = the output per acre obtained after the first phase of rapid growth
- \( b_2 \) = the output per acre obtained after the second output per acre plateau is reached.

Furthermore, it does not include a time trend variable. It is conceptually sounder than Ady Model, mentioned subsequently.

The size of the total elasticity of output with respect to cocoa price obtained, varies inversely with the age of the region.

Combining planting decision equation with planting output equation, the following estimating equation as obtained.

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\[ \Delta Q_t = b_2 a_0 \beta + b_1 a_1 \beta P_{t-k} + (b_2 - b_1) a_1 \beta P_{t-s} + b_1 a_2 \beta C_{t-k} \\
+ (b_2 - b_1) a_2 \beta C_{t-s} + C \Delta R_{t-1} + d \Delta H_{t-1} + e \Delta P_t \\
+ (1-\beta) (\Delta Q_{t-1} - C \Delta R_{t-2} - d \Delta H_{t-2} - e \Delta P_{t-1}) + w_t \] .... (3.32)

Where

\( Q_t \) = The amount of cocoa harvested in the year 't'

\( b_j \) = The potential yield per acre in the year 't' of cocoa planted in the year \( t-1 \)

\( k \) = The age at which cocoa trees begin to bear

\( R_{t-1} \) The amount of rainfall during the formative period between March and June

\( H_{t-1} \) = Humidity variable affecting the yield

\( P_t \) = Producers price in the year at which full bearing begins

The equation shows that the change in the cocoa harvested from year to year is determined by producer prices, rainfall, humidity and lagged changes in output. The presence of \( P_{t-K}, P_{t-S}, C_{t-K}, C_{t-S} \) indirectly determine the planting decision in their respective years. The presence of changes in \( P_t, P_{t-1} \) and \( H_{t-1} \) directly affect the output level in the years \( t \) and \( t-1 \).

Bateman found that \( Q_{t-1}, R_{t-2}, H_{t-2} \) and \( P_{t-1} \) were insignificant and very close to zero. This means that Nerlovian price expectations coefficient \( \beta \) was very close to one and implies that expected price was approximated, by actual price.

\[ \Delta Q_t = b_2 a_0 + b_1 a_1 P_{t-k} + (b_2 - b_1) a_1 P_{t-s} + b_1 a_2 C_{t-k} \\
+ (b_2 - b_1) C_{t-s} + C \Delta R_{t-1} + d \Delta H_{t-1} + u_t \] .... (3.33)

was final reduced form of estimating equation.
(ii) The Ady Equation

\[ \Delta Q_t = a_0 + b_1 a_1 (1 - \beta) P_{t-k-1} + b_1 a_1 \beta W_{t-k-1} - a_2 Q_{t-1} \]
\[ - a_2 C R_{t-k-1} - a_2 d P_{t-1} + C \Delta R_{t-1} + d \Delta P_t \] ......(3.34)

The number of independent variables has been kept to seven, one more than, the number in Bateman's reduced equation and Ady have been kept the planting decisions and planting output models deliberately simple.

The earliest attempts to quantify the price elasticity of supply of the crop was made by Ady on Ghana, then the Gold Coast, for the period 1920-40.

The long-run supply function used was:

\[ \log Q_t = \log a + b \log P_{t-9} \] ......(3.35)

Where \( Q_t \) = output in year \( t \) approximated by export figures \( P_{t-9} \) = price of cocoa nine years ago deflated by a price index of important consumer goods. Climatic factors were not considered because of lack of data to construct the index. The short run price elasticity of supply by regressing the equation of residuals of equation (4.31) on the current prices of cocoa (\( P_t \)) The study conducted by Ady \(^{13}\) was in 1949 and was a pioneering effort in attempting to quantify the degrees of price responsiveness of primary producers.

(iii) The Behrman Equation

\[ \Delta Q_t = [(1-\delta) + (1-\beta)] \Delta Q_{t-1} - (1-\delta)(1-\beta) \Delta Q_{t-2} + \Delta Q_{t-3} + C \Delta P_t \]

\[ + [d-c(1-\delta)(1-\beta)] \Delta P_{t-1} + \{ -d[(1-\delta)(1-\beta)] + (1-\delta)(1-\beta)c \} \Delta P_{t-2} \]

\[ + (1-\delta)(1-\beta) d \Delta P_{t-3} + b_1 \delta \beta [a_1 \Delta P_{t-4} + a_2 \Delta C_{t-5}] \]

\[ + (b_2 - b_1) \delta \beta [a_1 \Delta P_{t-6} + a_2 \Delta C_{t-7}] + u_t \]

...... (3.36)

Where \( P_t \) = Price of cocoa for the year \( t \)
\( C_t \) = Price of coffee for the year \( t \)

This is rather formidable equation with ten independent variables. The expectation and adjustment co-efficients \( \delta \) and \( \beta \) respectively enter symmetrically into the co-efficients so that a two point identification problem exists.

Behrman analysed the problem at the aggregate level for eight countries - Ghana, Nigeria, the Ivory Coast, the Cameroun republic, Brazil Equador, the Dominican Republic and Venezuela - in his study on monopolistic cocoa pricing, covering the period 1947-48 to 1963-64. The finding of an inverse relationship between age and degree of price responsiveness is in line with what Bateman discovered in his study of regional supply functions for Ghana.\(^{14}\)

All the supply response models discussed had made use of Nerlovian model. The differences were only in the selection of variables and the

\(^{14}\) Jere. R. Behrman, 'Monopolistic cocoa pricing'.

consequent changes in estimation procedures. All the later studies as mentioned in chapter II were an improvement over Nerlovian model. The models had been proved to be much beneficial to the supply behaviour of agricultural economy. These can also be used to study the supply response of a typical agricultural economy like Kerala. The present study, in the light of studying those models discussed, has adopted Nerlovian expectation adjustment model which includes Koyck lag model, for studying supply responses of both seasonal as well as perennial crops. Variables were selected accordingly avoiding the estimation problems and with suitable lags.
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