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CHAPTER 2
SURVEY OF EXISTING LITERATURE

2.1 Econometric Application in Agricultural Economics:

The perceptions of economists on the functioning of the farm economy in less developed countries differ. Their policy recommendations therefore on the roles structural reforms and price and technology policies for agricultural development also differ. Bliss and Stern (1982:51) attribute the difference between the positions to the assumed importance of rational economic behavior on the part of farmers, the view of competitiveness and efficiency of markets, the distribution of power and wealth, and the role of institutions, cultures, and beliefs.

According to Schultz, 'farmers the world over, in dealing with costs, revenues and risks are calculating economic agents. Within their small individual allocative domain they are fine-tuning entrepreneurs, turning so subtly that many experts fail to see how efficient they are' (1978:4).

Bhaduri (1973) believes that the powers that reside with the landlord in the land market carries with it both a monopsony in the labor market and tight hold on credit. Bharadwaj (1974) notes the co-existence and interaction of multiple modes of production and argues that property relations are complicated in semi-feudal economics where power is exercised through privilege as much as through markets.

Many including Bharadwaj and Rudra (1982), have questioned the relevance of assumptions such as profit maximization and mobility of resources guided by freely fluctuating market forces. The ubiquitous use of Cobb-Douglas production function for characterizing agricultural technology, neglect institutional factors and government policies, inadequate attention paid to stochastic specification, failure to establish links between theoretical constructs and observable magnitudes, inappropriate uses of statistical techniques in inference, are some other criticisms leveled against empirical research in Indian agricultural economics.

Most empirical works in the field are based on simple neo-classical model of a competitive firm maximizing profit in a non-stochastic environment. With recent developments in economic theory and econometrics and availability of better data base, it is possible to rectify some of the deficiencies and gaps in applied research.

Even a general framework will not be adequate to analyze all the factors affecting farmers behavior. Given our limited knowledge about the nature of the interaction between economic and non-economic factors and the need to keep the analysis within manageable limits, we can only treat the non-economic factors as exogenous. With gradual shifts in agricultural policies from structural reforms to market-oriented policies, and the growing monetization of Indian agriculture, the need to analyze the effects of price signals and technology policies on farmers input-output choices is obvious.

A symbiotic relationship between economic theory and econometrics is necessary when a researcher depends on non-experimental data, e.g., survey data or secondary data provided by governmental and non-governmental agencies. This relationship is useful in deriving meaningful hypotheses and in providing a priori knowledge regarding the choice of variables,
functional forms and restrictions on the parameter values. Agricultural economists classify inputs under different categories. One distinction is between essential and non-essential inputs. Land, seed, minimum labor for sowing and harvesting are examples of essential inputs. They are essential in the sense that output becomes zero if any one of the inputs takes a zero-value. Fertilizers, pesticides, tractor services are examples of non-essential inputs.

*Just and Pope (1978)* draw a distinction between protective and non-protective inputs, depending on whether the variance of output decreases or increases with that input. This distinction is useful when yield is affected by a random factor like weather (one of the elements of $s$). Irrigation and pesticides are viewed as protective inputs while fertilizer is viewed as a non-protective input.

The linear production function used by *Bliss and Stern* is of the form
\[
q = a_0 + a_1 v_1 + \ldots + a_n v_n
\]

with $a_i \geq 0$ and $v_i \geq 0$. The function may be viewed as first-order linear approximation to an arbitrary production function around a given input vector. The marginal products $f_j$'s are constant. It is homogeneous of degree one if $a_o = 0$. The function permits zero values for inputs, implying that all inputs are perfectly substitutable.

The popular Cobb-Douglas, production function is of the form
\[
q = A v_1^{a_1} v_2^{a_2} \ldots v_n^{a_n}
\]

$A > 0$, $a_i > 0$ for all $i$ and $v_i > 0$ for all $i$.

The function is homogeneous of degree $\sum a_i$, where $a_i$ is the elasticity of output with respect of $i$th input. Thus, marginal products are functions of input levels. $A$ may be interpreted as (neutral) efficiency parameter. The function has only $n+1$ parameters. The two principal drawbacks of the function are that,

(a) it does not permit zero value for any input; and

(b) the partial elasticity of substitution between any two inputs is equal to unity (thus ruling out complementary inputs).

Incorporation of a multiplicative random term implies that variance of output increases with the level of any input (thus ignoring protective inputs).

The multi-input CES production function
\[
q = A^{\sum d_i} d^{1-p}
\]

$A > 0$, $r > 0$, $0 \leq d_i \leq 1$ $\sum d_i = 1$ and $p \geq -1$.

has $n+2$ parameters. It is homogeneous of degree $rp$ in $v$'s. The elasticity of substitution between input pair $i, j$ is given by $1/(1 + p)$. $d$ is a distribution parameter. Like the Cobb-Douglas, CES is a strongly separable function. It permits zero value for any input. Its principal weakness is that it allows the same value of elasticity of substitution between any input pair. It is possible to generalize to allow both for non-homogeneity and different values of AES between different input pairs, as done by *Mukerjee (1963)* and *Dhrymes and Kurz (1964)*.
Their function is
\[ q = A_0 \sum_i (d_i v_i P)^{-r} \]  
\text{eq. (2.1.4)}

It has \(2n+1\) parameters. The difficulty is that the above equation is non-linear in parameters and hence direct estimation of the function is difficult.

To avoid arbitrary restrictions on technology and to facilitate econometric estimation, flexible functional forms that are linear in parameters are desirable. The translog function, proposed by Christensen, Jorgenson, and Lau (1973) has the form
\[ \ln q = a_0 + \sum_i a_i \ln v_i + \sum_{i,j} a_{ij} \ln v_i \ln v_j \]  
\text{eq. (2.1.5)}

\(a_i > 0, \ i = 0, 1, \ldots, n, \ a_{ij} = a_{ji} \) for \(i \neq j\),
\(i, j = 1, 2, \ldots, n\)

It has \(1+n(n+1)/2\) parameters (after imposing the symmetry condition). It may be viewed as a second-order approximation of \(\ln q\) in powers of \(\ln v_i\) around a known point. It permits different values of \(AES\) for different input pairs. It is homogeneous of degree \(1\) (reduces to the Cobb-Douglas case), when \(\sum a_{ij} = 0\). Homotheticity can be tested. Its principal weakness is that it does not allow zero value for any input.

The generalized Leontief function proposed by Diewert (1971) takes the form
\[ q = a_0 + \sum_i a_i v_i + \sum_{i,j} a_{ij} v_i v_j \]  
\text{eq. (2.1.6)}

\(a_i > 0, \ i = 0, 1, \ldots, n, \ a_{ij} = a_{ji} \) for \(i \neq j\),
\(i, j = 1, 2, \ldots, n\)
and \(v_i > 0\) for all \(i\).

It also has \(1+n(n+1)/2\) independent parameters. It may be viewed as a second-order approximation of \(q\) in powers of \(v_i^2\) around a known point. It is homogeneous of degree one when all \(a_i = 0\) for \(i = 0, 1, \ldots, n\). It allows different values of \(AES\) for different input pairs. It permits zero values of some inputs.

The quadratic function may be written as
\[ q = a_0 + \sum_i a_i v_i + \sum_{i,j} a_{ij} v_i v_j \]  
\text{eq. (2.1.7)}
\(a_i > 0, \ i = 0, 1, \ldots, n, \ a_{ij} = a_{ji} \) for \(i \neq j\),
\(i, j = 1, 2, \ldots, n\) and \(v_i > 0\) for all \(i\).

It may be viewed as a second-order approximation of \(q\) in powers \(v_i\) around a known point. It has the same number of parameters as the translog function. It is linear homogeneous when \(a_0\) and all \(a_{ij}\)'s are zeros. It accommodates zero values for certain inputs and the \(AES\) for different input pairs can be different.

Definition of a multi-crop, multi-input production function is not unique. One simple case is cultivation of crops that are technically independent in the sense that each crop can be grown in a separate plot, but a joint decision has to be made on the allocation of certain common fixed...
inputs like land, capital services, managerial ability. Jointness, in a technical sense, arises when two or more products are produced jointly, e.g., paddy and straw, mutton and wool.

Denoting \( y_i \) for crop 1 and \( y = (y_2, \ldots, y_m) \) for other crops, and \( v \) and \( s \) as defined earlier, we can write a multi-crop, multi-input production function as

\[
y_i = g(y, v, s).
\]

The function must be non-increasing in output variables \((y_2, \ldots, y_m)\) and non-decreasing in input variables, \(v\)'s. The Hessian matrix associated with \( g \) is assumed to be negative semi-definite. A generalization of the concept of returns to scale has been done by Baumol, Panzar and Willig (1982), and Lau (1978).

Like Bliss and Stern, the term market has been used in a general sense as "to refer simply to the condition under which exchange of the services of factors take place and the arrangements in force for organizing that exchange. There is no implication that the market is in any sense a formal one with a specified location; still is there any suggestion that the market is perfect or competitive...".

The following questions are pertinent in economic analysis of the functioning of product and factor markets in agriculture:

(a) whether or not the assumption of price-taking behavior is valid?
(b) whether or not prices reflect social opportunity costs?
(c) whether or not markets are in equilibrium, and when they are in disequilibrium how do (if at all) adjustments towards equilibrium take place?

In a seminar paper, Marshack and Andrews (1944) introduced random variations in technical and allocative efficiency among firms in an industry, and consider identification and estimation of Cobb-Douglas production functions. Their stochastic specification of the production function is

\[
q_i = A_{v_{1i}}^{a_{1i}} \cdots v_{ni}^{a_{ni}} U_{0i}, \quad i = 1, \ldots, n.
\]

They interpret \( U_{0i} \) as reflecting technical efficiency and as depending on the technical knowledge, the will, effort, and luck of a given entrepreneur. The multiplicative form of \( U_{0i} \) implies that the production functions of all farms are identical up to a neutral disembodied productivity differential (Zellner, Kmenta, and Dreze (1966:786)).

In most applications, the random term \( U_{0i} \) is written as

\[
U_{0i} = e^{U_{0i}} \quad \text{with} \quad U_{0i} \sim N(0, \sigma^2_0) \quad \text{for all} \ i.
\]

Since \( U_{0i} \) is a log normal variable, the conditional mean and median outputs are

\[
E(q_i/v_{1i}, \ldots, v_{ni}) = A_{v_{1i}}^{a_{1i}} \cdots v_{ni}^{a_{ni}} e^{\sigma^2/2}
\]

\[
Med(q_i/v_{1i}, \ldots, v_{ni}) = A_{v_{1i}}^{a_{1i}} \cdots v_{ni}^{a_{ni}}
\]

Marshack and Andrews do not maintain the assumption of exact profit maximization, allowing for random errors in equations \((h)\), i.e.,
and interpret $U_j$'s as due to differences in firms' abilities to maximize profits. $U_j$'s are assumed to be normal variables with means $= 0$ and variance $\sigma^2$ for all $i$. The sample farms may exhibit systematic errors as a result of institutional or other constraints with regard to satisfying the first-order conditions. Therefore $(n)$ can be modified as

$$P_{ji} = a_j \left( q_i / v_{ji} \right) = r_j U_{ji} + u_{ji}$$

Denoting $\log q_i$ as $x_{0i}$, $\log v_{ji}$, $\log A$ as $K_0$, and $\log (r_j R_j / a_j)$ as $K_j$, $(p)$ and $(O)$ can be written as a simultaneous equation system

$$x_{0i} = a_1 x_{1i} + \ldots + a_n x_{ni} + k_0 + u_{0i}$$

$$x_{0i} = x_{1i} + k_0 + u_{1i}$$

$$\ldots$$

$$x_{0i} = x_{ni} + k_n + u_{ni}$$

**Marshall and Andrews** noted that the reduced form equations for $x_j$'s would depend on all the disturbance terms $u_j$'s. Therefore, direct estimation of the production function equation of $(p)$ by the ordinary least squares method will result, in general, in consistent estimators.

**Rudra, Wise, and Youtopolus (1969), and Lau and Youtopolus (1971),** emphasized that there is no need to make these arbitrary assumptions. The observed variations in input-output bundles are traceable not only to random variations in technical and allocative efficiencies, but also to systematic variations in quantities and qualities of fixed inputs, the prices paid and received by farmers in a farm sample. Hence, it is desirable to incorporate the 's' variables explicitly in the production function, and rewrite it in a general form as

$$q_i = f(v_i, s_i, u_i)$$

The fixed inputs are non-marked and hence the problem amounts to maximizing short-run profit. The input demand and output supply functions depend on $p$, $v$'s and $s$'s.

The econometric modeling of the frontier production function is stimulated by the work of **Aigner, Lovell, and Schmidt (1977)**. They write the stochastic production function as

$$q_i = f(v_{i1}, \ldots, v_{ni}) e^{\varepsilon_i - t_i}$$

where $\varepsilon_i$ denotes randomness or statistical noise and $t_i$ technical efficiency $\varepsilon$'s are assumed to be identically and independently distributed normal variables with zero mean and constant variance. $t$'s are assumed to be independent and identically distributed truncated (at zero) normal variables. $\varepsilon$'s are assumed to be independent of $t$'s. The distribution of the composite error is given in **Aigner et al. (1977)**.

The corrected ordinary least squares regression method, due to **Timmer (1971)**, is easier to apply when $f(\cdot)$ is Cobb-Douglas. **OLS** estimators of the coefficients of log $v_j$'s are best linear
unbiased. Since the constant term contains the scale effect (mean of $t_j$), the scale parameter estimate is corrected by shifting the function until no residual is positive and one is zero.

* Battese, Coelli, and Colby (1989) estimate a frontier function with farm level data from ICRISAT villages for ten years. They use the Cobb-Douglas function with land, labor, bullock labor, and total input cost (costs of fertilizer, manures, pesticides, and machinery use). One novel feature of their work is that coefficients in the linear aggregation of input measures, such as land (unirrigated and irrigated), human labour (owned and hired) are estimated along with the elasticity coefficients. Since total input cost is zero for some farms in some years, the log of the variable is pre-multiplied by $D_{it}$, where $D_{it}$ is dummy variable with values 1 or zero if the $i$th observation on the input costs has not positive input costs, respectively. The model is estimated using ML methods. The predicted efficiencies range from 0.662 to 0.914, the estimate for the mean efficiency being 0.837.

The rationale for introducing technical efficiency in the form of a multiplicative term is not clear. Given $v$’s inter-farm variations in outputs arise primarily through differences in the amounts of fixed factors and natural factors. The assumption that the marginal rate of substitution between any two variable inputs is independent of the quasi-fixed factors (particularly entrepreneurial ability) is not realistic. To estimate production frontiers for interdependent multiple outputs, see Kalirajan (1986).

Farm size is measured by cultivated area and productivity per ha is taken as gross income per ha in case of farm business (yield per ha in case of a single crop). Based on the size-wise productivity FMS data for different regions, several writers found an inverse relationship between farm-size and productivity. Sen’s (1964) explanation for this is that cultivation is done in small (peasant) farms up to the point where the marginal product of labor is below the ruling market wage and stops on the large (capitalist) farms at the point where the marginal product is equal to the market wage. Many other explanations, both quantity and quality based, have been offered for the alleged inverse relationship.

Many including Bharadwaj and Rudra have tested the hypothesis by postulating a relation of the form

$$\ln y_i = A + B \ln x_i$$

where $y$ is productivity per hectare of a crop and $x$ is area in hectares (sometimes adjusted for quality). The null hypothesis $B = 1$ is tested against the alternative hypothesis $B < 1$.

In FMS reports and in Saini’s work the hypothesis is formulated in terms of the returns-to-scale parameter. With a Cobb-Douglas production function, the null hypothesis is that the sum is less than one. This procedure is also subject to many problems. Since the function does not permit zero value for any input, many writers either use observations containing non-zero values for inputs or measure such variables as $c_j + v_j$ where $c_j$ is a positive constant so that log of $(c_j + v_j)$ is finite even if $v_j = 0$.

In the absence of a priori knowledge regarding the relationship between $v$ and $s$ variables, some fit separate production functions for different seasons, farm sizes, regions, varieties, type of tenancy, etc. Other use the Cobb-Douglas form with dummy variables to capture regional, irrigation, tenancy effect, etc. This procedure implies that the rate of technical substitution between any two variable inputs is independent of shift variables. Often, no justification is
given for direct estimation of the production function by the OLS method. We frequently encounter negative values for some input elasticities (particularly capital and bullock labor). These results are contrary to intuition and suggest the need for greater caution in formulation, specification, and estimation of production models. It is worth using flexible functional forms such as generalized Leontief, quadratic and translog (when all input values are positive).

The duality theory, developed by Shephard, Uzawa, and McFadden, enables a researcher to use the cost function (the profit function) as the starting point and avoids the difficulties of deriving the input demand (and output supply) functions, while at the same time insuring consistency with the hypothesis of cost minimization (profit maximization).

Lau (1978) develops a relationship between frontier production function and frontier profit function. Let the production function for ith firm be

\[ q_i = q_i^* (v_i, s_i) q_i^0 \quad 0 < q_i^0 < 1 \]  

\text{eq. (2.1.19)}

where \( q_i^* \) is the frontier function and \( q_i^0 \) is an index of neutral technical efficiency. The relationship between the marginal product of input \( v_j \) and the factor price for the ith farm is

\[ \frac{\partial q_i}{\partial v_j} = k_{ji} (r_{ji} / p), \]  

\text{eq. (2.1.20)}

where \( k_{ji} \) an input and farm specific index of allocative (price) efficiency.

Lau and Youtopolus (1971) use the profit function approach to test the hypothesis of economic rationality. Their specification of the deterministic form of production function is

\[ q_i = A_i f(v_i, s_i) \]  

\text{eq. (2.1.21)}

where the superscript \( i \) refers to the ith farm. This form allows for neutral variations in the efficiency parameter and differences in the quantities of fixed inputs.

They use Cobb-Douglas function with labor as variable input, and land and capital as fixed inputs, and use state level FMS data for 1955-57, grouped under farm size classes. Their maintained hypothesis is that the production function is identical for large farms (with 10 acres more) and small farms up to neutral efficiency parameter. They run a regression of log profit on size dummy, regional dummies, log money wage rate, log interest on fixed capital, and log cultivable land. Their finding is that the coefficient of size dummy is significantly (at 5 per cent level) less than zero, implying that small farms are more profitable, at all observed prices of 1, given the distribution of fixed factors of production. Youtopolous and Lau try to identify and isolate the causes for such differences. They find that both small and large farms are price efficient. Also, evidence for constant returns-to-scale, attributing the superior technical efficiency if the small farms to the direct supervisory and leadership role of the owner-manager.

Kalirajan and Shand (1988) specify and estimate a normalized quadratic profit function, and supply and variable input demand functions. They consider three variable inputs (labor, chemicals, and animal power), two fixed inputs (land and capital flow), and three outputs (cotton, chillies and pulses). Their database is a random sample of 240 farmers in Madurai district during 1979-80. Their profit function is quadratic in two normalized (by the price of chillies per kg) product prices, three normalized variable input prices, and the two fixed inputs.
The two output supply functions and three input demand functions are linear in the normalized output and input prices, and the fixed inputs. They use symmetry restrictions and theoretical restrictions involving the parameters of the output supply and factor demand functions, on the one hand, and the profit function, on the other hand. These equations are estimated using restricted Aitken's least squares method. The validity of the restrictions is tested using the Wald test statistic.

They find evidence for profit maximization hypothesis and obtain positive own-price supply elasticities (around 1) and negative own-price input demand elasticities, which are inelastic. According to them, cotton and chillies do not seem to be mutually price competitive in supply while chillies and pulses tend to be.

For an application of the duality approach, based on a translog cost function, to study substitution and complementarity among inputs in paddy cultivation in Haryana, see Chopra (1985).

Bapna, Binswanger, and Quizon (1984) present six systems of agricultural output supply and factor demand equations for the semi-arid tropical parts of Andhra Pradesh, Madhya Pradesh, and Tamil Nadu. These systems are derived from the generalized Leontief and normalized quadratic profit functions. They use an additive error component model to pool cross-section and time-series data. Some novel features of their approach are estimation of the output supply and input demand functions at different levels of commodity aggregation, inclusion of a number of shift variables such as rainfall, road density, market density, etc. Their database is incomplete in many respects and hence their estimates of the elasticities are subject to the biases resulting from the omission of variables. In contrast to the Kalirajan and Shand paper, symmetry and convexity conditions are not satisfied in some equation systems.

Many researchers use farm level data for one period to estimate input demand and supply functions. It is important to ascertain whether the price variability recorded (e.g., average labor cost, average cost of chemical inputs, average product price, etc.) reflects true variability in prices of differences in quality and time of transactions, and measurement errors. Also, institutional features such as price support programs, crop insurance programs, and credit constraints are ignored in these studies.

Zellner, Kmenta, and Dreze provided justification for direct estimation of the production function under the assumption of expected profit maximization and certain conditions about the disturbance terms in the production function and the equations based on the marginal conditions. Departures from static profit maximization model assumptions can be dealt with greater ease in the direct approach than in the dual approach.

In models with more than two crops, e.g., Wolgin (1975), Srinivasan (1971), Mythili (1988), the random terms $\theta_1$ and $\theta_2$ enter multiplicatively, i.e. gross revenue becomes

$$P_1 f(v_1, s_1) \theta_1 + P_2 g(v_2, s_2) \theta_2$$

where $f$ and $g$ denote the production functions for crops 1 and 2. Now it becomes necessary to specify the joint distribution of $\theta_1$ and $\theta_2$. Some simplify the problem by considering one risky crop and one riskless crop. In a paper (1971) dealing with the allocation of a variable input...
between irrigated and unirrigated plots, Srinivasan assumes that

\[ \theta_i = a_i w + b_i \quad i = 1, 2, \]

\text{eq. (2.1.23)}

where \( w \) is weather variable, and \( a \) and \( b \) are constants. This formulation permits different means and variances in yield per ha of irrigated and unirrigated lands, given \( v \)'s and \( s \)'s. Its advantage is that wealth is linear in the random variable \( w \).

Just Pope (1978), Feder (1980), suggest that while increases in some inputs (e.g. fertilizer) may increase the variance of output, increases in other inputs (e.g. pesticides) may decrease the variance of output. To accommodate this possibility, they propose a functional form of the type

\[ q = f(v, s) + h(v, s) \theta \]

\text{eq. (2.1.24)}

where \( f \) and \( h \) are assumed to be linear homogeneous. They assume \( E(\theta) = 0 \) and \( E(\theta^2) = \sigma^2 \), and hence \( E(y) = f(v, s) \) and \( \text{Var}(y) = h^2(v, s) \sigma^2 \). In contrast to the multiplicative specification of \( \theta \), the coefficient of variation of \( y \) depends on \( v \) and \( s \). One common feature of the models with one random variable, Srinivasan's model and those of Just and Pope, and Feder, is that the random variable enters into the wealth function linearly; this simplifies comparative static analysis. Econometric estimation of Just and Pope, and Feder models should pay attention to the heteroscedasticity problem.

Rao (1965), Saini (1979), and Rangaswamy (1982), and in FMS reports, the Cobb-Douglas production functions are fitted for years in different agricultural seasons (corresponding to different states of nature). In general, we observe non-neutral shifts in the coefficients (sometimes input elasticities changing signs from good year to bad year). Estimates of fertilizer response functions based on experimental data also reveal that the coefficients are very sensitive to the state of nature (drought year, normal rainfall year, or year with excess rainfall). These types of shifts are inconsistent with the multiplicative specification for \( \theta \).

Rangaswamy raises the following questions regarding fertilizer application to dryland cotton at Kovilpatti: (1) Do farmers under-invest in fertilizer in relation to the risk-neutral optimum? (2) How much of the under-investment can be attributed to risk and how much to other factors like credit constraint, lack of knowledge, etc.?

His procedure is as follows. Using the experimental data for 1971-72 to 1973-74 he estimates fertilizer response functions and computes the returns (net of fertilizer cost of application) at different levels of nitrogen per ha for each year. The fertilizer dose that maximizes the expected returns is considered as risk-neutral optimum level. The standard deviation of net returns is taken as a measure of risk. The rates of trade-off between the expected returns and the standard deviation are estimated up to the risk-neutral optimum level. The risk aversion optimum level is at the point where the slope of the iso-utility curve (based on Binswanger's estimation of risk aversion coefficients for semi-arid tropical farmers) equals the trade-off in the mean-SD frontier.

He found the trade-off almost constant at around 1.0 from 10 kg to 40 kg of N and then it rises to 1.29 to 50 kg N and to 2.73 at 60 kg N - the risk neutral optimum. He finds that the average dose of fertilizer applied by farmers works out to 7 kg/ha in comparison to the optimal risk-neutral dose of 60 kg N/ha and the optimal risk averse dose of 50 kg N. He reports that
19 per cent of the investment gap, 10 per cent of the yield gap, and 4 per cent of the gap in net return can be explained by risk-induced under-investment.

Singh and Nautiyal (1986) estimate the probability distribution of the profitability of fertilizer application in HYVs of wheat and paddy crops in four different agro-climatic regions of Uttar Pradesh. The risk of achieving a minimum desired return or losing money is determined from the distribution of the profitability. The rate of return from investment of fertilizer is computed as $R = \frac{p q (q_f - q_0)}{C_f}$, where $p q$ is the product price, $q_f$ the yield from an optimum level of fertilizer application, $q_0$ the yield without fertilizer application, and $C_f$ the cost of fertilizer. They use fertilizer experiment data for generating the mean and standard deviation of yields and estimating marginal physical products based on fertilizer response functions. Using the Monte Carlo technique they compute the probabilities of getting different values of $R$. Their results show that the probability of $R<1$ varies from 0.20 for paddy in the Eastern region to 0.06 in Western region, and for wheat from 0.06 in the Eastern region to 0.09 in the Western region. They report wide variations in $R$ in every region. The average expected rates of return are above 2.4 in the case of wheat and above 1.67 in the case of paddy.

Bliss and Stern use the expected utility maximization framework for analyzing risk in wheat cultivation in Palanpur. Assuming a linear production function and using farm level data for one season, they find that the ratios are 3.5 for land, 3.8 for fertilizer at the time of sowing, and 3.2 for ploughing. The implied value of relative risk aversion parameter is 10. They attribute the high value to risk aversion, cost and availability of credit, and choice of a good agricultural season for estimating the value of the marginal product.

Malathi (1985) uses FMS data relating to rainfed groundnut in South and North Arcot districts for 1981-82. She classifies the deviations between monthly water requirements and actual monthly rainfall under five states; scanty, deficient, normal, good, and excess. She uses rainfall dummy variables along with a Cobb-Douglas production function with land, labor, biochemical inputs, and capital. Her estimates of marginal risk premia $E(pMP_j - r_j)$ are 2.98 for labor and 0.88 for BC inputs. Assuming a constant relative risk aversion function, her estimates of parameter $R_R$ vary from 4.0 in smallest farm size group to 2.5 in the largest; estimates of proportional risk premium varying from 0.29 to 0.16. Her estimates of ratios of input level under risk neutrality are 0.48 for labor days and 0.55 for BC inputs; the ratio of risk averse output level to risk neutral output being 0.72. The proportional risk premium is negatively related to net assets and positively related to interest rate.

Using the FMS data for three agricultural years 1981-82 to 1983-84 and Cobb-Douglas production functions with land, human labor, size groups, Mythili estimates the production functions for rainfed groundnut and jowar in the kharif season and irrigated groundnut and paddy in the rabi season. Her estimates of proportional risk premia are 20.42 per cent for rainfed farms and 0.563 and 0.467, respectively.

Sankar and Mythili (1991) pooled the FMS data for three agricultural years and estimated the following form of production function

$$q_s = a + b x'_s + \frac{1}{2} (x'_s H x_s) C's x_s$$

along with size group and zonal dummies, both at farm business level, and for irrigated and rainfed groundnut. They find evidence for the inclusion of the state dependent vector of land,
labor, bullock labor, and materials c’s. Their estimates of the values of marginal products of land, labor, bullock labor, and material inputs fluctuate from year to year. Treating human labor and material inputs as variable inputs, the marginal risk premia per rupee of expenditure on the variable inputs work out to 0.78 for irrigated groundnut and 1.24 for unirrigated groundnut.

Mythili finds a positive correlation between number of crops and farm size, and number of crops and number of fragments. The correlation between the percentage of net area irrigated to net sown area is negative, implying, that, other things being equal, crop diversification is lower in irrigated than in rainfed tracts (presumably due to higher risk in rainfed farms). The coefficient of variation in profit (gross income less variable cost) in irrigated areas decreases from 0.103 for farms cultivating only one crop to 0.071 for farms cultivating two crops, and to 0.034 for those cultivating more than 2 crops; the corresponding figures for rainfed areas are 0.704, 0.510, and 0.481, respectively.

Even though these studies are based on different model specifications, time periods, databases, and estimation procedures, it is possible to draw some general inferences regarding the magnitude of the risk aversion parameter, marginal risk premiums for variable inputs, and levels of variable inputs usages. The relative risk aversion parameter appears to premia are positive for labor and bio-chemical inputs, but their magnitudes vary depending on farm size, source of irrigation, and crop. The marginal returns to fertilizer use are stochastic and the actual dosages are far below the risk-neutral levels.

Sankar and Mythili (1991) tried to empirically identify the factors responsible for annual variations in the proportion of net sown area to cultivated area, cropping intensity, and cropping pattern, using simple tools such as bi-variate tables, correlation analysis, and decomposition exercises. These types of exercises provide some understanding of the extent of shifts due to changes in the state of nature and their differential impact on different categories of farmers.

Weather induced uncertainty is largely responsible for annual fluctuations in agricultural production. Ray (1987) finds from regression analysis of data from 1951 to 1965 that over 70 per cent of the variations in cereal production around its line could be explained by a rainfall index. Krishnaji (1988) reports the coefficient of variation in net production of foodgrains per capita of 8.1 per cent based on the data for the period 1961-84.

The literature on bufferstocks of foodgrains is largely descriptive. Since bufferstock operations involve huge expenses for the government, determination of the optimum bufferstock is necessary. Krishnaji estimates a buffer stocks requirement of 13 million tons for a population of 750 million to ensure against an unforeseen shortage in any given year. His estimate is based on a per capita net mean production of 440 gms per day with a standard deviation of about 30 gms and the assumptions that 1.6 times the standard deviation is adequate to provide a cover against an abnormal shortfall.

Ray (1987), using a simple market model (allowing shifts in supply and demand functions), finds that the bufferstock operation can moderate the excess of price and farm income fluctuations only when the expected growth rates in demand and supply are equal. The program can reduce the variability in price and farm income provided the demand and supply curves are inelastic. Based on a historical analysis of rain-induced production fluctuations, he considers it
‘appropriate to have a maximum stock of 15 to 18 million tons of cereals and follow the storage rules aimed at stabilizing consumption with about 3 per cent variations’.

Raj Krishna (1967) assigns three functions of a positive price policy in agricultural development: (a) accelerate growth of agricultural output as a whole, (b) to accelerate or decelerate the growth of outputs of individual crops to steer the crop mix according to plan targets, and (c) to secure adequate increases in the marketed supply of food crops.

Raj Krishna (1963) uses the Nerlovian adjustment model to estimate short-run and long-run elasticities of supply (acreage) of agricultural commodities for the Punjab region before independence. His equations are:

\[ A^*_t = a_0 + a_1 P_{t-1} + a_2 Y_{t-1} + a_3 W_t + U_t \]  
\[ A_t - A^*_t - 1 + c(A^*_t - A_t - 1) \]  
\[ A_t = c_0 + c_1 P_{t-1} + c_2 Y_{t-1} + c_3 I_{t-1} + c_4 W_t + (1-c) A_{t-1} + cU_t \]

The dependent variable is measured as the standard irrigated area in the case of cotton, maize, sugarcane, and rice crops, irrigated or unirrigated area for wheat depending on the season, unirrigated area for jowar, gram, and barley, and the percentage of unirrigated area under bajra to unirrigated area in all summer crops. \( P_{t-1} \) is the post-harvest price of the crop deflated by an index of the post-harvest price of the alternate crops, with a year lag. He considers three ‘shifter’ variables. \( Y \) is the yield of the crop deflated by an index of the yields of alternative crops. It is included in the equations for cotton and rice because of the significant upward trends in the yields due to varietal improvements and expansion of irrigated area. \( Z \) is the total irrigated area in all crops of the season. Rainfall \( (W) \) has been included in the equations for unirrigated crops, as it is an important factor determining the acreage planted under these crops. Changes in input prices have been neglected for want of data. It is assumed that the demand functions for individual crops facing the producers are highly elastic and hence no output demand functions have been specified. Data related to the period 1914-15 to 1945-46. Equation (a) is estimated by the OLS method. The Durbin-Watson test does not indicate the presence of a serial correlation of \( U_t \)’s.

Except for jowar and gram, Raj Krishna obtains positive own price elasticities for all other crops. The short run price elasticities range from 0.08 for irrigated wheat to 0.72 for cotton (American) while the long-run price elasticities range from 0.14 for irrigated wheat to 1.62 for cotton (American). He draws some general conclusions:

(i) The models of farm supply behavior which have been found to work with the data for Western countries not only do not break down when applied to Indian data but yield plausible, interesting, and internationally comparable results.

(ii) The net effect of price variables determining supply are well specified, and vice versa.

(iii) The relative importance of price and non-price factors varies from crop to crop.

Askari and Cummings provide tabular summary of the results for different crops in different countries. In general, the short-run supply elasticities are rather small. The magnitudes of the
elasticities depend on many factors - the kind of relative price variable used, the shift variable included, the region, the season, the crop, level of aggregation, etc.

Many researchers are not explicit about the theoretical framework from which the expression for desired acreage is derived. This results in ad-hoc procedures for functional forms and measurement of variables. If we use a multi-crop, multi-input profit maximizing model then all product and input prices must enter. Since the profit function is homogenous of degree zero in prices we can define the prices by one of the output or input prices. If we use a portfolio model, as in Behrman (1968), Nowshirvani (1971), Wolgin (1975), then the variances and covariances of price and yield variables appear. In a portfolio model of farm cultivating foodgrains (for own consumption) and cash crops, Nowshirvani shows that a negative foodgrains area response to foodgrains area response to foodgrains price is possible. In a model involving a risky crop and riskless crop in an expected utility framework, Sankar and Mythili (1991) show that the response of acreage under risky crop to an increase in price is positive, under the hypothesis of decreasing absolute risk aversion. This result holds also in the Kataoka version of safety first model. However, in contrast to the profit maximization model under certainty, the effect of an increase in the price of a variable input on the demand for variable input is uncertain. In the expected utility model, determinants of risk aversion must also be included in supply response functions.

Some, including Narayana and Parikh (1987), use the ARIMA process expectations for the expected revenue and shift variables. A major attack on the use of the expected revenue and shift variables. A major attack on the use of the adaptive expectations model came from Muth as early as 1961. He suggests procedures for deriving expressions for expected variables endogenously from the very model used. Thus, the expectation coefficients will depend on the structural parameters and the shift variables.

Nerlove in his 1979 paper notes the inadequacy of the model, especially in the context of the developing countries. His model was meant to study the response to price of US farmers in the production of corn, cotton, and wheat in the period prior to the introduction of price supports and acreage allotments. In India we have price support and procurement programs for major crops. When the programs are effective, the support price provides a lower bound for the price of the crop. In such a case, we can use the support price (announced at the time of sowing) or the relative price instead of Nerlovian type of price formation. Yield uncertainty is minimized as a result of the crop insurance program. Increased provision of public credit and public investment in rural infrastructures would make the own-price supply elasticities more elastic. Unfortunately, no empirical work has been undertaken to develop a farm supply model taking into consideration these institutional developments.

De Janvry and Subbarao’s (1986) general equilibrium model deals with agricultural price policy and income distribution in India. They treat outputs as exogenous. The Narayana-Parikh-Srinivasan (1987) model consists of nine commodity sectors in agriculture and one non-agricultural sector. This model is being applied to answer a number of policy questions.

What is effect of an increase in the foodgrains price on the marketed surplus of foodgrains? Mathur and Ezekiel (1961) postulate an inverse relation between the two on the assumption that farmers’ cash requirements are fixed. Their hypothesis also implies that farmers’ own consumption is residually determined.
This is a questionable assumption, especially for farmers' living above the subsistence level.

Krishnan (1965) examines the relation between the marketed surplus and the price using a simple model. Let

\[ Q = \text{total net output of foodgrains (exogenous variable)}, \]
\[ P = \text{price of foodgrains}, \]
\[ Y = QP = \text{income of the farmer}, \]
\[ r = \text{proportion of output consumed by the farmer}, \]
\[ M = Q(1-r) = \text{the marketed surplus}, \]
\[ rQ = D(P, Q, P) = AP^a(QP)^b = \text{demand function for foodgrain}, \]
\[ a < 0, b < 0. \]

The elasticity of the marketed surplus with regard to price is

\[ E_M^P = -(b + a)(r / (1-r)) \quad \text{eq. (2.1.29)} \]

Since 0 < r < 1, the elasticity is positive only if own the price elasticity of demand is higher (in absolute value) than the income elasticity of demand. His estimates of a and b are -0.3584 and 0.5216, respectively. Therefore the elasticity of marketed surplus with regard to price is -0.3030. In this case, the income effect outweighs the substitution effect and, therefore, the proportion consumed increases.

Thamarajakshi (1969) estimates linear and log-linear relationships of marketed surplus with the net barter terms of trade, index of agricultural output, and time as explanatory variables. Both output and time are positively and significantly (at a 5 per cent level) related to the marketed surplus. The coefficient of the terms of trade is negative, but not significant at 5 per cent level.

Bardhan and Bardhan (1971) note that a number of prices affect farmers' grain marketing decision. The per capita production of cereals (Ox) depends on the price of cereals in relation to that of other agricultural products \((P_x / P_y)\) and a non-price shift parameter \(A\).

\[ O_x = O_x(P_x / P_y, A) \quad \text{eq. (2.1.30)} \]

Per capita consumption of cereals \(C_x\) is a function of income \((I)\) and the price of cereals in relation to the price of other consumables \((P_x / P_y)\):

\[ C_x = C_x(I, P_x / P_y) \quad \text{eq. (2.1.31)} \]
\[ I = P_x O_x + P_y O_z \quad \text{eq. (2.1.32)} \]

The marketed surplus \(s\) is

\[ s = I - \frac{C_x(I, P_x / P_y)}{O_x(P_x / P_y, A)} \quad \text{eq. (2.1.33)} \]

Assuming that the slope of the transformation curve is equal to the negative of the ratio of the prices of the two products, they derive the following equation,

\[ \log s = a_0 + a_1 \log (P_x / P_y) + a_2 \log (P_y / P_z) + a_3 \log A \quad \text{eq. (2.1.34)} \]

with \(a_1 < 0, a_2 < 0\) and the sign of \(a_3\) depends on the rates of growth of cereal and non-cereal outputs on account of the shift parameter and on the income elasticity of demand for cereals.
Using the data for 1952-54 to 1964-65, they report a value near unity for $a_1$, a negative but significantly, below -1 value for $a_2$ and a negative value for $a_3$.

*De Janvry and Kumar (1981)* develop a model to consider the response of marketed supply to changes in both product and factor prices. For the mono-crop in the Union territory of Delhi they consider wheat ($Q$) with fertilizer ($X$) and labor use ($L$) as variable inputs, and land ($T$) and capital ($F$) as fixed inputs. Denoting $r$ the fertilizer price, $w$ the wage rate, $f$ the fixed factor price, and $p$ the price of wheat, their marketable surplus equation becomes

$$M = Q \left( \frac{r}{p}, \frac{w}{p}, T, F, t \right) - C(\frac{p}{I})$$

where,

$$I = p Q \left( \frac{r}{p}, \frac{w}{p}, T, F, t \right) - r x \left( \frac{r}{p}, \frac{w}{p}, T, F, t \right) - wL \left( \frac{r}{p}, \frac{wp}{f}, T, F, t \right) - fF$$

Taking the total differential of $M$ with regard to $p$, $w$, $r$, $f$, $T$, $F$ and $t$, and writing it in terms of relative changes, they derive the elasticity expressions.

For application they use a normalized restricted profit equation based on the Cobb-Douglas production function, and labor and fertilizer demand functions. The data are based on records of small and large farms for two villages between 1968-69 and 1975-76. They assume income elasticities of 0.55 for small farmers and 0.30 for large farmers, and price elasticity of -0.4 for small farmers and -0.2 for large farmers. For the non-farm population they use an income elasticity of the marketed surplus of wheat with regard to price are -0.23 for small farmers and 0.26 for large farmers, the overall elasticity being 0.18. They study the impact on the marketed surplus of a pure inflation effect (when all relative prices remain constant).

The paper by *De Janvry and Kumar* enriches our understanding of the factors influencing marketed surplus of foodgrains. However, their use of the profit function approach is questionable, especially for small farmers. Further, the use of the Cobb-Douglas production function is highly restrictive as it implies that the elasticity of demand for $j$th input with respect to $i$th input price (or the crop price) is the same for all $j$.

*Barnum and Squire (1979)* develop a theory of farm household and apply it to semi-commercial paddy farms in Malaysia. In their model, the utility function depends on leisure, own consumption of market purchased goods and household characteristics; the agricultural output depends on labor use in farm other variable inputs and land. Total time is allocated among own farm labor, labor time sold and leisure. The model is closed with a budget constraint that states total expenditure on consumption of agricultural and market purchased goods equals sum of farm net income and non-farm labor income. In their empirical work they use the Cobb-Douglas production function and the linear expenditure system.

According to *Schultz (1964:133)* the notion of technological change in agriculture is in essence a consequence of either adding or dropping, or at least changing one factor of production. The input may be fertilizer, pesticide, tractor, pump-set, or harvester. There may be qualitative changes in inputs, e.g. the introduction of a High Yielding Variety (HYV) seed increase in labor skill. Given the same inputs, changes in cultural practices/methods of application may increase yield rates.

The HYVs of wheat and rice, introduced in India in 1966, were based on research work and experiments conducted in Mexico and the Philippines. These seed technologies were tested and implemented in India with government support. These HYVs are short-duration, fertilizer
responsive, photo-insensitive, and short-stem crops. They yield better results under controlled irrigation and with optimum dosages of fertilizers. The shift from traditional to HYVs means a shift from traditional to modern agriculture, in the sense that the shift requires greater use of non-farm purchased inputs like fertilizer, pesticides, insecticides, electricity, and diesel pumps, tractors, etc., and also greater information and skills on the part of the users.

Agricultural universities and research stations produce the new factors, test them on an experimental basis, and then release them. Seed multiplication can be faster when the seed-output ratio is small as in the case of paddy, wheat, and sunflower. In the case of groundnut, the seed-output ratio is high, about 1/6, which makes increased seed availability difficult. Apart from the availability of seed, elastic supplies of complementary inputs and credit are necessary for faster adoption. In Punjab and Haryana, within a year of introduction of HYVs of paddy and wheat about 30 per cent of the areas under the crops were shifted to HYVs and about 70 per cent of the areas were under the HYV crops within three years. This was possible because of public and private irrigation, fertilizer availability, and credit facilities.

McGrulik and Mundlak (1991) develop a conceptual framework for analyzing the effect of incentives and constraints in the transformation of Punjab agriculture. The techniques of production are identified by variety (modern (MV) or traditional) in the growing season (rabi or kharif), and method of production (irrigated or dry). Their multistage optimization model contains three sets of relations.

Many economists analyze the nature of bias in terms of changes in factor shares. In analyzing the production structure and demand for labor in post-war Japanese agriculture, Kuroda (1987) uses the cost function approach, utilizing the duality theory. He assumes an aggregate cost function of the translog form with output, factor prices (labor, machinery, intermediate inputs, land and other inputs), and time. Using the Shephard duality theorem, the cost share equation is derived.

Paul and Mehta (1991) also use the translog cost function (incorporating technological change) to provide measures of factor demand, elasticities of substitution, biases of technical change, and the test hypotheses about the structure of production technology in Indian agriculture during 1960-61 to 1982-83. Their output measure consists of crop output and livestock production. Their four input measures are labor, land, capital, fertilizer, and other inputs. Their cost share equations involve the logarithms of prices of four inputs, logarithm of output, and time. Dropping one of the share equations, they estimate the simultaneous equation system by the iterative non-linear Zellner method yielding maximum likelihood estimates.

Paul and Mehta find that the non-homothetic translog cost function describes a well-behaved production structure for their data set. The coefficients of time in labor and capital cost share equations are positive and statistically significant, implying that technical change has been biased towards the use of labor and capital. They argue that these biases cannot be explained in terms of a price-induced hypothesis: 'they only indicate the presence of biased innovation possibilities in Indian agriculture'. They report that technical change has been neutral to land use and towards the saving of fertilizer and other inputs.
Rangaswamy analyzes the factor using bias in shifting from the traditional to modern variety by estimating

\[ b_i = \frac{S_{im} - S_{it}}{S_{it}} \]  

where \( S_{im} \) = relative share of the \( i \)th factor in the value of output under modern technology, and \( S_{it} \) = relative share of the \( i \)th factor in value of output under traditional technology.

The technology is input-saving, neutral, or input-using with respect to the \( i \)th input, depending on whether \( b_i \) is less than equal to or greater than zero.

The new technology may be scale neutral but not resource neutral. The green revolution has benefited certain regions (Punjab, Haryana, Western UP, Coastal Andhra), certain crops (paddy, wheat, maize), and better-off farmers (Rao, 1989; Sidhu and Singh, 1986).

Rao (1989) notes that bio-technologies will release, to a significant degree, the agro-climatic constraints to crop production by genetically building up resistance in seeds to moisture stress, pests, diseases and adverse soil conditions. They save significantly on land, labor, and capital, and will be knowledge and skill-intensive. Hence, the distribution of gains from bio-technologies will depend increasingly on the access to new inputs and knowledge, on agriculture-industry relationships, and the dependence of the domestic industry on transactional corporations for critical inputs and services.

Next section presents briefly a Survey of Production Function studies on Indian agriculture.

2.2 Survey of Production Function Studies on Indian Agriculture:

The survey is confined to the studies published and oft-quoted ones. It includes sufficient number of studies on all the important crops in most of the states so as to facilitate a meaningful discussion on various aspects of production function studies. It contains 72 cross-sectional studies with 249 functions on crop production in 14 states and one union territory. These studies are undertaken during the period 1954-1984. A bird’s-eye-view of the studies is presented in Table 1 with information on its author, year of publication, objectives, crop/crops, state and year to which the data pertains, specification of the function and variable, and results.

Initially two factors seem to be mainly responsible for the spurt in the production function studies on Indian agriculture: (i) the availability of mass of quantitative data from Farm Management Studies (FMS) since mid 1950s and (ii) the publication of Schultzian hypothesis (1964) on allocative efficiency of traditional agriculture. As such no study is available prior to the commencement of FMS (1954) and very few, before 1964. Very few studies were undertaken during 1950s, one-third of them during 1960s, nearly half of them during 1970s and one-tenth of them during early 1980s.

The studies are heavily concentrated on North and North-west India. Uttar Pradesh alone accounts for nearly one-third of them and Punjab, one-fifth. Of the rest, Andhra Pradesh accounts for six studies, Maharashtra five, Haryana, West Bengal and Orissa four each, Bihar, Gujarat, Karnataka, and Tamil Nadu three each, Himachal Pradesh two, Rajasthan, Jammu & Kashmir and Union Territory of Delhi one each. Some of the studies are spread over several states.
Most of the studies have multiple objectives. Almost all the studies published before the Schultzian hypothesis (1964) examined Input-output relations as their only objective. Almost two-thirds of the studies published after it, examined Allocative efficiency, as the sole or one of the objectives, and almost a quarter of them, attempted to investigate Returns-to-scale as the sole or one of their objectives. These two are very much debated issues on traditional agriculture. Estimation of Marginal Productivity of Labor, another controversial issue on Indian agriculture, figured in four studies. Other important issues investigated are: Factor Substitution, Influence of Caste and Management on Production, Effect of Technology and Tenancy and Relative Economic Efficiency, Effect of Standardization of Land Variable on the Significance Levels of Elasticity Estimates.
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<tr>
<th>Sr. No</th>
<th>Author &amp; Year</th>
<th>Objectives of the Study</th>
<th>Area &amp; Year of date</th>
<th>Function for firm/crop</th>
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<td>60.</td>
<td>Singh &amp; Kahlon</td>
<td>1975</td>
<td>RUE</td>
<td>Central Punjab 1968-69</td>
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<td>Cobb-Douglas</td>
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L = Net Area Sown.
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<th>Model</th>
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The production functions which study the relationship between output and all inputs aggregated together, i.e., type two specification mentioned above, in a way examine the returns to scale. One such study is available from the Farm Management Studies. The Farm Management Studies were carried out for six states for the period 1954-55 to 1956-57. The data collected by these studies have provided rich resource material. Of the six studies, one relating to West Bengal fitted regression functions relating output with land and other inputs aggregated together. Though the fit of the regressions run for different years, districts and data collected through survey and cost accounting method, was good with high value of $R^2$, the signs were not consistent in all cases. This study has historical importance, being the first of its type applied to Indian data. Besides this study, in 1958, GD Agarwal, PN Driver and DK Desai adopted this approach. Recently, some of the authors who have run production functions in a regular way to examine the relationship between output and different inputs taken separately but simultaneously, have related total output and inputs in a functional form. These types of studies were undertaken to study if the returns to scale varied at different levels, i.e., increased, remained constant and declined thereafter. Such a study sought answer to the optimum scale of operation.

Production functions that examine the relationship between output and all the inputs taken together or separately have mainly three important objectives. They are:

(i) to measure production elasticities and marginal physical products to derive marginal returns to individual inputs and to study efficiency of allocation of resources,
(ii) to study the returns to scale, and
(iii) to investigate into input-output relationship, i.e., substitution among inputs.

Various functional forms employed to investigate production relation. Of all the forms of production function, the most widely used form is the Cobb-Douglas type. It is linear in log. This form of production function considers the relationship of the inputs taken individually but simultaneously with that of the output. Early in 1959, GD Agarwal and WJ Foreman used this form. The latest in 1969 was a study by GR Saini. In between Raj Krishna, AM Khusro, DK Desai, Ram Saran and PP Pillai have contributed studies using Cobb-Douglas production function. Most of the authors have used the farm management data collected by the farm management surveys of the first series covering the period of three years 1954-55, 1955-56 and 1956-57. Agarwal and Foreman carried out three exercises in one paper. They first related the total output with total inputs in a linear function. Then they employed Cobb-Douglas
production and tried several alternative combinations of inputs as independent variables. They ran production functions of Cobb-Douglas type for individual crops as well. Lastly, they ran polynomial functions relating output with one or two selected inputs at their geometric means. They got all the right signs with positive marginal product of all inputs taken individually. In aggregate function where total output was related with aggregate of inputs they got a very low value of coefficient. Cobb-Douglas type of production function gave a better fit on the whole but not for individual crops. But the value of $R^2$ was found to be higher for the polynomial function than that for Cobb-Douglas function.

CH Hanumantha Rao has used, like Ram Saran, production function to analyze agricultural data. His contribution lies in the adoption of disaggregated approach. He runs regressions separately for farmers in different size-groups and also for three natural regions of the erstwhile Hyderabad state. He uses Cobb-Douglas type of linear in log function and relates production with inputs of land and labor. His findings are mainly two. Firstly, he finds positive production elasticity of labor. Secondly, and importantly, he finds production elasticity of labor to be higher for bigger farmers with holdings above 5 or 10 acres and a reverse position for small farmers. He has used land as measured in units of area standardized by using land assessment per acre. He finds further the production elasticity of labor to be higher than that of land in two relatively less fertile regions and a reverse situation in the fertile tract of Marathawada.

Ram Saran carried out an intensive study of input-output relationship based on farm management data. He ran three different types of functions: (i) Spillman function, (ii) Quadratic function, and (iii) Cobb-Douglas function. He ran regression for individual crops as well as for combined output of individual of important crops taken together. He used the Spillman and quadratic type functions to study the relationship between output of individual crops such as rice and wheat and inputs of nitrogenous and other fertilizers. He used the Cobb-Douglas function too. Based on this function, he worked out the values of marginal products of different inputs and for different states and compared them with the factor costs. He also measured the returns to scale. He found returns to scale to be constant in all the cases he studied but the values of marginal products were found to be different from the factor costs in many cases. Particularly, fertilizers in some cases had marginal returns lower than the acquisition cost. The returns related to the years 1953-54 and 1954-55.

W. David Hopper investigated into the problems of allocation efficiency with the help of Cobb-Douglas type of production function. Using data relating to one village which he collected specially for his study, he examined the relationship between the value of marginal product of inputs like land, bullock, labor and irrigation water. He selected crops like wheat, barley, peas and grams. He found that the value of marginal product and prices of the services of different inputs were closely related. He also found the relative prices and market prices of factors and commodities to be very close to each other. Hopper measured prices in real terms, in terms of barley.

Meghnad Desai and Dipak Mazumdar gave a new thrust to the analysis of allocative efficiency. In particular, they examined the relationship between the value of marginal product and wage rate of labor employed in agriculture.
Studying the farms in West Bengal they divided the sample into sub-groups consisting of:

(i) farmers who employed hired labor and
(ii) farmers who did not employ hired labor.

They used linear as well as double-log production function. Among independent variables they included owned and hired labor, bullocks, implements and land. The dependent variables were in turn output and yield per acre. The findings of these authors are illuminating. Out of 12 regressions run for farmers hiring labor on wages, in cases they found the coefficient of labor to be positive and statistically significant. In 3 cases, though positive, it was found to be not significant. In contrast, for the group of farmers not hiring labor on wages, out of 12 equations, in 8 the coefficient of labor was statistically not significantly different from zero; and in the remaining 4 cases, though statistically significant, the coefficient was negative. The implication is clear. They claimed to have identified the group where the market forces did not bring about equilibrium in regard to allocation of labor. It may be noted that in their exercise the value of $R^2$ has been as low as 0.3 to 0.2 in regard to the farmers employing hired labor and 0.5 to 0.6 and even 0.8 to 0.9 (in 3 cases) for the other group. The analysis referred to the year 1956-57.

A more detailed and somewhat comprehensive analysis of resource allocation has been undertaken by Gian Sahota. His study covered 859 observations and 13 crops for 2 years, all drawn from the Farm Management data. The author claims to have achieved simultaneously isolation of inter-seasonal, inter-year and inter-regional differences in addition to the measurement of relationship between the value of marginal product and prices of inputs. Thus Sahota's study would claim the broader canvas of observation together with more precise calculation of the value of marginal product of factors as it would be net of influence of region, year or season and inter-farm differences in sizes. Sahota observed that no definite conclusion emerged regarding the sign of coefficient of labor. The value of marginal product of fertilizers and irrigation was above their respective costs. His study showed further that there were no significant inter-seasonal differences but regional differences were quite significant. He found that Madras was at the top probably due to the use of improved seeds. Though the effect of the size of the farm was observed in the case of some crops, the patterns differed for different crops. Thus no conclusive observation seems to have emerged from his study relating to the effect of the size of the farm on general production efficiency.

The above authors did not probe into the problem of multicollinearity, i.e., inter-correlation among inputs. Raj Krishna made an attempt to account for it and made alternative combinations of inputs as independent variables specifically to overcome multicollinearity. In his article published in 1964 he also worked out the value of marginal product of different inputs and found them, on the whole, to be in line with the acquisition cost of the inputs, the exception being that of land. In the same article, Raj Krishna examined the relationship between the total costs and total output, as well as the average product of land and labor with that of the scale of operation measured in terms of area of land holding, as well as total output. He examined these relationships both linearly and non linearly. In these exercises he obtained better fit, measured in terms of value of $R^2$ for Cobb-Douglas production function than that for other relationships. He found returns to scale to be close to one.
Khusro, in his study of production function relationship, makes an intensive inquiry into the returns-to-scale. Besides tabular analysis and graphic presentation, he ran regressions. He defined scale in terms of

(i) size of holding measured in acres;
(ii) area adjusted for variation in land revenue to take account of quality differences in land; and
(iii) total output.

He examined the relationship of the scale of operation with the returns measured in farm incomes and net profit. He used simple linear regressions and came to the conclusion that, for most part in most cases, the returns to scale were constant. One major exception to this was that yield per acre declined as land measured in unadjusted area increased. He found further that the net profit tended to increase as the size of the holding increased, whether the size was measured in adjusted or unadjusted area. He examined also the relationship between (i) the output and the cost per unit of output and (ii) the income and the ratio of cost to income. He took into account mainly the paid out costs. The regression results showed, in both these cases, constant relationship with no effect of the increase in output or income on cost per unit of output or on ratio of cost to income.

Saini's study, the latest in sequence, employs the Cobb-Douglas production function, Saini examined the problem of multicollinearity among independent variables but he did not find the problem serious enough to vitiate the results. Like Raj Krishna and Khusro he found the returns to scale to be constant for all the four regressions which related to two years, 1955-56 and 1956-57, and to two States, UP and the Punjab. His results corroborate to a large extent the results of Raj Krishna in other respects too. In the case of most of the inputs he finds the ratio of the marginal returns to factor costs to be close to one.

In addition to the above studies, there are a number of other studies that used Cobb-Douglas production function to measure the contribution of inputs to agricultural production specially during the post-planning period. D Radhakrishna attempted to measure production elasticities with respect to several inputs from the data for the West Godavari district. The production elasticities were used to derive the marginal value product of different inputs. His results showed that the elasticity of bullock labor was not significantly different from zero. On similar lines, B K Naik estimated marginal value of products of different inputs, based on survey data of Ankodia village. Though he obtained high value of R² in the function, the coefficients of independent variables were not significant. V Chennareddy also has a study on production function of Cobb-Douglas type. He also focuses attention on efficiency of use of inputs. For this he derives marginal productivity and factor costs to be not different from one.

Production function approach is used by Ram Dayal to measure the influence of rainfall of different months on yields. He studied the effect of rainfall of different months on yields.

The Cobb-Douglas type of production function used by most of the authors implicitly assumes an amount of flexibility in substituting one input for the other as underlying elasticity of substitution is one. The problem of input substitution can be examined directly by changing the form of production function. The forms used for this purpose are: (i) Quadratic, (ii) Square root and (iii) Spillman. V Y Rao and E O Heady employed quadratic and square root functions. They derived isoquants based on the production functions and from isoquants
they measured the marginal rates of substitution among different inputs. They found a high degree of substitution between fertilizers and land on the one hand and between fertilizers and labor on the other. Morton Paglin has run a production function relating to output per acre with costs per adopting the semi-log form of equation. Costs were of two types: (i) including family labor (cost C) and (ii) including cost of wages imputed to family labor (cost A). His exercise, carried out mainly in the context of examination of the concealed unemployment, showed curvilinear relation between the two variables with coefficient of correlation as high as 0.91, implying substitution of land by labor and capital. This substitution is especially observed among small farmers. Sahota has a major study devoted to the investigation of factor substitution. In this study based on farm management data, he examined the CES (Constant Elasticity of Substitution) type of production function and found that the elasticities of substitution of different inputs derived from CES production function were not different from one. Sahota used farm management data for different regions with break-ups for different size-groups. For a farmer in the real world it may not be possible to have such wide variations in resource use as would be observed on an All India scale.

There are two recent studies which imply lack of factor substitution. They are from (i) Pan A Yotopoulos, Laurence J Lau and Kutlu Somel and S V Setharaman. Of them Yotopoulos and his associates run a regression of semi-log equation with output per acre and inputs other than land per acre as dependent and independent variables respectively. On the basis of the results of the study they get the value of $s=0.423$. They also ran CES function and found the value of $s=0.295$ (for all farms) and a still lower elasticity of substitution between land and other inputs ($R^2 = 0.981$) : it varied, however, from 0.265 for large farms ($R^2= 0.974$) to 0.942 ($R^2= 0.959$) for small farms. They have used farm management studies data. The authors, however, have not accepted the result as they considered, on the basis of their hunch, this value to be low. They have then proceeded with Cobb-Douglas type of production function.

Sethuraman in his study of "Long Run Demand for Draft Animals in Indian Agriculture" based on farm management studies, examines ingeniously and in detail the problem of substitution among inputs as inferred from the derived demand for draft animals. By defining fixed and variable assets in the context of different length of periods, he gets magnitudes of elasticities of substitution between draft animals and other inputs in the short run and the long run separately. He has a positive observation to make. He studies different states separately and infers some complementarity between land and animal for Madras, 'some substitution' between land and animal in Bombay, and weak substitution in the Punjab in the long run context. In the short run context, he observed the substitution between labor and bullock to be low in Madras, and some complementarity in the Punjab.

A I Medani, VM Rao and CH Shah have raised methodological problems regarding production function. Rao has emphasized the need for proper specification of weather as an input. Instead of using rainfall as a proxy as has been done by Raj Krishna and others, Rao evolved a measure by which weather, not as measured directly from rainfall, but as a measure evolved indirectly from its differential impact on different types of soils can be taken account of. Medani has taken up a subtle point as to whether the coefficients for production functions for individual farms can be assumed as identical.
He has empirically tested his idea by fitting three different types of functions, viz.,

i) for individual farms with time series;

ii) cross-section and time-series data pooled together; and

iii) time-series data for a group of farms taken together.

In his exercise, he finds the first model to be the most relevant. However, the results of the three models do not differ materially from each other and hence the error in using model 2 or 3 would not be large. Various types of specification errors that might creep in the production functions have been pointed out with illustrations by Shah.

Most of the production functions so far discussed are fitted to the cross-section data. The main objective of the cross-section analysis is to examine the efficiency of the use of inputs. A number of attempts have been made to fit the production function to time-series data. The focus of attention in this exercise has been the investigation into the relative contribution of different inputs to the growth of production over a period of time. Raj Krishna, Ashok Parikh and T P Abraham and S K Raheja, Hanumantha Rao, Venkateswarlu and Shetty have made contributions on the subject. Raj Krishna has analyzed the Punjab data and Ashok Parikh has analyzed in detail the data for Punjab as well as other states. Venkateswarlu has analyzed the data for Andhra Pradesh. They have measured the contribution of different factors of production on the basis of production elasticities. One common conclusion that emerges from their studies is that, during recent past, fertilizers and irrigation have made a major contribution to the total output. During the Pre-war period irrigation alone was a major factor responsible for the growth of production in the Punjab state. In Andhra Pradesh the growth of production of crops is explained, in recent past, largely by the expansion of area under cultivation and the percentage of area under irrigation to total cropped area. The contribution of irrigation was overwhelming larger than that of expansion of area under crops, but fertilizers do not seem to have made a significant contribution. The analysis relates to 1952-53 to 1961-62. Unlike Raj Krishna and Venkateswarlu, Ashok Parikh went a step further. To avoid the multicollinearity problem he fitted first-differenced-log-form. Abraham and Raheja restricted their analysis to rice and wheat, used the data for All-India, taking southern and eastern regions for rice and western and northern regions for wheat. They tried four different forms of production function: (i) Linear, (ii) Cobb-Douglas, (iii) Semi-log, and (iv) Exponential. In their analysis, fit of all the different functions was found to be equally good. They, therefore, carried out further analysis on the basis of Cobb-Douglas type of production function. Unlike Raj Krishna or Ashok Parikh, they employed Taylor expansion to the first degree of approximation. On the basis of the results of this exercise they measured the contribution of different inputs to the growth of production of rice and wheat over the period 1951 to 1964. During this period they found the contribution of fertilizer consumption to be the largest in the case of rice. In the case of wheat, irrigation and expansion of area under the crop made the major contribution. However, Abraham and Raheja could not get over the problem of multicollinearity. In view of the multicollinearity, they pleaded for adopting the yardstick approach. They recommended that, with the help of these weights, various inputs may be combined in a composite index. They found that such composite index explained variations in production to a much greater extent than the usual form of production function type of analysis. Hanumantha Rao who also analyzed the Punjab data followed yet another method. He fitted exponential function to the production data for different districts in the Punjab. Juxtaposing the rates of the growth of crop
production against changes in the different inputs for different areas, he tried to explain the inter-district variations in the growth in terms of rates of changes in inputs.

Shetty has studied the problem of contribution of different factors to the growth of crop production, as a part of his Ph.D. thesis. They study in both at All-India level and at the level of individual States. The former covers the recent period from 1946 to 1963 and the latter covers a longer period from 1921 to 1955. Like Ashok Parikh and Raj Krishna, he too gets, on the basis of analysis of data for All India, the sum of production elasticities to be greater than one. He therefore refrains from interpretation in so far as the contribution of different inputs is concerned. He however gets much larger value of coefficient for unirrigated area. At regional level the picture is better. The sum of production elasticities was close to one and hence meaningful interpretation was possible. He found irrigation to be an important factor in the Punjab, Assam and UP, whereas the contribution of unirrigated area to the growth of the total output seemed to dominate in West Bengal. Fit of regression was found to be good with values of $R^2$ ranging above 0.60. However, many of the regressions had problems either of multicollinearity or auto-correlation. The analysis was confined to a few regressions that were free from both of them.

We have observed earlier Sahota's efforts to isolate inter-regional, inter-seasonal and inter-farm size-group differences in the efficiency of production. Ashok Parikh undertakes a similar exercise but with a different objective in view. In a cropwise, districtwise production function, he analyzes time-series data. He thus combines cross-section and time-series for ten districts of Madras for paddy, groundnut, chom, cambu and ragi. He uses data as observed for different years as well as first order differences. The latter represents an attempt to overcome in a way the problem of multicollinearity. In his exercise the value of $R^2$ varied very widely. It was low for groundnut and paddy and high for generally dry crops. He found that the area under crop, extent of irrigation and rainfall explained to a great extent the variation in production. In the exercise relating to variations in the production changes from year to year. He made an allowance for trend but he found that the trend value was significant only in the case of paddy.

The problem of production efficiency has investigated by scholars at more than one level. The efficiency of use of inputs has already been referred to. It has been analyzed in terms of the relationship of acquisition cost and value of marginal product of different inputs. Whether the scale of operation makes difference to the efficiency of the use of inputs is investigated with the help of size of holding and various indicators of efficiency. A major contribution in this respect has been the debate on the relationship between the yield per acre and the size of holding. Several contributions have been made and different issues raised in this regard.

Erven J. Long adduced statistical evidence to show that yield per acre was negatively related with the size of holding. To eliminate the influence of variations in soil and climate he confined his analysis to farmers selected from within the same village. Hanumantha Rao's major study and a recent paper include analysis of the relationship between the size of holding and efficiency. Through regression analysis he shows that per acre yield declines as the size of holding increases. The decline in per acre yield, when the effect of irrigation is kept out, is much smaller. At the same time relatively bigger farmers had lower per acre rental value of land especially when irrigation was included. Rental value is an index of the quality of land. Further, Hanumantha Rao finds that the net influence of tenancy on yield is imperceptible.
Khusro, Hanumantha Rao, D K Desai and others who studied the problem of scale and efficiency from various angles have come to the conclusion supporting Erven J. Long's observation. Evidence provided by P C Sarkar regarding West Bengal villages, however, leads to the opposite conclusion. This is rather an exception. Whereas most of the studies corroborate Long's conclusion, these, authors, along with other authors of some of the subsequent studies, have suggested a few amendments to the hypothesis of the negative relationship between the size of the holding and yield per acre. Instead of measuring the size in terms of surface area, if quality of soil is taken into account, the yield differentials among different groups are greatly reduced or totally eliminated. Khusro, Desai, and C H Shah have accepted this position. Khusro would use land revenue as a proxy for soil quality while Desai uses value of land for the same purpose. In regard to the relation of per acre yield and size of holding, Ashok Rudra has a different point to make; he suggests that, instead of measuring the yield per acre of sown area, if yield is measured on per acre of gross cropped area, the negative relationship between the yield and the size of the holding will be probably reversed.

The debate has raised several important issues. What the efficiency criteria should be is the central question. Khusro suggests that efficiency can be measured more appropriately if, instead of per acre yield, the return on the total resources for production is taken into account. The scale of operation need not be measured by the size of holding which is not only one of the several inputs. Instead, the quantity of output may be taken as an indicator of scale of operations.

Among those who have examined the efficiency of use of inputs for different size-groups in terms of the relationship between the value of marginal products and acquisition cost of inputs, authors like Raj Krishna who have looked at the problem in yet another way, have maintained that there are no perceptible inter-group differences in the efficiency of the use of different inputs by farmers in different size-gruops. Lau and Yotopoulos have examined the relative efficiency of small farmers vis-avis large farmers through profit maximization. They employed DL McFadden's profit function, expressing a firm's maximized profit as a function of prices of output and variable inputs of production and of the quantities of the fixed factors. They also employed the Cobb-Douglas production function. They arrived at the conclusion that small farmers were relatively more efficient.

Bandhudas Sen who examined the problem of relative efficiency of small farmers observed that, even after taking soil fertility into account, inter-farm differences in output per unit size are inversely related to the size of the farm. He observed further that small farmers have a higher level of inputs per acre. He made an allowance for soil fertility by using as proxy rental value and alternatively revenue assessment. He studied that data for the year 1955-56 for Bombay only. In a linear equation relating output per unit of rental value to inputs per unit of rental value, he gets the coefficient of 0.99. In similar exercise with revenue assessment he gets a slightly higher coefficient of 1.257. The value of $R^2$ varied between 0.7 and 0.9. Thus, on the basis of the results of regression, the conclusion would not be so evident as the author implies.

Sahota has undertaken a more sophisticated analysis. He allowed the intercept and the coefficients of the slopes to vary freely for different size-groups by using dummy variables. In his study he finds inter-group differences in efficiency to be imperceptible for many of the inputs. Only in the case of wheat and pulses, small farmers seemed to be using land
inefficiently. On the whole, he concluded that, with the present technique of production, farms of more than 20 acres were on an average inefficient for bajra; farms of less than 9 acres were inefficient for growing wheat and pulses.

*R Bharadwaj* investigated the problem of production efficiency by applying activity analysis. He found productivity to be higher on an average in the lower and the upper range of size-groups, particularly when combination of inputs excluding land was considered. In particular, the capital as input was observed to be influential in the upper range of size-groups in contributing to production efficiency. As against this, greater influence was exercised by land as an input in the lower range of size-groups. Regarding labor, he observed a low but positive correlation between size of holding and efficiency of labor use. A similar relationship was observed also between size of holding and capital or material inputs like seeds, etc. Taken together the negative influence of land as an input seemed to be more dominating than the positive influence of the other three inputs.

Despite many and varied studies regarding farm production behavior, its relation with inputs, efficiency, etc., a few substantive conclusions seem to emerge. No specific long-term trend seems to have been established through the evidence is more in favor of the rising trend till the early sixties. Similarly, among different components, that the contribution of land is dominant is suggested by most but not all studies. The specific contribution of different inputs, efficiency in use of inputs and the degree of inter-input substitution have remained inconclusive issues. Methodologically supremacy has not been established for any particular form of regression equation nor is the problem of multicollinearity satisfactorily solved. Despite the varied forms of equations used and the resolved problem of multicollinearity, a common observation seems to emerge from the production studies: the returns to scale seem to be close to one.

Though the overall impression of the studies relating to production behavior and production functions is one of an on-going exercise, these studies have given useful insight into the relationship between inputs and output.

*N J Kulkarni (1986)* in his paper on Economics of Rice production in India analyzes the productivity and production growth of rice at inter-regional level. This was confined mainly to few non-traditional rice growing regions. Between the TE-1971-74 and 1978-81, four states viz., Andhra Pradesh, Haryana, Punjab and Uttar Pradesh, which together shared less than 1/4th of the area and production of rice in the country during the base period, accounted for about 84 per cent of the increment in rice area, 97 per cent of the increment in irrigated rice area, 41 per cent of increase in HYV seeds area and more than 75 per cent of the incremental use of fertilizer in rice cultivation.

An analysis of cost of production data established that technological progress in rice production was accompanied by a reduction in real cost of production. In the case of average price realisation also, there was a considerable inter-regional price differences during 70s. Price operations have benefitted only farmers in the rice surplus regions as farmers in deficit regions continue to realise higher prices.

C A Rama Rao, et al. (1996) in his paper on "Inter-Zonal Disparities in Fertilizer Use in Andhra Pradesh" observed wide disparities in fertilizer use across different agro-climatic zones of Andhra Pradesh. North Telangana and Krishna-Godavari zones revealed higher use of fertilizers. Inter-zonal variations in fertilizer use were most prominent in high altitude and
Tribal zone. Area under irrigation and commercial crops, distance to fertilizer dealers and availability of credit influenced fertilizer use significantly. Fertilizer use for irrigated and dryland crops was not correlated. Area under irrigation had a negative influence on fertilizer use for dryland crops suggesting farmers inclination to invest more in crops where yield risk is low.

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