CHAPTER 4
THE SUPPLY OF NATURAL RUBBER

This chapter discusses the supply of natural rubber. Supply response generally refers to the variation of agricultural output and acreage mainly due to variation in prices. Supply response studies are of great importance in the context of agricultural price policies. One of the important strategies of the Indian rubber economy is to stimulate production through the instrument of price which presupposes the knowledge on the elasticity of supply.

4.1. CHARACTERISTIC FEATURES OF NATURAL RUBBER SUPPLY

Natural rubber is a perennial tree crop and amongst perennials natural rubber has the typical feature of broadly non-seasonal production and therefore, a more or less continuous harvesting period. In order to understand the determinants of natural rubber supply, the features characterising its cultivation and production has to be examined first.

The supply of natural rubber is characterised by the inherent biological features of production: (1) the long gestation period, (2) a long productive life span, (3) a yield profile resembling a flattened F-distribution curve, (4) non-seasonal production except for inclement weather and wintering effects; and (5) requiring a long period for the
impact of any agronomic or technological progress can be felt.

The gestation period refers to the time lag between the initial input and the first output. This period can range from five to twelve years depending on the type of clones and the quality of the seedlings planted, and the cultural practices and its environs. This is followed by a long production lifespan, characterised by an extended period of output flowing from the initial production. In case of natural rubber, the production lifespan usually ranges from 30 to 40 years, which again depends on the type of clones and quality of seedlings planted and the maintenance of the tree during its production lifespan. The resulting yield profile generally tends to increase rapidly in the first few years after production commences which levels off for about 10 to 15 years before the yield starts diminishing markedly.

Unlike other perennial crops, the production of natural rubber is not much influenced by the seasonality. The seasonality of natural rubber production is the outcome of wintering, and intense rainfall period during which the tapping of the trees are avoided. Fruit bearing perennial crops, on the other hand, are seasonal in that their harvesting is confined to specific periods within the year and output is less amenable to control by producers. In
contrast natural rubber output is available most part of the year (barring inclement weather and wintering) whose production can be controlled at any point of time. This is significant for small producers, especially, those using only family labour, since the problem of peak labour demand associated with the harvesting of the fruit bearing perennials does not arise. In the short-run, the decision to produce rubber depends on the decision to tap the tree or not. While the tree is to be tapped, the output flow could be controlled by the tapping frequency and intensity and the use of chemical stimulants. Thus the ability to halt production instantaneously (by not tapping) but limitations to increase output instantaneously beyond the trees' potential output introduces an asymmetry into the short-run production elasticity of natural rubber. This is because the producers can only respond to price rises only if the tapping rate is below the maximum feasible rate. Therefore, it is important to include asymmetry in supply response in specification of the model. Yet another way to capture this effect is considering the estimated short-run (annual) supply elasticities which is the average of the very short-run supply elasticities that account for the asymmetry. This asymmetry is important by the fact that more than 80 per cent of India's natural rubber production is accounted by
small holders. The reactions of the small holder producers to price declines are known to vary in accordance with the degree of price fall. Under a relatively small price decline, the small holders may tend to hold production at the existing level. This is to maintain their earning from rubber as decision to abandon their rubber cultivation, at least temporarily, to switch on to more remunerative activities would be rather remote in view of the high cost involved. When technology is considered, the effects of technological progress in natural rubber industry are felt relatively slow when compared to technological change in manufacturing. This is because experimentation in biological engineering and the subsequent diffusion and adoption of the new technologies takes place over a very long period. With these general characteristics of production function in mind we now consider the supply function for rubber.

4.2. THE SUPPLY FUNCTION FOR NATURAL RUBBER

The foregoing discussion has brought out certain distinctive features of the production function associated with natural rubber which is common to all perennial crops. The supply of perennials hinges on their long gestation and productive lifespan, which are fundamental to understanding investment and production behaviour in the industry.
Therefore, the time horizon considered by the natural rubber producers follows the lifespan of the rubber trees which is longer than that for producers of annual crops. In case of perennials the planted trees become the capital asset for the producer. Thus the planting and replanting decisions in perennials becomes a problem in capital theory where the objective is to maximize the present value of the discounted future stream of net returns from investment in rubber plantation. This becomes further complicated with respect to small growers practicing inter cropping who derive substantial income from such crops. But in view of data constraints, empirical perennial crop response studies have considered alternative crops rather than such complementary inter cropping.

Further, it is desirable that the relevant time horizon should also determine the time periods corresponding to the short and long-runs. Theoretically, at the producers level the short-run is that time period during which the productive capacity of the producer is fixed. This implies that the short-run supply variations are restricted only to variations in the use of the variable factors in combination with the fixed productive capacity. At the industry level, the short-run is restricted to a situation wherein time is not sufficient for the producers to enter the market. However,
in perennial crops, the productive capacity at any time period is represented by the existing stock of mature trees. In this case, it is rather difficult to distinguish between short-runs and long-runs because of continuous changing stock of mature trees and also the possibilities of switching between cultivation of natural rubber and other crops, especially in case of small producers. The problem is further aggravated since in case of natural rubber there is no distinct harvesting period. In order to illustrate the problem associated with the short-run and long-run supply responsiveness, let us consider the rubber production at any time period $t$. The supply function for rubber for any such period can be denoted as

$$Q = g(P_r, P_i, P_i^j, A_{(t)}, T, W, \ldots) \quad \ldots(4.1)$$

Where

$Q$ is output

$P_r$ is price of natural rubber

$P_i$ is the price index of products competing for inputs used in production of natural rubber

$P_i^j$ is the vector of prices of factor inputs

$A_{(t)}$ is the mature acreage

$T$ is the state of technology

$W$ is the weather variable
It is more appropriate to write output $Q_t$ from any given mature acreage $A(m)_t$ in any given period as

$$Q_t = A^m_t \cdot Y_t \quad A^m_t \leq A(m)_t \quad \ldots \ldots \quad (4.2)$$

Where $A^m_t$ is the mature acreage being tapped and $Y_t$ is the average yield per tappable area.

In any time period $t$, the mature acreage $A(m)_t$ may be considered proxy for existing stock of mature trees and hence the productive capacity. But, by definition, the short-run is the period during which $A(m)_t$ is fixed. This poses the problem of distinguishing the short-runs from the long-runs, since $A(m)_t$ is likely to change constantly as new mature acreage either due to new planting or replanting come into production. At the same time old mature trees removed or abandoned will go out of production. In the previous section, it was mentioned that the gestation period is influenced by the type of clones and the quality of seedlings planted. In view of this, $A(m)_t$ at any time period $t$ may be represented as

$$A(m)_t = A(m)_{t-1} + \sum_{i=6}^{10} N_{t-i} + \sum_{i=6}^{10} R_{t-i} + L_t \quad \ldots \ldots \quad (4.3)$$

for $6 \leq n \leq 10$

Where

$n$ is the gestation period of natural rubber

$\sum_{i=6}^{n} N_{t-i}$ is the sum of surviving new planting undertaken during the period $(t-6,t-n)$ that has come into production in the current period.
\[ \sum_{i=6}^{n} R_{t-1} \] is the sum of surviving replanting undertaken during the period \((t-6, t-n)\) that has come into production in the current period and

\[ L_t \] is the loss of mature trees in period \(t\) due to disease or age.

The change in the mature acreage between any two periods can be obtained by

\[ \Delta A_{(\Delta)t} = A_{(\Delta)t}^{10} - A_{(\Delta)t-1}^{10} = \sum_{i=6}^{t} N_{t-i} + \sum_{i=6}^{t} R_{t-i} - L_t \quad \ldots (4.4) \]

In view of non-seasonality of rubber, mature trees would therefore be constantly attaining production in accordance with the prior planting and replanting schedules. Thus, it is clear that except very short time periods, \(A_{(\Delta)t}\) would be changing continuously. Therefore annual production reflects the sum of both short-run and long-run supply responsiveness since production in any period \(t\) consists of

a) Short-run response to price changes and

b) long-run response to planting decisions taken \((t-i)\) periods ago for \(i = 6, 7 \ldots \ldots 10;\)

In other words, short-run supply response relates to actual output while long-run supply response relates to potential output.

The short-run supply response can be effected by varying the yield where the productive capacity of \(A_{(\Delta)t}\) in each
period \( t \) is fixed. The important factors which explain the short-run variations in supply are:

i) The tapping frequency \((F)\), which in general remain more or less same throughout the productive period of the tree. The short-run responsiveness will depend on the ability and willingness of the producer to vary the tapping frequency in response to the price fluctuations.

ii) The tapping intensity \((I)\), refers to the length of the tapping cut. In general, both tapping frequency and intensity are jointly determined.

iii) The number of trees tapped per acre \((N)\). This reflects the density of planting and the untapped reserve at the disposal of the producer.

iv) The use of chemical stimulant \((M)\). In the short-run, the yield can be increased by the application of chemical stimulants. However, continued usage of stimulants for a longer period causes adverse effect on subsequent yields.

Thus the yield function may be represented as

\[
Y = g_2 (F, I, N, V, G, C \ldots \ldots) \ldots \ldots (4.5)
\]

Where

\( V \) is the varietal composition of the trees

\( G \) is the age composition of trees
C is the cultural practices followed which has bearing in the condition of the tree.

There is vast literature on the methods to estimate supply function of natural rubber and most of these studies touch on the above aspects in one way or another. Most specifications, however, represent fairly simple modifications to the standard Nerlovian (1958) model of supply response for annual crops, to incorporate the characteristic features specific to natural rubber. The basic Nerlovian model consists of the following three equations.

i) An adaptive expectation model of price expectations. This is based on the hypothesis that the relevant price when planting rubber is the expected price since it takes time before the trees become productive. The approach with regard to actual and expected price is based on the work developed by Cagan (1956). Price expectations are postulated to be revised in proportion to the error associated with previous levels of expectation.

ii) Desired area as a function of expected normal or long-run prices. In this case desired or equilibrium output or area planted is influenced by the future expected real price.
iii) A partial adjustment model, relating actual area planted to desired area. At a given time farmers' have a desired output influenced by expectations about future demand and supply, alternative investments, expected prices and costs of production etc. From desired output, they derive their total acreage, new plantings and replanting which intern are influenced by the size, yield and ages of the existing stand of trees. But the actual or realised output or acreage may not always equal to the desired amount because the new planting or replanting may be damaged due to disease, weather or fall short due to other constraints. Therefore, in each period, output or acreage is adjusted only partially in proportion to the difference between the last periods actual output and the long-run desired equilibrium, or desired output.

The above relationship can be symbolically denoted as:

1) \[ P_t - P_{t-1} = r (P^i_t - P^i_{t-1}) \]
2) \[ A^i_t = a + bP^i_t \]
3) \[ A_t - A_{t-1} = r(A^i_t - A^i_{t-1}) \]

This model in its reduced form when estimated in terms of area or output, leads to the familiar Koyck's distributed lag model in current and past prices and a reduced from "supply function" in which current area planted/output is a
function of current and one period lagged prices and lagged area planted/output. Modification of this model for perennials attempt to account for by incorporating the gestation period of several (say K) years between the planting and first bearing; and age yield profits because of the fact that the yields vary in systematic fashion over the life of the existing stand.

However, empirical studies to assess the response of perennial crops are usually met with difficulties for want of adequate data about the age structure of the estate for a continuous period of about 30 to 35 years and inputs with their associated prices. Further, only macro level data will be available which results in a great deal of loss of information due to aggregation. When age-yield profile is not available, and only data on output, area and price are available we make assumption (see Bateman 1965 or Behrman, 1968).

1. Age yield profiles are zero upto the age of 7 years and constant thereafter.

2. The desired area to be planted in any year is a function of a constant long run expected price.

3. Actual area planted is a part accomplishment of long-run desired area.
Hartley (1982) opines that these assumptions are adhoc since it is rather difficult to determine which of these assumptions are not supported by data. Further, he argues that the resulting equation is not based on the underlying optimization model entailing minimization of the discounted present value of future stream of profits and as such not a supply function but an empirical association between output and prices. But unlike annual crops, planting decisions in perennials vary to a large extent. As explained in the previous section, producers make gross additions to the existing area under cultivation by new planting. Area may reduce due to removal or abandonment of area. Yet another possibility is that producers may rejuvenate their estates by replanting old plants with new stock. Thus changes in area represent the net effect of all these three types of area adjustment decisions. These features lead one to ratify Hartley's (1982) observations that production function for perennial crops are inherently dynamic.

Nerlove's model of supply response may be termed ad-hoc provided planting decisions of the growers are made under the two hypothesis (Hartley, 1982), namely,

1. producers follow recommended cultural practices;
2. producers select the variables' input level so as to maximize the present value of the expected future stream of profits; and

3. producers vary their levels of inputs in response to current prices and expected future state of variables.

Though, hypotheses (1) and (2) are logical, Hartley (1982) termed hypothesis (3) as an attempt to characterise the "real world" situation. Therefore, in the present situation, the Nerlovian adjustment lag model is adhered, since in case of rubber, the prices and yields are uncertain due to the low level of supply response and adverse weather conditions which make it difficult to make reasonably accurate projections. Therefore, it is assumed that the growers formulate expectations about the future based on current, lagged or a distributed lag of past prices. In this context, the Nerlovian model is not inappropriate, since the underlying response is neither one of following prescribed practices, nor is it an accurate discounting of future streams of net incomes. The specification of the model is outlined in the following sections.

Area Model

The Nerlovian adjustment lag model has been used to estimate the degree of responsiveness of area. A log-linear function was fitted with area as the dependent variable and
price, price related risk, lagged price and price of competing crops as exogenous variables. An alternative formulation of price was also tried. The variable was split into an increasing and decreasing variable. This was done to examine the fixed asset theory. Fixed asset theory suggests that farmers may be less responsive to price decreases than to price increases. The reason for this is most perennial crops like rubber have a very high acquisition cost and negligible salvage value. During favourable years resources may be committed to rubber production which are not removed and locked up in rubber production during the lean periods. Thus, the fixed asset theory implies irreversible supply functions. The method suggested by Wolffram (1971) was followed in order to generate increasing and decreasing price variables.

New Planting Model

New planting refers to new area brought under rubber cultivation. It comprised two components, area extended under rubber plantations and old area removed and replanted with improved clones. The farmers' response with respect of new planting was studied in terms of explanatory variables like prices, price related risk and subsidies. Further, each component of new planting namely extension planting (EA) and replanting (RA) are studied separately for their variation.
Yield Models

Average yield is influenced by factors such as price, weather, percentage of non-bearing area and technology. The short term movements in expectation of profits, which is linked to prices, could be expected to influence yields. Such expectation would lead to an intensification of cultivation practices and the increased use of fertilizers, chemicals and other inputs as well as intensive tapping practices including chemical stimulants. A trend variable is included to capture the effects of technology. The weather variable was quantified by means of a method suggested by Buller and Kin (1969). The forms of the functions are presented below.

Area Models

\[ A_t = a + a_1NB_{t-1} + a_2 R_{(t)} + a_3 A_{t-1} + a_4 P_{t-1} + \epsilon_t \]
\[ A_t = a + a_1 R_t + a_2 A_{t-1} + a_3 P^l_{t-1} + a_4 P^d_{t-1} + \epsilon_t \]
\[ NA_t = b + b_1 NB_{t-1} + b_2 R_t + b_3 P^l_{t-1} + b_4 P^d_{t-1} + \epsilon_t \]
\[ RA_t = c + c_1 NB_{t-1} + c_2 R_t + c_3 P^l_{t-1} + c_4 P^d_{t-1} + \epsilon_t \]

Yield Model

\[ Y_t = d + d_1 P_{t-1} + d_2 NB_{t-1} + d_3 T + \epsilon_t \]
\[ Y_t = d' + d'_1 P^l_{t-1} + d'_2 P^d_{t-1} + d'_3 NB_{t-1} + d'_4 T + d'_5 W_t + \epsilon_t \]

Where

\( A_t \) is total area under rubber

\( NA_t \) is new area under rubber
RA_t is area replanted with high yielding clones
Y_t is yield per hectare
NB_t is percentage of non-bearing area
R_t is price related risk
P_{t-1} is price of natural rubber lagged by one year
PC_{t-1} is price of competing crop (coconut) lagged by one year
P_{t-1}^i is increasing price variable
P_{t-1}^d is decreasing price variable
T is trend which includes the state of technology
e_t's disturbance terms
a_i's, b_i's, c_i's and d_i's are the regression coefficients.

Elasticities

The estimated relationship between rubber prices and production can answer the hypotheses such as whether rubber production is positively or negatively related to prices, do rubber producers increase or decrease the quantities of rubber produced when prices rise and finally whether these responses change over time? The answers to these questions may be found by examining the elasticities of production with respect to rubber price, i.e., the proportional change in production of rubber divided by the proportional change in the price of rubber. The elasticities can be investigated by examining the partial regression coefficient of the price
variable in a multiple regression of output on all the relevant factors.

Short and Long-run Elasticities

Producers need to make both short-run decisions concerning tapping and long-run decisions concerning planting. In the short-run, when prices rise, increasing output is limited to the potential output of the trees. When the price is relatively low output may be increased to offset reduction in unit revenues, especially if income is near subsistence level. In the long run there are possibilities of alternative investments. However, in rubber it is difficult to define short and long run production because mature acreage is constantly changing as immature acreage becomes matured and as old trees are replanted. One can define short-run elasticity as the response of output or acreage to price in one time period while long-run elasticity is defined as the elasticity over the time period necessary for complete adaptation.

Short-run Elasticity: The short-run elasticities were calculated with respect to lagged prices as well as the increasing and decreasing prices, for various dependent variables.
The estimation formula consists,

\[ E(p) = b \cdot \frac{P}{Y} \]

Where \( E(p) \) is the price elasticity

\( b \) is the slope coefficient of the price variable

\( P \) is the average wholesale price

\( Y \) is the average of the dependent variable in question.

Long-run Elasticity: The long-run elasticity of area was calculated from the Nerlovian adjustment lag model such that

\[ E(p)_{t} = \frac{E(p)}{r} \]

Where \( E(p)_{t} \) is the short-run elasticity and 'r' is the coefficient of adjustment which is equal to \( 1 - \lambda \) and '\lambda' is the regression coefficient of \( A_{(t-1)} \) in the Nerlovian adjustment model. The number of years required for the farmer to adjust his area to the extent of 95 per cent to the change in price, is provided by the formula:

\[ (1-r)^n = 0.5 \]

Where 'n' is the number of years and 'r' is the adjustment coefficient. The pattern of adjustment coefficients together with the elasticity structure would explain the extent of rigidities in production, similar to the specificity and fixity of resources (Singh and Rao, 1974). The aggregate short-run supply elasticity \( (E_{sa}) \) is calculated by summing up
the elasticity of area \((E_{ap})\) with respect to price and the yield elasticity \((E_{yp})\) with respect to price

\[
E_{ss} = E_{ap} + E_{yp}
\]

The long-run aggregate supply elasticity is calculated in a similar fashion except that the elasticity of area with respect to price \(E_{ap}\) is divided by the adjustment coefficient, \(r\)

\[
E_{ls} = \frac{E_{ap}}{r} + E_{yp}
\]

Explanation of the Variables

The variables included in the various supply response functions are briefly discussed here in order to understand its form and construction.

Area: \(A_t\). The actual area under rubber in hectares

New Planted Area: \(NA_t\). This refers to new area brought under rubber cultivation plus area removed and planted with superior clones, (ha).

Replanted Area: \(RA_t\). Area which has been removed and replanted with superior clones of rubber, (ha).

Yield: \(Y_t\). Refers to the average yield per hectare obtained by dividing the total production by the total tappable area under rubber, Kg/ha.

Non-bearing area: \(NB_t\). Expresses the area where the rubber trees have been planted or replanted less than 7 years back. This is expressed as a percentage of the total area.
Risk: $R_t$. Refers to the price risk and represents standard deviation of the price in the previous three years.

Price: $P_t$. Average wholesale prices of ungraded natural rubber in Kottayam market.

Price of Competing Crop: $P_{c_t}$. Average wholesale prices of coconut in the important markets in Kerala Rupees per thousand nuts.

Asymmetric Price Variable: The method suggested by Wolffram (1971) has been followed in this case. The procedure involves the splitting the price variable into sum of period to period rise in prices ($P^r_t$) and sum of period to period fall in prices ($P^d_t$). According to this method the concept of asymmetric response function is illustrated as follows.

$$A_t = a_1 + b_1 P_{t-1} \quad \ldots (4.6)$$

Equation (4.6) illustrates the general case where area planted in time $t$ is related to the lagged price. The equivalent Wolffram-type asymmetric supply function would be

$$A_t = a_2 + b_2 P^r_t + b_3 P^d_t \quad \ldots (4.7)$$

Where $P^r_t$ is the sum of all period-to-period rises in $P_t$ and $P^d_t$ is the sum of all period to period fall in $P_t$. The splitting of the price variable is based on the calculation of first difference $\Delta P_t$ of prices.

$$\Delta P_t = P_t - P_{t-1}$$
The \((n-1)\) first differences are used for the formation of a \(P_t^1\) variable, for the increasing and a \(P_t^d\) variable for the decreasing phase.

The \(\Delta P_t\) are separated into

\[ \Delta P_t \geq 0 \quad \text{and} \quad \Delta P_t \leq 0 \]

The \(P_t^1\) variable is generated by adding the first differences \(\Delta P_t \geq 0\) to an initial value, zero. The mathematical procedure involved is denoted below:

\[
\begin{align*}
P_t^1 &= P \\
P_{2t}^1 &= P_{1t} + \phi (P_2 - P_1) \\
P_{3t}^1 &= P_{2t}^1 + \phi (P_3 - P_2) \\
P_{nt}^1 &= P_{nt-1}^1 + \phi (P_n - P_{n-1}) \\
\phi &= 1 \text{ if } (P_t - P_{t-1}) > 0 \\
\phi &= 0 \text{ if } (P_t - P_{t-1}) \leq 0
\end{align*}
\]

The decreasing price variable \(P_t^d\) is constructed in a similar manner by adding the first differences \(\Delta P_t \leq 0\) to an initial value zero, considering the absolute value and ignoring the sign.

\[
\begin{align*}
P_t^d &= P \\
P_{2t}^d &= P_{1t} + (1 - \phi) (P_2 - P_1) \\
P_{3t}^d &= P_{2t}^d + (1 - \phi) (P_3 - P_2) \\
P_{nt}^d &= P_{nt-1}^d + (1 - \phi) (P_n - P_{n-1}) \\
\phi &= 1, \text{ if } (P_t - P_{t-1}) < 0 \\
\phi &= 0, \text{ if } (P_t - P_{t-1}) \geq 0
\end{align*}
\]
Further, equation (4.7) can be conveniently reformulated using Gollnick (1972) derivation as follows:

\[ A_t = a_3 + b_2 P_t + b_3 \Delta P_t^d \quad \ldots (4.8) \]

Where \( \Delta \) is \((b_3 - b_2)\) and \( P_t \) and \( P_t^d \) are defined as above. This formulation has an advantage in that the usual 't' test statistic on coefficient \( b \Delta \) also provides an appropriate test on the equality of the slope parameter (i.e., \( H_0: b_2 = b_3 \)) Trend: (T). This was included to capture the effect of the state of technology with 1966-67 = 1

Weather (\( W_t \)): Weather index was constructed based on the method suggested by Buller and Lin (1973) to study the impact of weather on yield. The steps involved in the construction of weather index are detailed below.

1. A five year moving average of yield was computed.
2. A linear-trend \( \hat{Y} = a + bT \) was fitted to the moving average, where \( T \) is the time.
3. Letting \( Y_{(w)} = Y - \hat{Y} \), be function of weather variable, normal weather \( N_{(w)} = \Sigma Y_{(w)} / N \).
4. The weather index was defined as the ratio of the weather effect \( Y_{(w)} \) in Kg per hectare to the normal weather effect in Kg per hectare if weather was normal, and then adding 100 to avoid the negative sign, such that \( 100 + Y_{(w)} / N_{(w)} \)
4.3. ESTIMATION OF SUPPLY RESPONSE EQUATIONS

Supply relations, otherwise called the supply curve, sets out the relationship between the quantities of product that will be "produced" at an expected price under given conditions of technology, input price etc. During any particular year the supply of a commodity like rubber is virtually the production since no quantity is retained for personal consumption by the estate owners. The supply therefore, comprises of two dimensions, area and productivity or yield per hectare; the two together determine the total supply. These two aspects have been analysed separately. Further, the response of farmers to rising and falling prices in allocation of resources have been examined and the results are discussed in the following sections.

4.3.1. Area Response

The Nerlovian Adjustment lag model assumes that the farmers in general have in mind a desired production and in the long run they will adjust the actual area to attain this desired production. If the desired area is greater than the actual area under rubber, they will undertake new plantings. On the other hand, if the desired area is less than or equal to the actual area there will not be any new planting. The supply response model for a perennial crop like rubber must explicitly consider the new plantings and removals.
Therefore, separate equations were estimated for total area response, new plantings and replantings. The independent variables were to influence the area decisions such as lagged area, lagged prices, price of competing crop coconut lagged by one year, subsidies, price risk and asymmetric price variable were regressed on total area, new planted area and replanted area respectively as dependent variables. The analysis was based on the data over the period from 1966-67 to 1989-90. Both linear and log-linear functions were tried using Ordinary Least Squares (OLS) method but log-linear equations were preferred by virtue of the goodness of the fitted equations. A combination of independent variables were tried and the most appropriate equations were retained for discussions.

**Total Area Response**

The total area response function was estimated as:

\[
\ln A_t = 86.653 + 0.684^{***} \ln A_{t-1} + 2.339^{***} \ln S_t - 0.656 \ln R_t
\]

\[
+ 3.340^{**} \ln P_{t-1} - 22.17^{***} \ln P_d^{t-1}
\]

\[
R^2 = 0.86 \quad F = 14.96 \quad D.W = 1.209(1C)
\]

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

**IC = Inconclusive**
The total area is found to be significantly responsive to all the variables included in the equation except the risk due to price. The signs of the coefficients are consistent with the expectations. For instance, the risk variable indicated a negative relationship with area even though the coefficient was not significant. Risk has a tendency to reduce the area by 0.65 per cent, the coefficient is non significant implying that risk does not induce farmers either to increase or decrease their area under the crop. In other words they are risk averse. The lagged price has a positive effect which is highly significant. The short-run elasticity of 3.34 indicates that for a one per cent increase in price, the total area under rubber would increase by 3.34 per cent. Similarly, lagged area as well as subsidy component have significant and positive effect on the area planted under rubber. An increase in subsidy by one per cent resulted in 2.34 per cent increase in the total area under rubber. The elasticity coefficient of 0.684 for lagged area yielded an adjustment coefficient \((1-0.684) = 0.316\). This implies that in one year as high as 31.6 per cent of the total desired change in area is realised. Further, the decreasing price variable included to examine the asymmetry in supply response was found to be highly significant with a coefficient \((-) 22.17\). This suggests that the decrease in area due to a
Table 4.1. Estimates of elasticities of natural rubber supply

<table>
<thead>
<tr>
<th>Model</th>
<th>Price</th>
<th>Asymmetric price</th>
<th>Decreasing price</th>
<th>Subsidy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area</td>
<td>3.340</td>
<td>-22.170</td>
<td>2.599</td>
<td>2.339</td>
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<tr>
<td>New planting 0.382</td>
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<tr>
<td>Replanting 0.769</td>
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<td>0.754</td>
<td>0.155</td>
<td></td>
</tr>
<tr>
<td>Yield:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1)</td>
<td>0.335</td>
<td>-2.559</td>
<td>0.326</td>
<td>-</td>
</tr>
<tr>
<td>(2)</td>
<td>0.294</td>
<td>-2.290</td>
<td>0.287</td>
<td>-</td>
</tr>
</tbody>
</table>
fall in price is substantially less when compared to increase in area due to rise in price. This is so, because by construction, the decreasing price coefficient is equal $b_2 - b_1$. Therefore, its significance implies that $b_2 - b_1 = -22.17$. Thus $b_2 = b_1 - 22.17$ and from this it follows that $b_1 > b_2$ indicating that the relative fall in area due to decrease in price is less when compared to increase in area in response to rise in the price. This is further explained by the elasticity coefficient, 2.599 for decreasing price as against the normal price elasticity of 3.34 as provided in Table-4.1. This result substantiates the fixed asset theory which implies that due to fixity of resources, planters do not remove area already brought under rubber cultivation during falling prices due to wide disparity between cost of planting and salvage value of a unit of rubber planted.

Using the adjustment coefficient $(1-A)$, the time taken for area to respond to the extent of 95 per cent of the change in price was estimated as follows:

$$(1 - 0.684)^n = 0.05$$

This gives a value of $n$ equal to 2.60 years. A comparatively short period for adjustment together with the short-run price elasticity of 3.34 and long-run price elasticity of 10.57 explains a very high responsiveness of area to price changes in rubber. A similar high long-run
price elasticities of supply were obtained for rubber by Tan (1984) using a different model, namely "Wicken's and Greenfield's". She obtained a long-run elasticity coefficient of 37.378 for India and 13.091 for Sri Lanka.

**Planting Decision Response**

The estimated equation for new planting is given by:

\[
\ln NA_t = 10.097 + 0.365^{***} S_t + 0.130 \ln R_t + 0.382^{**} \ln P_{t-1} \\
(3.815) \quad (1.28) \quad (1.76)
\]

\[
- 1.399^{***} P_{t-1} \\
(2.56)
\]

\[ R^2 = 0.95 \quad F = 110.78 \quad D. W. = 1.787 \ (NA) \]

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

NA = No auto-correlation.

Like the 'total area', the area under new plantings responded positively to expected price and subsidy. However, the coefficients of elasticities with respect to expected prices and subsidies for new plantings were less when compared to the total area response. An increase of 1 per cent in subsidy has increased the area under new plantings by 0.385 per cent and similarly by 0.382 per cent for a percentage increase in expected price. Unlike in the case of total area response, the risk coefficient for new plantings has a positive sign. However, the coefficient with
respect to price risk was rather low and non-significant suggesting that risk has no influence on new planting decisions. As in the case of total area response, an asymmetric relationship was found in the new planting decisions also. The coefficient of asymmetric price variable was highly significant suggesting that the response of newly planted area due to increase in price is more compared to decrease in area due to fall in prices to the extent of 1.40 per cent.

Replanting Response

The OLS estimates of replanting response function is provided below.

\[
\ln RA_t = 13.296 + 0.255^{*} \ln S_t + 0.769^{*} \ln P_{t-1} - 1.991^{*} \ln P_{t-1} - 0.387 \ln CP_t - 0.129 \ln R_t
\]

\[
\begin{align*}
(2.372) & \quad (1.906) & \quad (-1.575) \quad (0.678) & \quad (0.773)
\end{align*}
\]

\[R^2 = 0.61 \quad F = 5.64 \quad D.W = 1.802 \text{ (IC)}\]

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

IC = Inconclusive

All the variables considered had the expected signs for their coefficients. Evidently, the expected prices and subsidy variables had a positive influence on area replanted. The elasticities with respect to expected price and subsidy
were 0.769 and 0.255 respectively. Eventhough, the variables representing the price of competing crop and risk had the expected signs, these coefficients were not significant. This suggests that coconut is not a competing crop for rubber. This is plausible because coconut is usually grown in low lying areas, especially in sandy soils and rubber on the other hand, at higher elevation and sloppy lands. The results indicated that risk had no influence in determining the area replanted. It is interesting to note that eventhough, the decreasing price variable has a negative response, it is not significant. From this, it implies that unlike total area response and new plantings, the replanting response does not explain the fixity of assets or asymmetry in response. The reason for this is not far to seek, because removal and replanting is done in the case of old and uneconomic trees which is determined by the subsidy incentives. When prices are high the planters have better liquidity and take up the replanting encouraged with the subsidy incentives. The pace of replanting will not slow down when there is fall in prices as it entails the removal of unproductive plants.

From the regression equations it is clear that the variables included could explain reasonably well the variations in the supply of natural rubber as indicated by
the goodness of fit. The variations explained were 86 per cent, 96 per cent and 71 per cent in case of total area, new planting and replanting models respectively. The results indicated that the increase in rubber area is mainly explained by the variation in rubber prices and subsidy incentives. Risk and coconut prices had no significant impact on planting and replanting decisions. Further, an asymmetric relationship was revealed with respect of total area and new planting decisions confirming the fixed asset hypothesis, whereas such a relationship was absent in case of replanting decisions.

4.3.2. Yield Response

The yield models were used in order to understand the second dimension of supply, the other being area, and to study how yield would respond to certain exogenous variables. The yield variable was regressed on independent variables namely lagged yield, trend, lagged price, decreasing price and weather. As in the case of area model, log-linear functions were estimated using Ordinary Least Squares (OLS) method. A combination of variables were tried and the most appropriate equations are retained for discussions.
The fitted equations are presented below.

1) \[
\ln Y_t = 3.03 + 1.089^{***}\ln Y_{t-1} + 0.1095^{***}T - 0.122\ln P_{t-1} - 0.501\ln P_{t-1}^d
\]
\[
\text{IC = Inconclusive.}
\]

**Figures in the parentheses are t-ratios**

*** denotes level of significance at 1 per cent.

In equation (1), the trend variable showed multicollinearity with lagged prices and the price coefficient was negative even though the $R^2$ value was 0.87. So the equation was re-estimated excluding the trend variable as given below.

2) \[
\ln Y_t = 16.128 + 0.458\ln Y_{t-1} + 0.335^{***}\ln P_{t-1} - 2.559^{***}\ln P_{t-1}^d
\]
\[
\text{IC = Inconclusive.}
\]

**Figures in the parentheses are t-values; ***, ***, and *** denote the level of significance at 10 per cent, 5 per cent, and 1 per cent respectively.
With the dropping of the trend variable the $R^2$ was reduced to 0.69 in equation (2) and in equation (3) the inclusion of weather as an additional variable has slightly improved the $R^2$ to 0.74. It is interesting to note that the coefficient for expected price in both these equations were positive and highly significant. From equations (2) and (3), it can be seen that lagged prices significantly influenced the yield to the extent of 0.34 and 0.29 per cent respectively. This seems plausible because planters may adjust the yield in response to short run price expectations through the intensive cultivation and by varying the tapping decisions. Uma Devi (1977); and Viju and Prabhakaran (1988) also obtained positive elasticity with respect to current and lagged prices, respectively. Weather had a significant and positive contribution to productivity. Further, it is seen that the extent of fall in yield due to a one per cent fall in price is smaller when compared to the rise in yield due to a percentage rise in prices. In other words, it can be inferred that the decline in yield during the periods of falling prices is comparatively less than the increase in yield during the periods of rising prices. Thus, the yield response also indicated an asymmetric relationship as it was noticed in the case of area response.
The aggregate supply elasticity was obtained by the addition of the two components of the output elasticities estimated. The response to output to price is a combination of elasticities of acreage to price and of yield to price. Thus the long run aggregate supply elasticity estimated was

\[ E_L = 10.57 + 0.29 = 10.86 \]

and the short-run elasticity:

\[ E_S = 3.34 + 0.29 = 3.63 \]

These figures indicate that in the short-run supply will increase by 3.63 per cent and in the long-run by 10.86 per cent in response to a unit change in the lagged price. Therefore, the hypothesis that the natural rubber output in India is highly responsive to prices has been accepted. This is justified not only form the high elasticity coefficients obtained but also from the fact that rubber production has recorded a high growth rate of 6.4 per cent per annum and remarkable increase in the total production to the extent of 3,29,615 tonnes in 1990-91 from 50,530 tonnes in 1965 - 66.

From the foregoing analysis the following conclusions would emerge.

i) Contrary to other perennials, supply of natural rubber in India is positive and highly elastic.

ii) The elasticity of area is greater than that of yield.
iii) The longer the time span under consideration, the higher is the responsiveness shown by the producers.

iv) A certain degree of asset fixity is noticed in case of total area decisions and new planting decisions which is absent with respect to replanting decisions.