Energy Substitution in Indian Manufacturing : 1976-83

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TO MY MOTHER

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CERTIFICATE

Certified that the dissertation entitled **"ENERGY SUBSTITUTION IN INDIAN MANUFACTURING : 1976 - 83"** Submitted by Miss. **CHANDANA SANYAL** is in partial fulfilment of **MASTER OF PHILOSOPHY** degree of this University. This is an original work and has not been submitted for any other Degree to this or any other University to the best of our knowledge.

We recommend that this dissertation be placed before the examiners for evaluation.

(for) Prof. M.M. Agarwal
(Chairperson)

Dr. A. Barua
(Supervisor)

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CHAPTER I

INTRODUCTION

1.1 Need for Energy Substitution

Modern economic growth is just unthinkable without energy as a factor of production. Energy being a necessary input in the production process of most industries poses two distinct types of problems in the development of an economy. In the short run, where the technology is given for the economy and factor substitution possibilities are limited, the energy crisis results from an imbalance between demand and supply of energy. For an economy which is primarily dependent on imported energy resources, the process of growth is bound to lead to short run BOP crisis if exports are not enough to pay for imports. Economic growth apart, the other factors which have significantly contributed to the short run BOP problem is the exercise of monopoly power of the world energy suppliers in setting energy prices since the early 70s.

In the long run, however, there exists various adjustment possibilities which may reduce the demand and supply imbalances. The supply side adjustment may come from discovery of new or alternative source of energy which would allow us to overcome the physical limits to resource availability. But if we consider the physical stock of resources as given, then the adjustment will be from the demand side and in that case the response of energy demand to higher energy prices will primarily be a question of technological choice. In response to exogenous increase in energy prices, a producer will try to introduce energy saving innovations. The reduction in the demand for energy as a result of innovation or energy saving technology may be termed as the technical change response to energy crisis. Alternatively, a producer may try to substitute other factors of production for energy within the production process. This we may like to term as the factor substitution response to energy crisis.

Substitution can take other forms also. We may have interfuel substitution where one kind of energy (say, solar energy) is being substituted for another (say petrol). Such kind of substitution result from the search for an alternative source of energy through technological innovation and hence, this would come under technological response to energy crisis. Similarly, where substitution involves a change in the 'product mix' of the economy from high energy intensive products to low energy intensive products, demand for energy must fall as a result. This effect also results from technological change in satisfying human wants.

'Substitution' in fact is the real idea behind energy conservation. If energy conservation means response of energy demand to higher energy prices, then substitution becomes the key adaptive mechanism - an idea subtly different from the assumption that energy conservation only involves reduction in ' wastage' of energy use.

It has to be remembered that resources, by definition, have no intrinsic worth but they derive their values from the useful services or products they yield. Therefore, as long as other methods can be found to fulfill the same functions at no extra real cost it is possible to achieve demand reduction without affecting real income growth rates. The whole line of argument is based on the assumption that no individual stock of resource is absolutely essential - substitutes exist or will be found to replace it.

In this study, our main focus of attention will be on the response to energy crisis in terms of factor substitution. The long run economic impact of higher energy prices may be much smaller than expected if the effect of higher energy prices is to substitute other factors of production e.g. labour, capital and material equipments in place of energy rather than curtailing otherwise productive activities. In the presence of such substitution possibilities the economic cost of higher prices will be a relatively smaller proportion of the economy.

In the present work, we will study a few large scale Indian Industries to examine whether it provides for such substitution and if so, to what extent.

To what extent this substitutability exists is purely an empirical question. In the standard production function analysis the extent of such substitutability is measured by the elasticity of substitution between various factors. Elasticity of substitution measures the ease with which one factor may be substituted for another, to maintain a given level of output. A typical profit maximizing firm always chooses that bundle of input which minimizes its cost of production. Inputs other than energy also enters the firm's production process. A firm's response to an increase in the relative price of energy will depend, to a larger extent, on the elasticity of substitution between various energy and non- energy inputs provided by the chosen technology.

A positive elasticity of substitution among energy and non-energy inputs, say capital implies that capital can be substituted for energy so that the same end product can now be produced with less energy input and more of capital input. This is 'process specific' substitution where factor proportions change in such a way that if there is an increase in the relative price of any input the firm is able to maintain its output level without really affecting the 'real cost' of production.

A negative elasticity of substitution implies factors are complementary to each other in the production process. In such cases, economic growth, via capital accumulation is bound to lead to ever increasing demand for energy input as capital accumulation proceeds. On the other hand, a falling demand for energy in response to increased energy prices will have a deflationary impact on the economy.

Thus, it is quite evident that the substitutability/ complementarity relationship between energy and non-energy inputs will have different economic implications and therefore the sign and the magnitude of elasticity of substitution parameter is of prime importance in future policy formulation. Therefore, an attempt to estimate the elasticity of substitution among energy and non-energy inputs of production becomes an extremely useful exercise.

Econometric estimation of partial elasticities of substitution between pairs of inputs has been the subject of several econometric studies. The earlier studies on production function analysis tacitly assume negligible substitution between energy and other intermediate inputs (material) viz-a-viz labour and capital inputs. In econometric application separability conditions have been assumed so that the gross output (y) may be 'separated' into 'value added' component and a component represented by energy (E) and materials (M) input.

Thus, $F(K, L, E, M, A) = F(g(k, L), E, M, A)$.

Where K, L, E, M denotes inputs of capital, labour energy and material and A is the index of technology.

The subfunction, $g(K, L)$, is homothetic[1] and identified as 'value added'. The separability assumption imposes severe restrictions on the AES between pairs of inputs. This implies elasticity of substitutions between energy and capital or labour input must be the same which seems to be highly implausible both from theoretical and intuitive grounds. Thus, one may conclude that there is no theoretical justification for the use of real 'value added' as a measure of production and therefore energy and material should be included in the production function.

1.2 Theoretical Background

In econometric analysis, the elasticity of substitution is measured by the so called Allen Partial Elasticity of substitution (AES) between pairs of inputs, is due to Allen (1938).

AES measures the response of derived demand for an input to input price change, holding output and all other input prices fixed. Consider

a production function $Y = f(X_1, X_2 \, .. \, Y_n)$

where Y = gross output

and X_i = aggregate inputs of production

The Neo-classical analysis of factor demand assumes that the production function is continuous twice differentiable and is characterised by constant returns to scale.

For such a function, the AES is defined as

$$\sigma_{kr} = \sum_{i=1}^{n} \frac{X_i f_i}{X_k X_r} (f^{-1})_{rk}$$

where $(f^{-1})_{rk}$ is the rkth element of f^{-1}, f^{-1} being the inverse of the bordered Hessian matrix of the function 'f'.

and $f_i = \partial y/\partial X_i$ and $f_{ij} = \partial^2 y/\partial X_i \, \partial X_j$.

For any unequal values of r and k, the value of σ_{kr} is called the Partial Elasticity of substitution of the pair of factors X_k & X_r (as against all other factors). It's value depends on, and, varies with, the grouping of factors employed.

We will have $\sigma_{kr} = \sigma_{rk}$

The interpretation of σ_{kr} proceeds as follow : If the market price of one factor, say X_r, rises, then the demand for this or any other factor is affected in two ways. Firstly, the cost of production is now higher and the product dearer. For a decreasing demand law, the amount of the product sold is less and there is an all-round proportional decrease in the demand for the factors. Abstracting from this effect, the factor is now relatively more expensive than other factors and it pays to substitute other factors for X_r in production. the demand for X_r thus decreases on account of substitution.

There will be two cases :

(1) If $\sigma_{rk} > 0$ then the demand for X_k increases in response to an increase in the price of factor X_r on account of substitution; the factor Xk takes part in the replacement of X_r in production. In this case, the factor X_k is said to be a substitute for the factor X_r, at the grouping of factors considered.

(2) If $\sigma_{rk} < 0$, then substitution results in a decrease in the demand for X_k; the factor X_k, like the factor X_r, has been partly replaced by other factor of

production. Here, the factors X_k and X_r are said to be 'complementary ' at the grouping considered.

The sign of σ_{kr}, thus indicates whether X_r and X_k are substitutes or complementary factors.

If estimates of the co-efficients of a particular functional form are available; the bordered Hessian can be computed, inverted and the σ-s found accordingly for specific input levels. In fact σ can also be computed from the dual minimum cost function. Economic theory tells us that technology may be represented either by a production or a cost function provided certain regularity conditions are satisfied. (Shephard' Duality theory, 1953)

Thus dual to the above production function there exists a minimum cost function c = g(p1,...pn) where 'c' represents the level of cost for the cost minimizing input combination and P_i represents input prices. This result is due to Shephard [1953].

Following Diewert (1974) we can characterize the duality between cost and production function as follows:

Consider an 'n' factor production function 'f' where $z=f(x_1 \ldots x_n)$ means that z is the maximal amount of output which can be produced during a given period of time using x_i units of input (i=1,2 ... n).

Then, corresponding to f, there is a cost function C(z,p) defining for each z>0 and $p_i > 0$ (i= 1,2 ... n) the minimal cost of obtaining z. If 'f' is regular then there is a one to one correspondence between cost function and production function, with the latter given in terms of the former by

$$f(x) = \frac{1}{\max}\{c(p)/p'x = 1\}$$

where c(p) ≡ C(1,p) [unit cost function] is also regular.

Regularity, in this context, implies that for all x≥0, 'f' is positive, positively homogeneous of degree one and concave. A regular function is also non-decreasing. These two functions f(x) and c(p) are thus dual to each other. Given c(P) we may reconstruct f(x). The knowledge of 'c' enables us to find the derived demand functions and the cost shares by means of Shephard's Lemma which states that if c(p) is a regular and differentiable unit cost function then we can obtain a system of derived demand functions as $x_i(z,p)=zc_i$.

Where xi(z,p) is the cost minimizing demand for input 'i' needed to produce z and

$$c_i = \frac{\partial c(p)}{\partial p}$$

Alternatively, we can obtain the cost share equations also.

Clearly

$$\sum p_i x_i = z\sum p_i c_i = zc(p) .$$

Using Euler's Theorem on linear homogeneous functions. Eliminating the (unknown) output z we find expressions for the cost shares S_i,

$$S_i = \frac{p_i x_i}{\sum p_i x_i} = \frac{z p_i c_i}{z c(p)} = \frac{p_i c_i}{c} \quad i=1,2..n$$

Thus, four possible approaches may be taken for an econometric representation of technology - the production function, the cost function, the factor demand functions and the factor share functions. Data requirement for statistical estimation differs among them.

In case of the cost function estimates of σKr can be obtained directly from the parameters of the function.

$$\sigma_{rk} = \sum_{i=1}^{n} \frac{P_i X_i}{X_k X_r} \cdot \frac{\partial^2 C}{\partial P_r \partial P_k}$$

This was originally proved by Uzawa (1962) for homogenous production functions.

If the parameters of the specific functional forms of a cost function have been estimated that can be used to derive elasticity of substitution for given factor levels and total cost Allen has shown [p.508] that when production is efficient and when the supply of inputs is perfectly elastic, the AES will have the following relation to price elasticities of derived demand.

$$\sigma_{rk} = E_{rk} / \alpha_k \, where \, E_{rk} = \frac{\delta X_r}{\delta P_k} \cdot \frac{P_k}{X_r}$$ is the price elasticity and

$$\alpha_k = \frac{P_k X_k}{\sum_{i=1}^{n} P_i X_i}$$ is the share of the K^{th} input in total input costs.

Therefore, for the purpose of the estimation what we now need is a specific functional form for 'c'. In this study we will be using the Transcendental Logarithmic cost function (Christensen, Jorgenson and Lau, 1971), which belongs to the family of flexible functional forms.

Earlier research work in modelling producer behaviour has concentrated largely on a few specific functional forms for the production relationship, the two most popular being the Cobb-Douglas (1928) and CES models (Arrow and Others) : 1961)

The CES form has shown considerable flexibility in modelling the technology for a firm producing a single output using two inputs. But it appears to be highly restrictive in case of more than one product or more than one input as shown by Uzawa (1962) and Mcfadden (1963). It is restrictive because of the assumption of constant elasticity of substitution. In the case of two inputs it turns out that all these elasticities are equal so that the elasticity of substitution for the production function turns out to be, a constant. (In case of CD function elasticity of substitution is unity). In the context of several inputs the assumption of constant elasticity of substitution implies that partial elasticity of substitution between any pair of inputs is equal and the possibility of complementarity is ruled out.

In order to overcome the restrictive conditions imposed by the CES Functional form on AES a number of highly generalized functional forms have been proposed lately, using the duality relation between the cost and production functions which places no 'a priori' restriction on the partial elasticities of substitution.

Among these are the Transcendental Logarithmic (Tlog) (Christensen, Joregenson and Lau, 1971), Generalized Cobb- Douglas (GCD) and Generalized Liontief (GL). The GCD and GL have been introduced by Diewert (1971).

Although if may not be possible to express explicitly the underlying production function (corresponding to these cost functions) in a neat and tidy form, Shephard's Duality theory tells us that if we estimate econometrically the parameters of cost function the parameters of the corresponding production function can be obtained provided producers behave competitively in the factor market.

There are several advantages of using cost function rather than a production function for estimating production parameters:

1. It is not necessary to impose homogeneity of degree one on the production process to arrive at the estimated equations. Cost functions are homogeneous of degree one regardless of the homogeneity properties of the production because a doubling of all the prices will double the cost but will not effect factor ratios.
2. In general, the estimates on equations have prices as independent variable rather than factor quantities

which the firm or industry level are not proper exogenous variables. Entrepreneurs make decisions on factor use according to exogenous prices which makes the factor level decision variables.

3. If a production function procedure is used to derive estimates of elasticities of substitution or of factor demand in many factor case, the matrix of estimates of the production function has to be inverted. This will inevitably exaggagerate estimation errors. No inversion is necessary when cost function is used.

4. In production function estimation, high multicollinearity - among input variables often causes problems since there is usually little multicollinearity among factor prices. This problem does not arise in a cost function.

5. Translog function has some special advantages. In the special case of the translog cost function problems of neutral or non-neutral efficiency differences among observation units (or of neutral and non-neutral economies of scale can be handled conveniently).

Therefore, these problems will not result in biased estimates of the production parameters. Most methods of estimating production function cannot handle these problem properly.

The Translog Cost Function

Let, $y = f(y_1, y_2, \ldots\ldots\ldots\ldots y_n)$ be a continuous, twice differentiable production function (1)

Where x_i = Input levels,

$C = g(y, p_1, \ldots\ldots\ldots\ldots p_n)$ represents the minimum cost function dual to the above production function where, p_i = factor prices,

The Translog Cost Function is written as a logarithmic Taylor series expansion to the second term of a twice differentiable analytic cost function around variable levels of 1.

(ie. $\ln Y=0$, $\ln P_i=0$, $i=1,2 \ldots n$)

We can rewrite the cost function in natural logarithms,

$\ln C = f(\ln Y, \ln P_1 \ldots \ln P_n)$

Denote the 1st and 2nd order derivatives at $\ln(.) = 0$ as follows,

$$|\ln C|_0 = V_0, \quad \frac{\partial \ln C}{\partial \ln Y}\bigg|_0 = V_Y \quad \frac{\partial \ln C}{\partial \ln P_i}\bigg|_0 = V_i$$

$$\frac{\partial^2 \ln C}{\partial \ln P_i \ \ln P_j}\bigg|_0 = Y_{ij}, \quad \frac{\partial^2 \ln C}{\partial \ln P_i \ \ln Y}\bigg|_0 = Y_{iy}$$

The equality of the cross derivatives implies the symmetry constraint

$y_{ij} = y_{ji}$

Then the Taylor series expansion is as follows :

$$\ln C = V_0 + V_y \ln y + \sum V_i \ln P_i$$
$$+\frac{1}{2}\sum_i \sum_j Y_{ij} \ln P_i \ln P_j + \sum_i Y_{iy} P_i \ln Y + remainder$$

This function is an approximation of an arbitrary analytic function. With the proper set of constraints on its parameters it can be used to approximate any one of the known production and cost functions. The first power terms of this cost function represents a Cobb-Douglas cost function.

Thus, $y_{ij} = 0$, $y_{iy} = 0$ are the required parameter restrictions which would give CD cost function.

It is a functional form in its own right if the remainder is neglected and if we assume all derivatives and cross derivatives to be constant. The latter constraint implies symmetry and is imposed in the parameters are estimated in regression equations.

The function must satisfy the following conditions :

1) Linear homogeneity in prices. When all factors prices double the total cost has to double. It implies

$$\sum_i V_i = 1, \quad \sum_i Y_{ij} = 0, \quad \sum_j Y_{ij} = 0$$

2) Monotonicity : The function must be an increasing function of the input prices.

3) Concavity in input prices : This implies that the

matrix $\partial^2 c \,/\, \partial P_i \, \partial P_j$ must be negative semi definite within the range of input prices.

Homogeneity of degree one in prices does not impose homogeneity of degree one of the production function in inputs. Almost no constraints are imposed on elasticities of substitution or of factor demand which makes the function more general than other fundamental forms currently in use.

The function can be estimated directly in its first derivatives which by Shephard's Lemma are factor shares

$$\frac{\partial \ln C}{\partial \ln P_i} = \alpha_i = V_i + \sum Y_{ij} \ln P_j + Y_{iy} \ln Y$$
$$i = 1, 2 .. n$$

Where $\sum \alpha_i = 1$, the adding up restriction

Both sets of estimation equations are linear in logarithms and have proper exogenous variables on the right hand side if the analysis pertains to firms or an industry.

Now for the translog cost function we can have the estimated γ_{ij} parameters which have little economic meaning of their own but are related to variable elasticities of substitution and of factor demand as follows :

$$\sigma_{ij} = \frac{1}{\alpha_i \alpha_j} \gamma_{ij} + 1 = \frac{\gamma_{ij} + \alpha_i \alpha_j}{\alpha_i \alpha_j} \quad for\ all\ i, j, i \neq j$$

$$\sigma_{ii} = \frac{i}{\alpha_i^2} (\gamma_{ii} + \alpha_i^2 - \alpha_i) \quad \forall i = 1, 2 .. n.$$

where α_i = share of the i^{th} input in total cost i =1,2 .. n.

It has been already mentioned before that if the parameters of a specific functional form of a cost function have been estimated AEUS defined as

$$\sigma_{kr} = \frac{\sum P_i X_i}{X_k X_r} \cdot \frac{\partial^2 c}{\partial P_r \partial P_k} \quad i = 1, 2 \dots n$$

can be use to derive elasticities of substitutions for given factor levels and total cost.

As for the price elasticities we have already shown

$$E_{ij} = \sigma ij . \alpha_j, \quad i,j = 1,2..n$$
$$= \gamma_{ij} / \alpha_i + \alpha_j \quad \forall i,j, i \neq j$$
$$E_{ii} = \gamma_{ii} / \alpha_i + \alpha_i - 1 \quad \forall i = j$$

If the γ_{ij} parameters have been estimated and if the factor shares are known, all elasticities can be estimated. Since, estimate of σ_{ij} and E_{ij} are linear transformations of the y_{ij} parameters whose econometric properties are known, the econometric properties of the elasticities are known as well.

No matrix of estimates has to be inverted in estimating the cost function[2].

In econometric estimation of a cost (or production function) sometimes the separability restriction is imposed on the inputs. The concept of separability is extremely important and widely used in production models. In this particular study we will be using the separability assumption. Therefore before concluding this chapter we will briefly discuss the concept of separability restriction.

<u>Separability</u>

We consider a twice differentiable strictly quasi-concave homothetic production function with a finite number of inputs each having a strictly positive marginal product.

The denote the production function as $Y = F(X_1, X_2 \ldots\ldots\ldots X_n)$. The set of 'n' inputs is denoted as $N = [1, 2 \ldots\ldots n]$ and is partitioned into 'r' mutually exclusive and exhaustive subsets $[N_i \ldots\ldots\ldots N^r]$, a partition called R.

We denote the first and second partial derivatives of F(x) by F_i and F_{ij}

$$F_i = \frac{\partial F}{\partial X_i} \quad ; \quad F_{ij} = \frac{\partial^r F}{\partial X_i \partial X_j}$$

The production function F(x) is said to be weakly separable with respect to the partition 'R' if the MRS between any two inputs X_i and X_j from any subset N_s, $S=1,\ldots\ldots r$ is independent of the quantities of inputs outside of N_s i.e.

$$\left(\frac{\partial}{\partial X_k}\right)\left(\frac{F_i}{F_j}\right) = 0 \;\; \forall i, j \in Ns \text{ and } k \notin Ns$$

This condition can alternatively be written as

$$F_j . F_{ik} - F_i F_{jk} = 0 \;\; , \;\; \forall \; i, j \in Ns, k \notin Ns$$

The terminology of weak separability was coined by Strozt (1959).

Dual to F(x) there exists a cost function

$$C(y, p_i \ldots\ldots\ldots\ldots p_n) = H(y) \cdot G(p),$$

where $G(p)=G(p_i \ldots\ldots\ldots\ldots p_n)$ is a function of the 'n' input prices only.

Assuming G(p) is twice differentiable,

$$Let\ G_i = \frac{\partial G}{\partial P_i}\ and\ G_{ij} = \frac{\partial^r G}{\partial P_i \partial P_j}$$

G(p) is weakly separable with respect to the production R in input prices if and only if F(x) is weakly separable w.r.t. the same partition R in input quantities.(Lau : 1972)

Berntdt and Christensen (1973) have shown that when F(x) exhibits CRS the following are equivalent restrictions on F(x) at any point in input space.

(1) Weak separability of N_s w.r.t. partition k.

(2) Equality of the AES,

$$\gamma_{ik} = \gamma jk\ \forall i, j \in Ns\ and\ k \notin Ns$$

Thus separability restriction on the production(cost) function is equivalent to certain equality restrictions an the AES

(3) The existence of a consistent aggregate prices index p^s and consistent aggregate quantity index q^s and the elements of N^s.

A consistent aggregate index of a subset of inputs exists if and only if the subset of inputs is weakly separable from all other inputs. And a consistent sub-aggregates price index p^s exits if and only if the corresponding consistent sub-aggregate quantity index exits.

Thus, in the linear homogenous gross output production function Y=F(K, L, E, M) the inputs KLE are homothetically weakly separable form M if and only if we can write,

$Y = F^*[H (K, L, E), M]$

It implies that the marginal rate of substitution between any two inputs in the subfunction 'H' is independent of the quantity of materials used.

If the dual minimum cost function corresponding to the above production function is $C = G^* (P_K, P_L, P_E, P_M)$ where P_i denotes input prices assuming homothetic weak separability of materials from the other three inputs the above cost function can be written as $C = G^* (G (P_K, P_L, P_E), P_M)$.

The following restrictions are imposed on the Allen partial elasticities of substitution :

$\sigma_{KM} = \sigma_{LM} = \sigma_{EM}$

In the light of the above theoretical background an attempt is being made in the present study to estimate the extent of energy substitution possibilities in select large scale industries in Indian manufacturing sector.

With this explanation of the relevant concepts necessary to build up the theoretical framework on which the present study is going to be based we present in brief a scheme of the study before proceeding to the next chapter.

1.3 PLAN OF THE STUDY

In chapter I we have discussed the general objective of the study and we have also presented the basic theoretical framework on which the present study is going to be based. In chapter II we will present a survey of existing literature on energy substitution from which follows the scope and coverage of the present study in chapter III. Chapter IV will present the econometric model and discuss the method of construction of variables. In chapter V we will discuss the empirical results and in chapter VI we will conclude by highlighting our major findings and suggesting certain policy implications and future directions of research.

CHAPTER II

SURVEY OF THE EXISTING LITERATURE

The unusual developments in the world energy market during the '70s had led to a series of studies of production function analysis for the purpose of estimating the energy substitution parameters in manufacturing industries.

These studies explicitly recognize energy as a separate input in the production function. The econometric exercise with many factors of production has been facilitated by the pioneering works of Mcfadden, Diewert (1971) and Christensen, Jorgenson and Lau(1971) in the field of econometric estimates of flexible forms of production functions or the corresponding cost functions. The previous chapter discussed these in detail.

Berndt and Wood (1975) for the first time investigated into the cross substitution possibilities between energy and non-energy inputs for the US company.
Following Berndt and Wood, several major studies have been carried out such as by Halverson and Ford (1977), and Hudson and Jorgenson (1974) for the US economy, Melvyn Fuss (1977) for the Canadian Manufacturing and J.R. Magnus (1979) for Netherlands. Similarly studies based on cross section data have been done by R.S. Pindyck (1979) and Griffin and Gregory (1976).

The recent studies based on more disaggregated industry data include those of Field and Grenbestein (1980), A.L. Walton (1981) Harper and Field (1983), Gorfalo and Malhotra (1984) for the US economy and of Alamada. J Mann for the Puerto Rican economy.

The basic model used in all these studies has been the dual cost function corresponding to any multi input flexible production function. The empirical analysis hypothesises profit maximization by producers in situation where the response of agents to relative price changes are not constrained by supply bottlenecks and non-market forces like government intervention.

The models are estimated as multivariate regression models with jointly distributed disturbance terms. Methodological differences lie in the data base (time series/ cross section/ pooling etc., construction of variables, exclusion or omission of particular inputs, level of aggregation, method of estimation and the choice of functional forms.

Most of these researchers, barring a few, have employed the translog cost function for the purpose of estimation. Generalized Cobb-Douglas and Generalized Leontief are the other two functional forms that have also been employed. With this general background, we would like to discuss the existing literature in two sections - section I dealing with the literature for countries other than India and section II dealing exclusively with the studies based on Indian manufacturing sector.

2.1 International Studies on Energy substitution

The seminal study of Berndt and Wood (1975) has been an attempt to find the extent of substitution possibilities between energy and non-energy inputs in aggregate US manufacturing for the period (1947-71). They assumed a translog cost function with four inputs - Capital(K), Labour(L), Energy(E) and Materials(M) for the U.S. economy.

The model has been estimated by Iterative three stage least squares method of estimation.

Using the above model they find energy and labour to be slightly substitutable [AES is 0.65] and energy and capital to be strongly complementary [-3.2]. Energy demand is found to be highly price responsive - the own price elasticity being about [-0.5].

Hudson and Jorgenson (1974), in order to explore the inter-relationships between relative demand for energy and other non-energy inputs have constructed an inter-industry model of producer behaviour in terms of the four aggregates - capital, labour, energy and materials, as a part of their General Equilibrium macro economic model for the US economy. The model was first used to project economic activity and energy utilization for the period 1975-2000 under the assumption of no change in energy policy. In this model the energy group (E) consists of five energy types and materials (M) group consists of inputs of agriculture, manufacturing, transportation, communication, trade and services, and competitive inputs for the non-energy sector.

Assuming a translog cost function for the US economy and using time series data (1947-71) they have estimated three sub models - aggregate (KLEM) sub model, energy sub model (E) and material sub model. Assuming separability of individual components within an aggregate in put first the energy and material sub models were estimated. In the second stage, the aggregate sub model was estimated. The prices of energy and materials aggregates in the aggregates model were represented as functions of inputs that make up each of the aggregates.

Results of the KLEM aggregate sub model shows capital-energy complementary and labour energy substitution.

A common feature of the above two studies is that both are based on times series data and arrive at similar results regarding energy-non-energy input substitution.

In an attempt to investigate into the generality of these results Griffin and Gregory (GG) (1976) estimated a translog model using pooled time series-cross section data. Data was pooled across the manufacturing sector of nine OECD countries at five yearly intervals of time for the period

1955,1960,1965,1969.

Assuming weak separability of materials input they have estimated a three input translog model. The model has been estimated by Iterative Zellner Efficient Method of Estimation (IZEF).

According to them, a pooled inter country sample is more appropriate for the study of production function because:

(1) Range of input price variation obtained from single country time series data is extremely limited ; and

(2) Observations between countries tend to reflect long run adjustments as price differences between countries tend to be the result of long standing national tariffs, indirect tax and subsidy policies. As opposed to this, time series data for the single country is likely to give short run estimates.

In the short run energy and capital are likely to be complementary but in the long run the relationship is one of substitution.

They have, in fact, estimated three models. Model I assumes a single homogeneous cost function for all countries, Model II allows for different efficiency parameters between countries ie. a system of cost share equations with different country intercepts in each equation, but common slope co-efficient and Model III, the most general case, allows both intercept and slope co-efficient to vary across countries.

In contrast with the time series results of Berndt and Wood and Hudson and Jorgenson, GG find energy and capital are substitutable, (estimates ranging from 1.02 to 1.07). They argue that their results imply that energy and capital are substitutes in the longer run.

Labour and energy are also found to be substitutes, elasticities ranging from 0.72 (Denmark) to 087 (USA). Own price elasticity of energy demand is observed to be around (0.8) for all the countries. Comparison of this result with Berndt and Wood's (-0.45) may suggest that short run response of energy demand to changing energy prices is likely to be more inelastic than the long run response.

They have pointed out to two major limitations in the model which may question their interpretation of the elasticity differences.

(1) Exclusion of materials which are included in the earlier two time series studies may bias the findings if weak separability condition is not valid.

(2) In contrast to the use of Iterative three stage least square method of estimation by Berndt and Wood where input prices have not been treated as exogenous, results of Griffin & Gregory's study may suffer from simultaneous equation bias.

They have tested for weak separability of materials and their separability findings differ from those of Berndt and Woods (1975) separability assumption is found to be valid sufficiently for a separating and the value added relationships into a three factor Capital-Energy-Labour (KLE) Model.

Following Hudson and Jorgenson(1974) procedure, Griffin (1976), Fuss (1977) and Pindyck (1979) have developed translog model to study inter-input and interfuel substitution.

Griffin (1976) has used a translog cost function with five inputs of capital, labour, coal, gas and oil. Assuming Assuming that coal, gas and fuel will make up a separable and homogeneous aggregate two submodels were constructed,

(a) One in which capital-labour and aggregate energy inputs are determined and

(b) A sub_model in which specific fuel inputs are determined.

He estimates the complete model for 20 OECD countries at four intervals of time 1955, 1960, 1965, 1969 and find both labour and energy and capital-energy to be substitutes.

Melvyn Fuss (1977) estimates a similar model for the Canadian economy for the period (1961-71) pooled across five regions of Canada with nine inputs; labour,capital, material and six energy types. The major contribution of Fuss is the forging of an explicit link between the energy sub-model (which results from the separability restriction) and the model explaining the demand, for aggregate inputs

Malnivaud's Minimum Distance Estimator has been used to estimate the model.

His major findings indicate substitution between energy and labour inputs but slight complementarily between energy and capital.

All the own price elasticities are found to be negative and significantly different from zero at conventional level of significance.

Following the same path as Fuss, Pindyck (1979) estimated both inter input and inter fuel substitution using pooled time series cross section data for a cross section of ten OECD country for the period (1963-1973).

He estimates a seven input model with capital labour-energy and four energy types.

1) Following Fuss, he assumed that production function is weakly separable in the major categories of labour,energy and capital.

2) Following Griffin and Gregory be makes the assumption that KLE inputs are as a group separable from material(M). The model has been estimated by Zellner Iterative method of estimation.

They find capital-energy to be substitutes. Their estimates of elasticity of substitution is close to that of Griffin and Gregory's (1.01) which according to them confirms Griffin and Gregory's assertion that pooled international data will reflect long run relationship which is one of substitution. Labour and energy are found to be substitutes with AEC ranging between (.42 and 1.17).

Own price elasticity is about -0.8 which is again comparable with that of Griffin and Gregory's estimate but higher than most earlier studies indicating that long run elasticity has been estimated. The estimate would have been smaller in the short run, according to them.

J.R. Magnus (1979) estimated a time series three input (KLF) model for the Dutch manufacturing sector for the period (1950-70). A unique feature of his model is the use of an extension of Diewert's (1971) Generalized Cobb-Douglas cost function. Assuming weak homothetic separability of material from labour, energy and material he estimated the model. In fact, he estimates two models based on the extended Generalized Cobb-Douglas cost function, the difference between them lying in the measurement of the price of capital services.

Model I ignores the anticipated capital gain while estimating price of capital services. Model II includes the capital gains term in estimating the price of capital services. He has also estimated a translog counterpart of the two models. GCD model has ben estimated by GLS.

For the first model GCD and Translog results are quite comparable. The Second model seems to be more sensitive to the choice of functional form. Results for the GCD models show, substitution between energy and Labour, AES fluctuating around

(1.29) in Model I and around (0.95) in Model II.

Energy and Capital are found to be highly complementary, AES estimate about (-2.19) in Model I and (-2.45) in Model II. Own price elasticity of energy is about (-0.23) and (-0.19) in the two models. But in the second model this is positive from (1976-73).

In an attempt to reconcile the alternative estimates of elasticity of substitution between capital and energy in terms of differences in measurement of capital services Field and Grebenstien (1980) did a cross section study for U.S. two digit manufacturing with four inputs - physical capital, working capital, Labour and Energy, for the year 1980. Method of Estimation is IZEF. They contend that the value added approach and service price approach to measuring Capital cost is expected to yield divergent results.

In the value added approach Cost of capital = value added - payroll while in the service price approach, cost of capital = (quantity of physical capital) X (prices). The former measure includes both working capital and physical capital whereas the latter is the cost of reproducible capital alone. The difference in results is therefore due to the fact that the two types of capital behave in quite different ways as regards their relationship with energy input.

Their findings show that reproducible capital and energy are for the most part compliments while working capital and energy are largely substitutes in production.

Thus, at the level of aggregate US manufacturing a value added approach to capital cost would be expected to show capital - energy substitution while a service price approach would show complementarity because in the former approach the portion of value added not accounted for by payments to labour is dominated by the presence of working capital.

For most of the studies mentioned so far data have been highly aggregative, applying to total manufacturing, or perhaps to the various two digit sectors comprising that total. Of the very few efforts that has been made to investigate energy substitution relationships at the regional level the first one was by Walton A.L. (1981).
He explored the regional and industrial variations process as measured by the substitution elasticities among individual inputs in the manufacturing in Middle Atlantic Census Region for the period. (1950-73).

He estimated a three input translog model with capital, labour, materials, electric fuel and fossil fuel as the major inputs. Method of estimation is (IZEF).

Industrial output in the region has been disaggregated into five manufacturing sectors. The main focus of the study was to show how much valuable information is lost through aggregation. They have compared their estimates with the national estimates of Berndt and Wood(1975) and unlike Berndt and wood capital with respect to both energy types are found to be substitutes labour and electric energy are substitutes but labour and fossil fuel are components.

B.C. Field and C. Harper (1983) also attempted to estimate energy substitution relationships in US manufacturing at the regional level.

They report elasticities of substitution estimated from region-specific models containing inputs of capital, labour, energy and material, for the major two digit manufacturing industries, using state cross section data for the years (1971-73). They have organized all states into three regions and specified aggregate cost function for each region. No cross region parameter restriction has been used. Method of (IZEF).

Their major findings indicate the cross price elasticity of labour and energy are negatively significant for a number of sectors implying these inputs to be complements rather than substitutes. Regarding elasticity of capital and energy, the elasticity coefficients are distributed on both sides of zero and few are significant, therefore no definite conclusion can be reached regarding substitutability/ complementarity between labour and capital.

Own price elasticities of energy inputs show a wide range over sectors and regions. Considerable difference across regions regarding cross and own prime elasticities.

Gorfalo and Malhotra (1984) made a similar attempt at capturing regional variation using pooled cross-section time series data. Units of cross section are states which were pooled into nine census regions and for two time periods (1963-66) and (1974-77).

1. States are selected as the units of cross section to focus on regional variation.
2. The two time periods were selected in order to capture the effect of the change in relative price of energy inputs before and after the '73s, the year of the oil shock.

A three input (KLE) translog model was estimated using the (IZEF) Method of Estimation.

Energy and capital are found to be substitutes in the pre-oil shock period. (σKE, 0.23), at the national level, but they are complements in the post-oil shock period (σKE,-0.35).

Energy and labour are observed to be highly substitutable in both periods but magnitude is considerably higher in the '70s.

At a regional level, substantial regional variations in the magnitude of σ_{KE} are found to exist.

Almada J. and Arthur J. Maan (1985) carried out a study almost in similar line with that of Gorfalo and Malhotra (1984), by estimating the input substitution possibilities for both the pre and post oil shock periods, for the Puerto Rican economy.

But they have used time series data - the two different time periods being (1956-72) and (1973-82). They have estimated a three input (KLE) translog model using (IZEF) method of estimation.

Their major findings indicate energy and labour were as especially strong substitutes in the pre-1973 period. The relationship weakens after 1973, but it is maintained.
Capital and energy were complements in the pre-energy price shock era while this association was completely turned around into one of substitutability after 1973.
As for own price elasticity of energy, demand was found to be decidedly more price inelastic in the post oil shock era.

An Overview

From the above survey we can draw certain broad conclusions regarding the empirical evidences on the extent of factor substitutability. In Table (2.1) we present the estimates of the major studies. Three major conclusions can be reached from the above table.

1 All studies have found labour and energy to be substitutes although the magnitude of the estimates differs across studies (ranging between 0.8 and 3.35 for the US economy)

2 The capital-energy relation however are widely divergent across studies both in terms of sign and magnitude. (estimates range between (-0.31) and (-3.22) for EK

TABLE 2.1

COMPARABLE ESTIMATES AN INDUSTRIAL DEMAND FOR ENERGY : SURVEY OF THE MAJOR STUDIES

		Country	σ_{KE}	σ_{LE}	E_{EE} (own price elasticity of energy demand)
1	Berndt and Wood (1975)	USA	-3.22	0.65	-0.47
2	Hudson & Jorgenson	USA	-1.39	2.16	0.07
3	Griffin & Gregory (1976)	USA Nether-land	1.07 1.02	0.87 0.86	-0.79 -0.78
4	Fuss (1977)	Canada (Ontario)	-.02	2.41	-0.49
5	Pindyck (1978)	Canada US Nether-lands	1.48 1.77 0.59	1.43 0.70 1.41	-0.87 -0.84 -0.85
6	Magnus (1979)	Nether-land	-2.34 (GCD1) -2.08 (GCD2) -2.06 (TL1) -0.30 (TL2)	0.89 0.66 0.85 0.60	-0.16 0.29 -0.20 -0.57

complementary (US economy) & between (.59) and (1.77) for EK substitution).

3. Estimates of the own price elasticity of energy is generally in the range of (-0.4 to -1.08) and mostly the results are significantly different from zero. This shows that energy demand is adequately price responsive.

The Issue of EK Complementarity-substitutability : The most interesting finding that emerges from a survey of the empirical results is the conflicting evidences regarding the relationship between capital and energy. For production models involving more than two inputs there is no justification to hypothesize either EK substitutability or EK complementarity. But EK substitutability appears to be supported by the weight of the engineering evidences. Evidence of energy conservation potential due to EK substitution is consistent with a positive elasticity of substitution between energy and capital. For example, new equipments can be designed to achieve higher thermal efficiencies but at greater capital cost. The engineering literature is replete with such examples.

This casts serious doubts on the econometric evidences of EK complementarity. Therefore, the question that arises automatically is whether there is any possibility of reconciling the alternative econometric evidences of E_K substitutability and KE complementarity.

The most often cited studies in this regard are that of Berndt and Wood (BW) (1975) and Griffin and Gregory (GG) (1976). Berndt and Wood find σ_{KE} to be significantly negative while GG find σ_{KE} to be significantly positive for the national economy. Both BW and GG have attempted to reconcile the apparent inconsistency in results [BW (1979) and Griffin (1981)]. This reconciliation has focused on two fundamental differences in the studies.

1. Separability assumption
2. Pooling of data.

According to BW such conflicting econometric evidences arise because different elasticity estimates are being compared. When separability is assumed the estimates are gross elasticities. When, not assumed, they are net elasticities. The studies which have ommitted material have estimated gross elasticity. The net elasticity which allows for substitution between (KLE) aggregate and M can indicate KE complementarity. That is why GG and Pindyck find EK substitution in contrast to EK complementarity found in the four input model of BW.

The magnitude and direction of differences between gross and net estimates depend on the degree of substitution between material and non-material inputs and the share of capital cost where the production function has three inputs (KLE).

However, when responding to BW, Griffin(1981) points out that given the size of the capital share the degree of substitution between materials and non-material input would have to be at an implausible high level in order to reconcile the differences between the estimates. Therefore, even if BW's explanation tends to reduce the disparity between the two results it does not adequately explain the discrepancy.

According to them, the difference in results is due to difference in long run and short run estimates which arises due to the use of different data base. BW by using time series data has estimated short run elasticity and since adjustment possibilities are limited in the short run the elasticity estimate is more likely to show complementarity between energy and capital. While GG pooled international sample shows energy-capital substitution because cross section/pooled cross section data reflects long run adjustment possibilities and the true long run relationship between energy and capital is one of substitution. Thus, the two results can be reconciled if energy and capital are short run complements and long run substitutes.

Robert Pindyck (1978), at a later stage uses a similar methodology as GG's and confirms his results. But BW have again shown that GG and Pindyck's pooled estimates are not inconsistent with their time series result of EK complementarity. Moreover, Melvyn Fuss's pooled time series/ cross section data also yields EK complementarity. This issue of cross section vs. time series estimates has been considered in a recent paper by David Stapleton who vigorously demonstrated that the problem is not only of data variation but are of dynamic specification. Dynamic models with endogenous adjustment paths are now available and these studies show EK complementarity contrary to GG's assertion.

According to BW, if the explanation in terms of gross/ net price elasticities or pooled time series data base fails to explain the discrepancy in results then there should be a third factor accounting for the differences. This, according to them is errors in data measurement. There are possibilities of reconciliation on this basis, particularly the measurement of capital. They claim that GG is testing KE substitution using erroneous data.

(1) There are differences in GG approach to measuring capital and labour expenditure in US vis-a-vis other countries.

(2) Differences in treatment of taxes in the measurement of K service price.

(3) Wrong way of treating non-physical K in measuring K service expenditure.

BW's data has been revised to reflect GG's definition of all variable and significant substitution is found between all inputs.

As has been mentioned earlier, B.C. Field and Grebenstein (1980) has attempted to reconcile the alternative results in terms of 'value added' and 'service price' approach' to measuring capital cost. According to them working capital and energy are likely to have substitution relationship while physical capital and energy are likely to have a complementary relationship. Thus BW, by adopting 'service price' approach to capital cost measurement finds EK complementarity and GG using a 'value added' approach finds EK substitution, the portion of 'value added' not accounted for by expenditure on labour being dominated by the presence of working capital.

The issue of substitutability/complementarity of between energy and capital is yet to be resolved and calls for further research with alternative model specifications.

2.2 The Indian Experience

All the studies on energy-non energy input substitution mentioned so far, except the one by Alamada J. and Arthur J. Mann (1985) for the Puerto Rican economy, are restricted to the manufacturing sector of the industrialised nations. There are very few studies relating to the developing countries. Certainly substitution possibilities have development implications for future economic growth in the already developed world. But the results based on developed country experience should not be directly used for policy analysis in developing countries.

So far as the Indian Manufacturing Sector is concerned there are quite a few studies both at the disaggregated industry level and at the level of aggregate manufacturing. But as expected, the literature is not at all extensively developed considering the fact that the interest of researchers in this area is very recent. The earlier literature was concerned with 'value added' relationship ignoring the possible role of intermediate inputs including energy.

The studies on energy and non-energy input substitution relating to Indian Manufacturing have been carried out by Williams and Laumas (1981) P.C. Apte (1983), Edward Lynk (1983), D.C. Vashisht (1984), M.N. Murty (1986), Paul Murty and Jha (1991) and Goldar and Mukhopadhya (1991).

Williams and Laumas (1981) estimated a four input (KLEM) translog model for the period 1968 using cross section data for eight manufacturing industries at the two digit level. They attempt to study the character of Indian Manufacturing sector by examining the performance of an average firm in the industry and assuming that this correctly depicts the behaviour of the industry as a whole.

It is being assumed that production functions are the same among sub-industries within a specific two digit group but differ across two digit categories. All the industries are classified into sub-classes by the industry number. The data are available for each sub-class. By dividing the total number of firms into each of these other totals, all the information is reduced to the average firm in each sub-class for each industry group.

The model has been estimated by the IZEF method of estimation.

For each of the product groups the relationship between different types of inputs appears to be mostly substitutes for one another. Capital and energy are found to be substitute for all product groups but labour and energy are complements for some of the products groups.

Own price elasticity of aggregate energy tends to be greater than the own price electricity of other inputs indicating that the firms product response can be manipulated sufficiently by energy inputs.

P.C. Apte (1983) attempted to estimate energy substitution possibilities for five three digit large scale manufacturing industries (Cotton textile, cement, machine tools, electrical cables and wires, power equipment). Using pooled cross section time series data where the units of cross section are states and period of analysis is 1968-71. Following Fuss (1977) and Pindyck (1978) he estimated an energy sub-model with three items (i) solid fuel, (ii) liquid fuel (iii) electricity and an aggregate model with the aggregate inputs of capital, labour, energy and material. The model has been estimated using Iterative Zellner Efficient Method of Estimation.

For the purpose of estimation states were divided into four regions (North, South, East and West) and regional intercept dummies were used to account for regional variation. The model explains inter fuel substitution quite well, but the performance of the model at the aggregate level explaining substitution between energy and non-energy inputs is not as good.

Using the above model they find labour and energy to be substitutes in all five industries. However, capital and energy are by and large complementary (in four of the five industries).

Own price elasticity of energy is found to be around (-0.4) for three of the five industries.

Edward Lynk (1983) did a time series study for the planning period (1952-71) for fourteen organized Indian industries at the three digit level using a four input (KLEM) model.

A unique feature of his model is that instead of using the more popular translog approximation to the cost function he has employed an adaptation of Diewert's (1971) Generalized Leontief parameterization as a result of the findings of Caves and Christensen (1980) that in the case of non-homothetic production function the regular region of the GL approximation is superior to that of translog. The system of input demand equations was estimated by Generalized Least Squares Method.

Their principle findings show broad evidences of capital-energy substitution. Labour-energy are found to be substitutes in some of the industries. Evidence of factor substitutability vary across industries.

Substitution between labour and energy is observed in matches, bicycle, woollen textile ad plywood and between energy and capital in non-ferrous metals, fruits and vegetable processing, woollen textiles and plywood. There is increasing substitution between capital and energy i bicycles, matches, cotton textiles and woollen textiles and declining substitutability in non-ferrous metals.

All the above studies are restricted to the period till 1971. There are a few other studies which cover an extended time period upto the '80s

D.C. Vashisht (1984) estimated a time series model at the level of total manufacturing for the period(1960-71). He has employed a translog model using capital, labour and three types of energy inputs - coal, oil and electricity.

Following a similar methodology as P.C. Apte's he has also estimated an energy sub-model and an aggregate model consisting of the aggregate inputs of labour, capital and energy. But he excludes material as an input in the aggregate model. The model has been estimated using Iterative Zellner Efficient method of estimation.

His times series study finds capital and energy to be complimentary (but estimate of cross price elasticity statistically insignificant) Labour and energy are found to substitutes.

Energy is found to be the most price responsive among the aggregate inputs.

M.N. Murty (1986) estimated a model consisting of the aggregate inputs of capital, labour, material and three energy inputs of coal oil and electricity. To allow for the possibility of interfuel substitution they have estimated an energy sub-model following P.C. Apte (1983) and D.C.Vashisht (1984). The aggregate model consisting of the aggregate inputs of K, L, E and M has been estimated at the second stage. The model has been estimated by IZEF methods of estimation.

Contrary to the findings of Vashist's time series study for the aggregate manufacturing they find capital and energy to be substitutes and labour and energy to be complements. Energy inputs are found to be highly price responsive .

Paul, Murty, Jha (1991) estimated a time series model for four manufacturing industries defined at three digit industrial classification for the period (1960-61,–1982-83). The four industries studied Iron and Steel, Cement, Cotton textiles and Gas and Electricity. A non-homothetic translog cost function has been estimated with three inputs of capital

(K), Labour (L), energy and material combined(EM). Energy and material were clubbed together as one input.

There exists adequate substitution possibilities between factors of production in Indian manufacturing industries and basic relationship between pairs of inputs has remained unchanged over the sample period.

Labour and EM exhibits substitution in all industries. Capital and EM are complementary inputs in production of cotton textile and iron and steel and substitutes in the other two.

B.N.Goldar and H. Mukhopadhya (1991) did a time series study for the period (1951-82) for five three digit manufacturing industries - cotton textile, cement, paper, non-ferrous metal and iron & steel. They have estimated a three input (K, L, E) model using a new approach called the Cost Price Approach due to Conrad (1983). It combines factor substitution in the neo-classical theory with partially fixed factor proportion in the Leontief approach. In this approach, the quantity of an input used by the firm is divided into two parts : one part is free for substitution as relative prices change while the other part is tied to bound to other inputs. In effect, the effective price of an input consists of its own price and weighted sum of the prices of other inputs, the weights being dependent on how other inputs are tied to the input in question. Conrad approach yields share equations non-linear in parameters.

Along with this cost price model, they have also estimated a traditional translog model.

Both the models have been estimated by the full information maximum likelihood (FIML) method of estimation.

Parameter estimates of the cost price model are found to exhibit higher significance than that of the translog model. Results of the translog model indicate that labour and energy are substitutes in all the five industries.

Regarding capital and energy, results differ across industries. Results for cotton textile, cement and paper industries show a substitutable relationship between capital and energy while the other two show complementarity. Own price elasticity of energy ranges from (-0.78) to (-1.45).

As for the results obtained from the cost price model elasticity estimates labour and energy is positive for all the five industries and results tally with the results obtained from the translog model. For capital energy, estimates obtained from the cost price model have in cases signs opposite to the signs of the estimates based on the translog model. Own price elasticity of energy is lower in the cost price model.

The difference in results in the two model indicate the presence of high degree of 'boundedness' among the inputs which the translog model cannot adequately take into account. Thus, the responsiveness of input demand to price changes is being overstated.

From the above survey of the empirical literature one can attempt to reach certain conclusions regarding the estimates of industrial demand for energy in Indian Manufacturing Sector. Problem of comparability arises because of differences in the level of aggregation - some of the studies relate to the aggregate manufacturing while some are industry specific studies. But inspire of that, certain broad traits are being observed.

Of the two studies at the level of aggregate manufacturing by Vashisht (1984) and Murty (1986) opposite results are noted regarding the sign of both labour-energy and capital-energy elasticity of substitution.

1) Broad evidences of labour-energy substitution is found by most of the researchers. The magnitude and significance of estimates of course vary across industries but the sign is generally positive, for the disaggregated industry level studies.

Murty's is the only study which finds labour-energy complementarity. Williams and Laumas also finds negative elasticity of substitution for some of the industries.

But on the whole, there is considerable agreement among the researchers regarding the relationship between labour and energy.

2) Evidences on capital-energy elasticity estimates are widely divergent. At the aggregate level Vashisht reports capital-energy complementarity while Murty finds substitution.

Thus it is difficult to reach any definite conclusion regarding the nature of capital-energy relationship.

As for the own price elasticities of energy demand the estimates are quite high and have the proper sign in most cased. In a few specific cases own price elasticities are positive indicating the violation of cost minimizing behaviour of economic theory.

In the light of the above empirical evidences on Indian industries one can examine whether the divergent results such as energy-capital complementarity/ substitutability can be reconciled in a similar fashion as has been done for other country.

Thus for example using cross section as well as time series data one can study whether the GG explanation of short run and long run elasticities can be extended under Indian conditions. According to GG time series data should generally give short run estimates showing EK complementarity while estimates from cross section/pooled cross section data reflects long run elasticities showing EK substitutability.

In contrast to the GG assertion we find for the Indian economy divergent results.

For instance Lynk using time series finds KE substitution and P.C. Apte using pooled data finds KE complementarity. But Williams and Laumas, using cross section data finds EK substitutions and D.C. Vashisht's time series study finds EK complementarity. Coming to the more recent studies Murty's time series study shows EK substitution for the aggregate manufacturing sector.

If we take industry specific example, results for cotton textile industry shows, complementarity when estimated from pooled data in Apte, substitution in Lynk (time series data), complementarity in Goldar (time Series). Only Williams and Lauma's cross section study shows substitution. Therefore we cannot reach any definite conclusion to the effect that time series data should show EK complementarty and pooled data set should give EK substitution.

This only indicates that there may be other factors to explain such divergent results. Hence a proper investigation into the issue is necessary. This is definitely an area which calls for further research.

CHAPTER III

SCOPE AND COVERAGE OF THE PRESENT STUDY

3.1 SCOPE OF THE STUDY

The survey of the literature on the empirical estimation of the elasticity of substitution between energy and non-energy input in the context of Indian manufacturing presented in the preceeding chapter suggests certain directions in which further research seems to be desirable.

Firstly, as we have already mentioned earlier, no attempt has yet been made to explain the observed conflicting empirical evidences regarding the energy substitution possibilities in Indian manufacturing. It is desirable therefore to try alternative models to examine the sensitivity of the results to model specification, different ways of defining variables, specification of functional forms, exclusion or ommission of particular input, and the data base (time series/ pooled cross section-time series) of the study. Considering the importance of the elasticity parameters in respect of policy formulation especially, for developing countries like India, the need for reliable estimates on energy substitution is strongly felt. Certain amount of research in this direction has been done in other countries as we have seen in our survey (chapter 2) above, but unfortunately none so far in India. Therefore, this was be considered as an important justification for the present work.

Secondly, the existing studies relating to Indian manufacturing has not considered the post '73 period exclusively to determine the impact of oil price shock on the nature of input substitution. The movement of real and also nominal energy prices were quite different in the pre-oil shock era and post oil shock era. Real energy prices fell during the mid 1960-s but rose during the 1970s. The post '73 rise in oil price was not just a temporary economic disruption. The oil market scenario has changed dramatically after 1973 affecting the entire world economy. Prior to the 1970s the oil market was more or less competitive in nature. Between '71 and '73 prices rose gradually with the gradual decline of spare capacity in the world and this led to the formation of 'cartels' and consequent rise of OPEC permanently establishing monopoly power in the world energy market.

Considering the importance of oil resource in the economic development of any nation these factors are going to have far reaching implications for economic growth strategies, especially for countries or regions which are large importers of petroleum-derived energy. Technology and lifestyle in most countries is very much dependent on oil and in the last couple of decades import of this liquid fuel has risen sharply. Although there are important substitutes among fuels, it is not easy to shift from liquid to other fuels in the short run for many reasons including the tendency for capital to be fuel specific and slow turn over.

Thus, oil is not merely one of several fuels, but one that is specific in its use in which substantial changes can occur only through technological changes.

That is why, the oil price hike of '73 provoked the 'energy crisis' in the '70s causing the greatest boom in commodity prices in recent years.

In the light of the above scenario, it becomes quite apparent that adjustment to steadily declining energy prices in the mid -60s will be considerably different from adjustment to rapidly rising prices in the 70s. These adjustments may be conceived of either as choice of technique, or technological change or choice of products. Given the nature of world energy market and available alternative sources of energy, firm behaviour must have changed drastically in the post '70s compared to the pre-oil shock era, the pattern of changes in the relative price structure of basic inputs affecting both own and cross price elasticities and also the elasticities of substitution between various inputs.

These structural and relative price movements are expected to have far reaching implications for net energy importers like India. Therefore it provides yet another justification of a study by treating the post '73 period exclusively as a separate sample.

For other countries there exist two studies addressing these issues. One is by Alamada. J and Arthur. J. Mann (1985) for the Puerto Rican economy and the other one is by Gorfalo and Malhotra (1984) for the US economy. But in the Indian context, the existing studies are either up to the period till 1971 or based on continuous time series till the eighties without making any distinction between the pre-oil shock and the post-oil shock periods.

It is therefore the primary purpose of this study to examine the nature of relationship between energy and non-energy inputs by considering exclusively the post '73 period for a few large scale manufacturing industries of India . A three input (KLE) translog model has been employed for the purpose of estimation assuming separability of materials as a fourth input in the production process. In the process of estimating substitution elasticities among energy and non - energy inputs we have attempted different methods of defining capital costs so as to examine if the divergent estimates of elasticity of substitution between capital and energy are essentially due to the way capital cost is defined.

Thus we have estimated two models using alternative definitions of capital cost. Model I uses the 'value added' approach to measuring capital cost where cost of capital is defined as the residual from gross value added after subtracting the expenditure on labour. Model II defines capital cost using the 'service price' approach where only physical capital is considered as the measure of capital input and cost of capital is defined in terms of service price of fixed capital.

The two models will be estimated separately in order to test the sensitivity of empirical results to alternative definitions of capital cost.

Field and Grebenstein (1980) has argued that energy interacts differently with physical and working capital. Thus 'value added' measure of capital being dominated by the presence of working capital should show energy - capital substitution while the service price measure should show energy-capital complementarity. We would like to investigate into this issue and find out whether Indian data confirm this result.

Model II again uses two different measures of capital in estimating cost of capital. First the cost of capital was computed with 'book value' of capital (as reported in ASI) as the measure of capital input, following Goldar and Mukhopadhyay (1991), Murty (1986), Paul, Murty, Jha (1991) and Lynk (1984).

But there are some serious limitations in using book value as a measure of capital input. The book value series on capital stock is not corrected and for actual depreciation and therefore under estimates the capital stock. Keeping in mind this limitation of data we have estimated gross capital stock at constant prices following the Perpetual Inventory method. [Hashim and Dadi (1973), Banerjee (1974) and Goldar].

We use pooled data for estimation purposes with states as our units of cross section .Data has been pooled over the time period 1976 -83. The reasons for using pooled data are the following:

I. The variations in input prices and cost shares are greater with a pooled data as compared with a time series data. (Houthakker, Nadiri, Griffin and Grcgory) Pooling increases sample size and is expected to yield better estimates.

II. Estimates of the elasticities are more likely to reflect long run pattern in contrast to estimates from time series data which are sensitive to short run fluctuations in the economy, especially when the study is conducted for a single country.

III. In estimating a single equation by using times series data for the entire economy, considerable inter-regional variations in the use of techniques are lost. Thus, using time series data it is not possible to distinguish empirically between difference in input choices between states.

Even if we assume that all states share identical production function for a homogeneous industry, factor-price equalization is quite unlikely to occur in the Indian situation due to lack of factor mobility and other hindrances. Therefore, the optimal input choice for different states are expected to be different. Different local tax structures and 'locational pulls' are major determining factors in causing relative input price variation across states.

IV. The problem of multicollinearity is frequent in single time series data (Fuss: 1977).

In order to investigate whether pre-73 and post-73 period samples are significantly different to make any meaningful comparison we have estimated the parameters of our translog cost function for the cotton textile industry for both pre-73 and post-73 data. Similar comparison of pre-73 and post-73 samples could not be carried out for the other three industries covered in our study because of time constraint.

3.2 PERIOD OF STUDY

The period of study is 1976-83. It could not be extended beyond 1983 because ASI census sector data are available only till 1983.

3.3 COVERAGE OF INDUSTRIES

The present study covers four three digit large-scale manufacturing industries, e.g., Cotton Textiles (ASI code: 231) Cement Lime and Plaster (ASI code: 324), Organic and Inorganic Chemicals (ASI code: 310) and Iron and steel (ASI Code: 330)

The value of output of these four industries accounted for a significant proportion of the value of output of the Indian Manufacturing sector as a whole. All four industries are extremely important for a developing economy like India. And also these industries are highly energy-intensive industries.

CHAPTER IV

THE MODEL AND METHOD OF VARIABLE CONSTRUCTION

4.1 The Model

We assume that the Indian manufacturing sector can be characterised by a twice differentiable continuous non-decreasing production function. Y = F(K, L, E, M) which relates gross output Y to the services of four aggregate inputs : capital (K), labour (L), energy (E) materials (M). Assuming homothetic weak separability of materials the above function can be written as Y = F (H (K, L, E), M). It is further assumed that F exhibits neutral technical change and is subject to constant return to scale.

The dual of the above twice differentiable production function is a twice differentiable cost function C = G (G (P_K, P_L, P_E), P_M). Where C is the unit cost function and P_i-s are input prices, i = K, L, E, M

We will be estimating the sub function G (P_K, P_L, P_E) Assuming that this cost function can be approximated upto the second order by a homothetic translog cost function. We proceed to write the translog form of the homothetic KLE, aggregate, 'G' as follows ;

$$\ln G = \ln\beta_o + \sum_i \beta_i \ln P_i + \frac{1}{2}\sum_i \sum_j \beta_{ij} \ln P_i \ln P_j$$

Subject to symmetry restriction $\beta_{ij} = \beta ji$

We get,

$$lnG = \ln\beta_0 + \beta_k lnP_k + \beta_L lnP_l + \beta_E lnP_e$$
$$+\frac{1}{2}\beta_{KK}(lnP_K)^2 + \beta_{KL} lnP_K lnP_L + \beta_{KE} lnP_K lnP_E$$
$$+\frac{1}{2}\beta_{LL}(lnP_L)^2 + \beta_{LE} lnP_L lnP_E$$
$$+\frac{1}{2}\beta_{EE}(lnP_E)^2$$

Imposing symmetry and linear homogeneity restrictions.

Linear homogeneity implies,

$$\beta_K + \beta_L + \beta_E = 1$$
$$\beta_{KK} + \beta_{KL} + \beta_{KE} = 0$$
$$\beta_{KL} + \beta_{LL} + \beta_{EL} = 0$$
$$\beta_{KE} + \beta_{EL} + \beta_{EE} = 0$$

Assuming perfect competition in the factor market input prices are treated as exogeneous given the level of output. Cost minimizing input demand functions are derived as follows:

$$\frac{\partial \ln G}{\partial \ln P_i} = \frac{\partial G}{\partial P_i}\frac{P_i}{G} = \beta_i + \sum_j \beta_{ij} \ln P_j$$

Using Shephard's Lemma linear cost share equations are obtained as

$$S_K = \frac{P_{KK}}{G} = \beta_K + \beta_{KK} \ln P_K + \beta_{KL} \ln PL + \beta_{KE} \ln PE$$

$$S_L = \frac{P_<}{G} = \beta_K + \beta_{KL} \ln P_K + \beta_{LL} \ln P_L + \beta_{EL} \ln P_E$$

$$S_E = \frac{P_{EE}}{G} = \beta_E + \beta_{KE} \ln P_K + \beta_{LE} \ln P_L + \beta_{EE} \ln P_E$$

Where total cost G = $P^{K.K} + P_{L.L} + P_{E.E}$

Sum of the cost shares is always unity. This is the adding up criterion which implies

$$\sum S_i = 1, i = K, L, E$$

Alternatively the above cost share equations can be written as

$$S_k = \alpha_k - (\beta_{KL} + \beta_{KE}) \ln P_k + \beta_{KL} \ln P_L + \beta_{KE} \ln P_E$$

$$S_L = \alpha L + \beta K_L \ln P_K - (\beta_{KL} + \beta_{LE}) \ln P_L + \beta_{LE} \ln P_E$$

$$S_E = \alpha_E + \beta_{Ke} \ln PK + \beta_{LE} \ln PL - (\beta_{KE} + \beta_{LE}) \ln PE$$

or

$$S_k = \alpha_K + \beta_{KL} (P_L / P_K) + \beta_{KE} (P_E / P_K)$$

$$S_L = \alpha_L + \beta_{KL} \ln (P_K / P_L) + \beta_{LE} \ln (P_E / P_L)$$

$$S_E = \alpha_E + \beta_{KE} \ln (P_K / P_L) + \beta_{LE} \ln (PL / P_E)$$

Incorporating the linear homogeneity restrictions.

The AES for the translog cost function are derived as,

$$\partial_{ii} = \frac{\beta_{ii} + S_i^2 - S_i}{S_i^2}$$

$$\partial_{ij} = \frac{\beta_{ij} + S_i S_j}{S_i S_j} \quad i, j = K, L, E \quad i \neq j$$

The price elasticity of demand for factors of production is analytically related to AES as

$$E_{ij}=\sigma_{ij}S_j \quad i,j=K,L,E$$
$$\sigma_{ij}=\sigma_{ji}, E_{ij}\neq E_{ji}$$

Stochastic Specification :

The parameters to be estimated are contained in the system of share equations since these equation systems are deterministic, they have to be made stochastic for econometric estimation.

We assume that deviations of the cost shares from the logarithmic derivatives of the translog cost function are the results of random errors in cost minimizing behaviour.

Errors of optimization can occur due to deviation of the firm's actual behaviour from its cost minimizing behaviour. To account for such random errors disturbance terms are added to the equations. and the equations are rewritten in the following form :

$$S_k = \alpha_K + \beta_{KL}(P_L/P_K) + \beta_{KE}(P_E/P_K) + U_k$$
$$S_L=\alpha_L+\beta_{KL}\ln(P_K/P_L)+\beta_{LE}\ln(P_E/P_L)+U_L$$
$$S_E=\alpha_E+\beta_{KE}\ln(P_K/P_E)+\beta_{LE}\ln(PL/P_E)+U_E$$

Each of these is a system of log linear equations with constraints on parameters both within and across equations.

Since the cost shares always add up to unity the sum of the disturbances across the equations is zero at each observation.

Thus,

$$\Sigma U_i = 0 \quad i = K, L, E$$

For the system of share equations disturbances are likely to be correlated. Therefore, the variance-covariance matrix of the disturbances is singular and non-diagonal.

In such a model we can arbitrarily drop the disturbance from one of the equations and specify that the column vector of the disturbance terms in the remaining equations is in dependently and identically normally distributed with mean vector zero and a non-singular covariance matrix.

Because of singularity of the disturbance matrix one of the equations has to be dropped from the system and the remaining two can be estimated jointly.

Zellner (1962) has shown that when disturbances across equations are correlated and if the correlation is known then the parameters can be estimated more efficiently by taking this information into account, furthermore, Zellner (1963) has demonstrated that even when the correlation is unknown, it is likely that using an estimate of the correlation will improve estimation efficiency.

This suggests the use of Zellner Efficient procedure for estimation of the system of cost share equations. But the problem with ZEF is that it is not invariant to the choice of equation deleted. A maximum likelihood procedure would provide estimates of parameters that are invariant to the choice of equations to be actually estimated. However, Kmenta and Gilbert (1968) have demonstrated that ML and Iterated ZEF leads to identical estimates. Iteration of ZEF yields consistent ML estimates.

In the present paper, it is the IZEF method which has been applied to the system of equations subject to symmetry and linear homogeneity restrictions. From the system of cost share equations We have dropped the equation for K. The standard assumptions made about the disturbances in multi variate regression models are also made here -

otherwise ij=K, E, L, r, s refer to states and t,t· to time periods.

By dropping the equation for k, we estimate the following two equation.

$$S_L = \alpha_L + \beta_{KL} \ln(P_K/P_L) + \beta_{LE} \ln(P_E/P_L) + U_L$$
$$S_E = \alpha_E + \beta_{KE} \ln(P_K/P_E) + \beta_{LE} \ln(PL/P_E) + U_E$$

After dropping an equation, of the various constraint only the symmetry constraint remains bindings. The others are automatically satisfied when we derive the parameters of the omitted equations based on them.

The parameter estimates of the equation for k can be determined from the parameter estimate of the other two equations using linear homogeneity property.

Use of Dummy Variables

Finally, it should be mentioned that the data sample used in this study is obtained by pooling time series (1976-83) and cross section (states) information. This fact has to be taken into account in the estimation procedure. It is unlikely that the data are drawn from a homogeneous sample due to regional differences in technology. To capture the effect of regional variation intercept dummies have been introduced into the system of cost share equations.[3]

$D_i = 1$ for the i^{th} state $i = 1,2...n = 0$ for others.

If there is a constant term in the regression equation, the number of dummies defined should always be one less than the number of groupings considered because the constant term is the intercept for the base group and the co-efficient of the dummy variables measure differences in intercepts.[4] Thus the total number of dummies we introduced is one less than the total number of states. The constant term in the share equation measures the intercept for the state for which there was no dummy.

4.2 DATA BASE AND CONSTRUCTION OF VARIABLES

The analysis is based on pooling time series (1976-83) and cross section (states) data. In our production function model, state is the representative of a firm. Basic data is drawn from Annual Survey of Industries, Census sector. Our model covers four three digit large scale manufacturing industries for the period (1976-83) eg., Cotton Textiles (ASI Code : 231), Organic and Inorganic Chemicals (Asi code : 310), Cement, Lime and Plaster (ASI code : 324) and Iron and Steel (ASI Code : 330)

For cotton Textile Industry we have also estimated the model for the period (1968-71). Upto 1971 ASI industrial establishments were defined broadly on the basis of what is known as ASI classification of industries. From 1973 onwards ASI classification was replaced by NIC classification. Due to adoption of this classification the industry codes in the two periods do not match exactly. From the table of concordance between ASI and NIC code reported in ASI volume I, we found out that ASI code 231 corresponds to NIC (2310,2320,2340,2350, 2360).

But 2310 (Cotton spinning and weaving) accounts for almost 96% of the total output and of all these industries taken together.

Therefore, we assume in our study that ASI 231 corresponds to NIC 2310.

For the period 1976-83, We'll be estimating two models based on alternative definitions of capital cost. Model I uses the 'value added' approach and model II uses service price approach to measuring capital cost.

Estimation of the cost share equations requires data on prices and cost shares of labour, capital and energy. The variables used in our analysis are constructed in the following way ;

Price of labour : Price of labour inputs is computed as the ratio of 'total emoluments' to 'total employees'. ASI gives data on both.

Regarding the measurement of labour input there were three available alternatives - man hours, 'workers' and 'employees'.

'Total employees' as measure of labour input includes both 'workers' and 'persons other than workers', the latter category of employees includes supervisor, technicians, managers, clerks and other similar types of employees. The latter category of labour may be treated as skilled labour and hence their services should be taken into account in the measurement of labour input.

Price of labour measured this way reflects to some extent the variation in the proportion of skilled and unskilled labour used in production process. But this measure of labour input involves the assumption that 'workers' and 'persons other than workers' are perfectly substitutable.

Price of Energy

Price index of energy input is computed as the weighted average of price indices of coal, oil and electricity. Till 1971, ASI used to publish item wise detailed breakup of fuel consumption.

For each industry at the four digit level state-wise data on quantity consumed of each fuel item and actual expenditure on it is available in these volumes. The major category of fuel items includes Coal, Coke, Diesel oil, Motor spirit and Aviation, Coal gas, other fuel oil, lubricant, Natural gas, electricity and water.

But after 1971 ASI stopped publishing the detailed breakup annually. Since then such data are available only at five yearly interval. Thus, during the period covered in our study we have the detailed breakup for one year only - 1978-79. Therefore, we will be using 1978-79 as the base year using the actual expenditure share of each fuel item for 1978-79 as weights in constructing the aggregate energy price index.

Of the various fuel items we have taken only three major categories - coal, oil and electricity which together account for more than 90% of total fuel consumption for most of these industries. For Iron and Steel and Cement Coke has been included because it accounts for a comparatively large share in total fuel consumption compared to the other two industries.

Oil includes the following five categories -

(a) Diesel oil (6) furnace oil (c) lubricating only (d) Other fuel oil and (e) Aviation and Motor Spirit.

Since the detailed breakup is available at four digit level the final figure on actual expenditure of fuel items is obtained by summing up the observations across the sub-industries at the three digit level.

For constructing the aggregate energy price index we have used the Laspyre's Price Index formula which gives :

$$P_E = \frac{p_c^1 q_c^0 + p_e^1 q_e^0 + p_0^1 q_0^0}{p_c^0 Q_c^0 + p_e^0 q_e^0 + p_0^0 q_0^0}$$

using base year quantities as weights.

P_E is the aggregate energy price index, P_c^1, P_e^0 and P_0^1 denote current year prices of coal, electricity and oil respectively. P_c^0, P_e^1 and P_0^0 are base year prices of the same items and q_c0, q_e^0 and q_0^0 denote actual quantities of coal, electricity and oil consumed in the base year.

Equivalently, one can write,

$$P_E = \frac{p_c^1/p_c^0 \cdot p_c^0 q_c^0 + p_e^1/p_e^0 \cdot p_e^0 \cdot q_e^0 + p_0^1/p_0^0 \cdot p_0^0 q_0^0}{p_c^0 q_c^0 + p_e^0 q_e^0 + p_0^0 q_0^0}$$

$$= \frac{p_c^1/p_c^0 \cdot v_0^0 + p_e^1/p_e^0 \cdot v_e^0 + p_0^1/p_0^0 \cdot v_0^0}{v_c^0 + v_e^0 + v_0^0}$$

where V_i^0, i =c,e,0 are the values of coal, electricity and oil consumed by each industry in each state.

Since state-wise data on actual prices of individual energy items are not available, All India Wholesale Price Indices have been used as proxy for the prices for all states. This involves a strong assumption that there is no inter-state variation in prices. This is definitely a limitation in our construction of energy price index.

The above method of construction of energy price index may limit the range of input price variation in the sample since we are not able to take account of the variation in energy prices across states. We do hope, however, that this is not going to affect the results significantly since our period of observation is rather short. Moreover as we are using the actual expenditure on each fuel item by different states as weights this will capture the inter-state variation in prices to some extent in the construction of our energy price indices.

All India Wholesale Prices for three major fuel items have been taken from Chandhok's India Data Base.

Indices for coal, mineral oil and electricity are available separately. The indices available at (1960-61) prices have been converted to (1978-79) base.

Thus, the fuel prices indices have been constructed with

1979 = 1 as the base period.

PRICE OF CAPITAL

Following Jorgenson and Grilliches (1967), the price of capital services, in the absence of direct taxation, can be written in the following way,

$$P_K = q_K(r+\delta-\dot{q}_K/q_K)$$

Where P_k : Service price of capital

q_k : Price of an investment good.

δ : Rate of depreciation

r : Rate of return on capital

$\dot{q}_k/q_k$: Rate of capital gain on that good

This method of estimating the price of capital services attempts to recognize the distinction between capital stock and capital services. It is not the stock but the service of capital which is to be treated as the factor of production. Thus, one must recognize the distinction between asset price and service price.

In the study by Jorgenson and Grilliches (1967) the asset price q_k and the service price P_K are related through the above equation. It states, given the price of investment goods, a measure of overall rate of return and estimates of the rates of replacement in assets of various types we can derive the service prices which can be used for estimating capital service.

Following Goldar and Mukhopadhya (1991), Murty (1986) and Paul, Murty and Jha (1991) we have ignored the capital gain component and assume our capital service price to be -

$Pk = q_k(r+\delta)$.

For rate of return an capital we have used the bank rate as proxy for prime lending rate following Goldar and Mukhopadhaya (1991). Prime lending rate is viewed as an opportunity cost of capital.But since there is no unique lending rate bank rate has been used as a proxy because they always move together. Alternatively, one could use the gross yield on preferential shares as Murty (1986) has done. However, there is very high positive correlation between bank rate and the yield on preferential shares (0.80) which justifies this methodology (Goldar, 1991).

Bank Rates have been taken from the Report on Currency and Finance, published by the Reserve Bank of India.

The price index for investment goods(q_k) has been computed in a similar fashion as fuel price indices, as the weighted average of the major components of fixed capital - machinery, transport, construction and other assets.

Land has been omitted as a factor from the total value of fixed capital, the share of land being marginal in the total value of fixed assets. The share of each of the other components has been computed as a proportion of this residual.

ASI, Census sector, gives detailed statewise break up of fixed capital for each industry at the four digit level. Respective shares of each industrial component of fixed capital in total value of fixed capital has been used as weights in constructing the price indices. The price indices have been constructed with 1979 as the base year because detailed break up is available only for that year. For q_k, thus 1979 = 1. Rate of depreciation is simply the ratio of value of depreciated assets as replaced in ASI and the book value of capital.

Due to non-availability of statewise data, our construction of the price indices of capital also suffers from similar problem as in the construction of energy price indices. In constructing the price index of investment goods we had to use the All India Price Indices for all the states.

The price index for transport equipment has been taken from Chandhok. As for Plant and Machinery and Construction implicit deflators reported in National Accounts Statistics have been used.

Cost of Capital

Model I: The cost of capital is computed as Gross value added (GVA) minus expenditure on labour. In our case expenditure on labour implies total emoluments.

This measure of capital cost has a major draw back. The residual of GVA less emoluments contains costs which are not associated with capital and it includes both physical and working capital.

Model II Cost of capital is being computed as $P_k K$

where as P_k = Service price of capital

K = Measure of Capital Input.

First, we have used the book value of capital as reported in ASI as measures of capital input. Cost of capital thus becomes $(r+\delta)k$, $(r+\delta)$ being cost of unit worth of capital.

In the next stage, we have made an improvement by using fixed capital stock estimated at constant prices, adjusting for depreciation. We have estimated value of capital stock at constant prices by adjusting ASI data on capital stock for price changes.

Estimation of Capital Stock

The published data by (ASI) on capital stock relate to book value of capital assets net of cumulative depreciation. The book value series is not corrected for price changes and it is often said that it underestimates the true capital stock.

In order to overcome the above limitations, we have estimated capital stock by using the Perpetual Inventory method (Hashim and Dadi, 1974 ; Banerjee, 1973; Goldar, Ahluwalia).

Our measure of capital input uses, the following formula, following Goldar.

$$K_T = Ko + \sum_{t=1}^{T} (I_t - DS_T)$$

Where K_0 : denote base year capital stock

I_t : the gross investment at the base year prices)

DSt : Amount of fixed assets discarded during year t,

The methodology followed for estimating I_t is as follows

$$I_t = (B_t + \ldots B_{t-1} + D_t) / P_t$$

Where B_t : is the book value of fixed assets at the end of year t,

D_t : is the amount of depreciation allowances made during year t and

P_t : is the capital goods price deflator

In the above method of estimating capital stock we have followed Banerjee (1975) in determining the bench mark year capital stock (K_0). Following him, we double the book value for the bench mark year (1976) as a measure of replacement value (at 1979 prices) of fixed assets for the year. We have used 1976/77 as the bench mark year but we have deflated the yearly gross investment at 1979 prices. Thus , the estimated Capital series is being expressed in 1979 prices. The construction of the capital goods price deflator has been explained before. It has been constructed as the weighted average of price indices of (1)Plants & Machinery (2) Transport Equipment and (3) Construction.

Following Goldar we have provided for correction of capital series for discarding of assets. About DS_t, there are several possibilities. This may be taken as Zero ($DS_t = 0$), or it may be taken as a constant amount

$$(DS_t - \overline{DS}),$$

or this may be taken as a fraction of previous years fixed capital stock $DS_t = \delta K_{t-1}$. Our estimates of capital are based on the third form. We have taken $\delta = .02$, assuming 2% rate of annual discarding in estimating capital stock at constant prices.

But fixing up 2% as the rate of discarding is quite arbitrary and is perhaps too low. Besides it should vary across industries. Rate of discarding should of course vary according to capital intensities. Perhaps the best way to solve the problem could have been to compute the rate of discarding separately for each industry on the basis of appropriate assumptions. But within the limited framework of the present study we could not attempt that and therefore accept it as a major limitation in our method of estimation of capital stock.

Multiplying the service price of capital by the estimated fixed capital stock at constant prices we get the value of capital services which equivalently expresses the cost of capital under the assumption of perfect competition and CRS.

Total Cost

Total cost is obtained as a sum of expenditures on labour, fuel and capital. Expenditure on labour is simply 'total emoluments' as reported in ASI and expenditure on energy is the value of 'fuel cost' as reported in ASI. Even though we've considered only three major fuel items e.g. coal, oil and electricity in constructing our fuel price index these three items account for more than 90% of total fuel cost. Therefore we can take 'total fuel cost' as reported in ASI as the estimate of expenditure on energy inputs in our model. As for cost of capital, Model I and II will gives different estimates. The estimation of capital cost has already been discussed.

Finally, cost shares are obtained as the ratio of the expenditure on each input to total cost.

For the period (1968-71) we have estimated the model for Cotton Textile Industry Construction of date is similar to that in model II of the latter (1976-83) period. Capital stock has been estimated with 1968 as the bench mark year at (1970-71) prices. Fuel price Index and price index of investment (q_k) has been constructed with (1970-71) as the base period.

CHAPTER V

ENERGY SUBSTITUTION IN INDIAN MANUFACTURING

-- EMPIRICAL ANALYSIS

We have estimated three input (KLE) translog model for the period (1976-83) for four large scale manufacturing industries e.g. Cotton Textile, Chemical, Iron and Steel and Cement. For the textile industry we have also estimated the same model for the period (1968-71) in order to compare the results of the two periods.

We have actually estimated two models based on two different approaches to the estimation of capital cost in order to test the sensitivity of empirical results to the definition of capital cost. Accordingly, Model I is based on value-added definition of capital (Griffin and Gregory, 1976; Pindyck, 1978) where cost of capital is defined as the residual after subtracting expenditure on labour from gross value added and Model II is based on the service price approach where cost of capital is defined as the value of physical capital in terms of service price (Berndt and Wood, 1975).

Model II is first estimated using the 'book value' of capital as the measure of capital input.[5] In the next stage, we have estimated gross fixed capital stock at constant prices as the measure of capital input. For both the models the cost share equation for capital has been deleted and the cost share equations for labour and energy have been estimated using Iterative Zellner Efficient Method of

Estimation. The parameter estimates of the deleted equations have been determined from the estimates of these two equations using linear homogeneity restrictions.

Since translog cost function belongs to the family of flexible functional forms which do not satisfy the positivity and concavity conditions globally, it is instructive to check the 'well behavedness' of the model in the sample region. The cost function will be well behaved if the monotonicity and concavity conditions are satisfied. Monotonocity is satisfied if the fitted cost shares are all positive. Concavity is satisfied if the Hessian matrix of substitution elasticities is negative semi-definite. In our model monotonocity is satisfied as the fitted cost shares are all positive. However, we have not performed the test for concavity. But the presence of negative own-price elasticities of factor demand in both the models is an indicator that the concavity condition may have been satisfied. It should of course be mentioned that negativity of own price elasticities is only a necessary but not sufficient condition for the cost function to be well behaved.

Thus, our translog model performs quite well for all the four industries. Having satisfied ourselves that the translog model provides a suitable representation of technology for these large scale manufacturing industries, we proceed to provide a summary of results obtained from the two models.

Table 5.1

IZEF Parameter Estimates of the (KLE) Translog Model : Model I
(1976-83)

	Cotton Textiles		Chemicals		Cement		Iron and Steel	
	Estimates	T Statistics	Estimates	T Statistics	Estimates	T Statistics	Estimates	T Statistics
DF		96		75		46		71
α_L	1.4563*	5.17	0.6369*	17.024	0.1448	0.78	0.4896*	5.76
	0.2816		0.0374		0.1856		0.848	
β_{KL}	-0.817***	1.37	-0.0442***	-1.66	0.0506	1.16	-0.0143	-0.67
	0.0595		-0.0266		0.435		0.0213	
β_{EL}	-0.0566*	-2.6	0.0288	1.2	-0.0474***	1.65	0.0023	0.1686
	-0.0217		0.1896		0.0286		0.0133	
α_E	-0.4482*	-2.95	-0.0853	2.3	0.339	0.89	0.6783*	4.93
	0.1518		0.0692		0.3384		0.1388	
β_{KE}	-0.1353*	-4.71	-0.1009*	-2.44	0.0582	0.59	-0.1217*	-2.71
	0.0287		0.0412		0.0981		0.0449	
$\bar{R}^2$(SL)	0.48		0.92		0.74		0.51	
$\bar{R}^2$(SE)	0.56		0.71		0.65		0.55	
SSE(SL)	0.51		0.11		0.0362		0.32	
SSE(SE)	0.08		0.18		0.26		0.44	
SE(SL)	0.0801		0.0419		0.0308		0.0693	
SE(SE)	0.0326		0.0536		0.0828		0.0813	
LLF	334.325		260.978		168.079		211.39	

Notes:

1. Figures in the parentheses indicate assymtotic standard error of estimates
2. * indicates estimates are significantly differ from zero at 1% level.
3. ** indicates 5 % level of significance
4. *** indicates 10 % level of significance
5. SSE denotes sum of squared errors
6. SE denotes standard error

Table 5.2

IZEF Parameter Estimates of the (KLE) Translog Model : Model II
(1976-83)

	Cotton Textiles		Chemicals		Cement		Iron and Steel	
	Estimates	T Statistics	Estimates	T Statistics	Estimates	T Statistics	Estimates	T Statistics
Degree of Freedom		97		75		41		71
α_L	0.7947*	14.82	0.6463*	13.16	0.3494*	7.83	0.4291*	11.65
	0.0536		0.049		0.0445		0.0368	
β_{KL}	-0.0752**	-2.28	-0.0255***	-1.36	-0.0326	-0.98	-0.0132	-1.18
	0.0329		0.0186				0.0111	
β_{EL}	-0.0645*	-3.76	-0.0346***	-1.65	-0.030***	-1.43	-0.0284**	-2.27
	0.0171		0.0209		0.0208		0.0124	
α_E	0.5401	-0.56	0.7299*	2.84	0.5904*	7.94	0.7786*	2.63
	0.0975		0.2562		0.07442		0.2957	
β_{KE}	-0.0311	-0.78	0.2602**	2.24	0.01043**	2.36	0.2321**	1.8
	0.0396		11.57		0.0441		0.01286	
$\bar{R}^2$(SL)	0.58		0.87		0.87		0.53	
$\bar{R}^2$(SE)	0.72		0.76		0.83		0.71	
SSE(SL)	0.21		0.18		0.0119		0.28	
SSE(SE)	0.04		0.38		0.071		0.32	
SE(SL)	0.047		0.0492		0.71		0.0633	
SE(SE)	0.0209		0.0717		0.0416		0.0677	
LLF	480.361		270.78		224.889		251.609	
DW	1.37		1.96		1.81		2.00	
DW	1.83		2.12		1.41		1.64	

Notes:

1. Figures in the parentheses indicate assymtotic standard error of estimates
2. * indicates estimates are significantly differ from zero
3. ** indicates 5 % level of significance
4. *** indicates 10 % level of significance
5. SSE denotes sum of squared errors
6. SE denotes standard error.
7. DW denotes Durbin Watson Statistics.

Results : 1976-83

The co-efficient estimates

The parameter estimates of the KLE translog cost functions for Model I and Model II are presented in Table 5.1 and Table 5.2 respectively. Model I results are based on value-added measure of capital cost and Model II results are based on estimated gross fixed capital stock at constant prices.

Co-efficients of the dummy variable are reported in Table 5.1 (a) and 5.2 (a) respectively.

Of the twenty reported co-efficient estimates (for four industries) in Table 5.1 (for Model I) nine are significant at 1 percent level and three at 10 percent level of significance.

In Table 5.2 (for Model II) seven of the twenty reported co-efficient estimates are significant at 1 percent level of significance, two at 5 percent level and three at 10 percent level.

Co-efficient estimate of Dummy variables

In both the models we have highly significant co-efficient estimates of dummy variable, most of which are statistically significant at 1 percent or 5 percent level of significance.

The estimates of the constant term in the equation represents the co-efficient estimates of the constant term for the states for which there was no dummy.

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COST SHARE EQUATION OF LABOUR (SL)

Table 5.1(a)

Coefficient Estimates of Dummy Variables: Model I

(1976-83)

Cotton Textiles

Dummy	Estimates	T Statistics
D1(MP)	0.0094*	0.19
	(0.0477)	
D2(TND)	-0.1295*	-2.83
	(0.0456)	
D3(PNB)	-0.157*	-3.6
	(0.0216)	
D4(UP)	0.0216	0.48
	(0.0442)	
D5(WB)	0.0923**	2.06
	(0.0447)	
D6(AP)	-0.0554	-1.26
	(0.0437)	
D7(ORS)	0.0069	0.1536
	(0.0499)	
D8(RAJ)	-0.0973**	-2.15
	(0.0457)	
D9(KAR)	-0.0547	-1.25
	(0.0435)	
D10(KER)	-0.074***	-1.61
	(0.0454)	
D11(GUJ)	-0.1235*	-2.56
	(0.0481)	
D12(MAH)	-0.0928**	-1.84
	(0.0503)	
D13(BHR)	-0.0125	-0.2809
	(0.0447)	
CONSTANT	1.4563*	5.1703
(HRY)	(0.02816)	

Chemicals

Dummy	Estimates	T Statistics
D1(AP)	-0.56*	-19.79
	(0.0283)	
D2(TND)	-0.4928*	-18.4
	(0.0267)	
D3(UP)	-0.4729*	-16.27
	(0.0291)	
D4(WB)	-0.359*	-13.21
	(0.0267)	
D5(AP)	-0.5383*	-15.79
	(0.034)	
D6(RAJ)	-0.4655*	-14.7
	(-0.0316)	
D7(KAR)	-0.5071*	-13.62
	(0.0372)	
D8(KER)	-0.4131*	-16.32
	(0.0253)	
D9(GUJ)	-0.5233*	-19.56
	(0.0267)	
D10(MAH)	-0.4849*	-19.41
	(0.0249)	
CONSTANT	0.637*	17.02
	(0.0374)	

Cement

Dummy	Estimates	T Statistics
D1(MP)	-0.1718*	-8.65
	(0.0198)	
D2(TND)	-0.1597*	-8.05
	(0.0198)	
D3(AP)	-0.1627*	-8.13
	(0.0199)	
D4(RAJ)	-0.097*	-9.78
	(0.0202)	
D5(KAR)	-0.117*	-5.83
	(0.02)	
D6(GUJ)	-0.1532*	-7.75
	(0.0197)	
CONSTANT	0.1448	0.07804
(BHR)	(0.1856)	

Iron and Steel

Dummy	Estimates	T Statistics
D1(AP)	0.2222*	-5.49
	(0.0404)	
D2(BHR)	-0.1956*	-5.04
	(0.0387)	
D3(GUJ)	-0.2473*	-5.89
	(0.0419)	
D4(HAR)	-0.2514*	-6.06
	(0.0414)	
D5(KAR)	-0.1632*	-4.03
	(0.0404)	
D6(MAH)	-0.1559*	-3.99
	(0.039)	
D7(MP)	-0.1699*	-4.3
	(0.0394)	
D8(ORS)	-0.1285*	-3.31
	(0.0387)	
D9(RAJ)	-0.1664*	-3.89
	(0.0427)	
D10(TND)	-0.2067*	-5.29
	(0.039)	
D11(UP)	-0.1834*	-4.59
	(0.0399)	
CONSTANT	0.4896*	5.76
(WB)	(0.0848)	

Note:

1. Figures in the parentheses indicate assymtotic standard error of estimates
2. * indicates estimates are significant at 1 % Level
3. ** indicates 5 % level of significance
4. *** indicates 10 % level of significance

Table 5·1(a)

IZEF Parameter Estimates of the (KLE) Translog Model : Model I

(1976-83)

COST SHARE EQUATION OF ENERGY (SE)

Cotton Textiles

Dummy	Estimates	T Statistics
D1(MP)	-0.0131	-0.66
	(0.0198)	
D2(TND)	0.0129	0.65
	(0.0198)	
D3(PNB)	-0.508*	-2.85
	(0.0178)	
D4(UP)	0.0021	0.11
	(0.0128)	
D5(WB)	0.0040	0.21
	(0.0186)	
D6(AP)	-0.0172	-0.96
	(0.0179)	
D7(ORS)	-0.0373**	-0.99
	(0.0187)	
D8(RAJ)	-0.0006	-0.0338
	(0.0186)	
D9(KAR)	-0.0403**	-2.25
	(0.0179)	
D10(KER)	-0.0725*	-3.76
	(0.0193)	
D11(GUJ)	0.0552*	2.6
	(0.0204)	
D12(MAH)	0.0144***	0.68
	(0.021)	
D13(BHR)	-0.0298***	-1.68
	(0.0183)	
CONSTANT	-0.4482*	-2.95
(HRY)	(0.1518)	

Chemicals

Dummy	Estimates	T Statistics
D1(AP)	0.2543*	7.26
	(0.035)	
D2(TND)	0.2297*	6.87
	(0.0334)	
D3(UP)	0.1998*	5.65
	(0.0353)	
D4(WB)	0.1118*	3.34
	(0.0334)	
D5(AP)	0.171*	4.26
	(0.0409)	
D6(RAJ)	0.003	0.0715
	(0.0387)	
D7(KAR)	0.1303*	2.4
	(0.0448)	
D8(KER)	0.0611**	1.88
	(0.0324)	
D9(GUJ)	0.2006*	6.04
	(0.0331)	
D10(MAH)	0.1005*	3.13
	(0.032)	
CONSTANT	0.0853	1.23
	(0.0692)	

Cement

Dummy	Estimates	T Statistics
D1(MP)	-0.16106*	-3.08
	(0.0522)	
D2(TND)	0.0655	1.25
	(0.0524)	
D3(AP)	-0.1274**	-2.39
	(0.0532)	
D4(RAJ)	-0.0905***	-1.72
	(0.0524)	
D5(KAR)	-0.1315*	-2.53
	(0.0533)	
D6(GUJ)	0.12943*	2.47
	(0.0522)	
CONSTANT	0.3039	0.89
(BHR)	(0.3384)	

Iron and Steel

Dummy	Estimates	T Statistics
D1(AP)	0.10075**	2.13
	0.0472	
D2(BHR)	0.0067	0.14
	(0.0455)	
D3(GUJ)	0.101**	2.03
	(0.0496)	
D4(HAR)	0.1579*	3.08
	(0.0512)	
D5(KAR)	0.0647***	1.35
	(0.0479)	
D6(MAH)	0.0198	0.43
	(0.0457)	
D7(MP)	-0.2274*	-4.87
	(0.0466)	
D8(ORS)	0.0794**	1.71
	(0.0454)	
D9(RAJ)	0.0778***	1.55
	(0.0501)	
D10(TND)	0.0217	0.47
	(0.4598)	
D11(UP)	0.1268*	2.69
	(0.0468)	
CONSTANT	0.6783*	4.95
(WB)	(0.1368)	

Note:

1. Figures in the parentheses indicate assymtotic standard error of estimates
2. * indicates estimates are significant at 1 % Level
3. ** indicates 5 % level of significance
4. *** indicates 10 % level of significance

COST SHARE EQUATION OF LABOUR

Table 5.2(a)

Coefficient Estimates of Dummy Variables: Model II

Cotton Textiles			Chemicals			Cement			Iron and Steel		
Dummy	Estimates	T Statistics	Dummy	Estimates	T Statistics	Dummy	Estimates	T Statistics	Dummy	Estimates	T Statistics
D1(MP)	-0.0404*	3.51	D1(MP)	-0.4241*	-17.07	D1(MP)	-0.0959*	-5.29	D1(AP)	-0.11445*	-3.17
	(0.0257)			(0.0248)			(0.0181)			(0.036)	
D2(TND)	-0.0292	-1.12	D2(TND)	-0.3486*	-14.11	D2(TND)	-0.139*	-11.48	D2(BHR)	-0.19916*	-5.86
	(0.026)			(0.0247)			(0.0121)			(0.0339)	
D3(PNB)	-0.0153	-0.68	D3(UP)	0.2895*	-11.52	D3(AP)	-0.107*	-8.85	D3(GUJ)	-0.1407*	-3.95
	(0.0225)			(0.2512)			(0.012)			(0.0356)	
D4(UP)	0.0262	1.1	D4(WB)	-0.2148*	-8.69	D4(RAJ)	-0.0845*	-6.6	D4(HAR)	-0.1536*	-4.46
	(0.0236)			(0.0247)			(0.0127)			(0.0344)	
D5(WB)	0.0782*	3.22	D5(AP)	-0.3665*	-13.82	D5(KAR)	-0.0898*	-7.29	D5(KAR)	-0.0944*	-2.77
	(0.0242)			(0.0265)			(0.0123)			(0.034)	
D6(AP)	-0.0204	-0.90	D6(RAJ)	-0.3513*	-12.14	D6(GUJ)	-0.1125*	-9.36	D6(MAH)	-0.069**	-2.01
	(0.0226)			(0.0289)			(0.012)			(0.0342)	
D7(ORS)	0.0301	1.33	D7(KAR)	-0.2925*	-11.58	CONTANT	0.3497*	7.83	D7(MP)	-0.0646**	-1.89
	(0.0226)			(0.0252)		(BHR)	(0.0495)			(0.0341)	
D8(ORS)	0.0227	0.94	D8(KER)	-0.3972*	-14.73				D8(ORS)	-0.1189*	-3.49
	(0.0233)			(0.0249)						(0.0341)	
D9(KAR)	0.0507**	2.000	D9(GUJ)	-0.3472*	-14.96				D9(RAJ)	-0.0452	-1.27
	(0.0253)			(0.0249)						(0.0356)	
D10(KER)	0.0444**	1.84	D10(MAH)	-0.351*	13.16				D10(TND)	-0.1256*	-3.69
	(0.024)			(0.0255)						(0.034)	
D11(GUJ)	-0.0355	-1.29	CONSTANT(HA	0.6463*	13.68				D11(UP)	-0.0425	-1.23
	(0.0273)			(0.049)						(0.0345)	
									CONSTANT	0.4291*	11.65
D12(MAH)	0.0546	-0.37							(WB)	(0.0368)	
	(0.0145)										
D13(BHR)	-0.032***	-1.42									
	(0.0225)										
CONSTANT	0.7947	14.82									
(HRY)	(0.0536)										

Note:

1. Figures in the parentheses indicate assymtotic standard error of estimates
2. * indicates estimates are significant at 1 % Level
3. ** indicates 5 % level of significance
4. *** indicates 10 % level of significance

Table 5.2(a)

COST SHARE EQUATION OF ENERGY(SE) Coefficient Estimates of Dummy Variables: Model II

Cotton Textiles

Dummy	Estimates	T Statistics
D1(MP)	0.0143	1.06
	(0.0135)	
D2(TND)	0.038*	2.71
	(-0.0139)	
D3(PNB)	-0.0043	-0.37
	(0.0173)	
D4(UP)	0.0031	0.25
	(0.0123)	
D5(WB)	-0.0028	-0.21
	(0.0128)	
D6(AP)	-0.0015	-0.0125
	(0.012)	
D7(ORS)	-0.0475*	-4.03
	(0.0117)	
D8(ORS)	-0.0702*	-5.76
	(0.0121)	
D9(KAR)	-0.0702*	-5.28
	(0.0132)	
D10(KER)	-0.0298**	-2.28
	(0.013)	
D11(GUJ)	0.0869*	6.03
	(0.0144)	
D12(MAH)	0.046*	3.75
	(0.0145)	
D13(BHR)	-0.0221**	-1.86
	(0.0188)	
CONSTANT (HAR)	-0.0549	-0.56
	(0.0975)	

Chemicals

Dummy	Estimates	T Statistics
D1(MP)	0.3218*	8.91
	(0.0316)	
D2(TND)	0.2947*	8.205
	(0.0359)	
D3(UP)	0.1703*	4.61
	(0.0369)	
D4(WB)	0.0922*	2.58
	(0.0357)	
D5(AP)	0.2219*	5.78
	(0.0383)	
D6(RAJ)	-0.0531	-1.11
	(0.0474)	
D7(KAR)	0.0599***	1.5
	(0.0397)	
D8(KER)	0.0723***	1.94
	(0.0371)	
D9(GUJ)	0.28*	7.2
	(0.0388)	
D10(MAH)	0.1888*	5.002
	(0.0377)	
CONSTANT(HA	0.7299*	2.84
	(0.2562)	

Cement

Dummy	Estimates	T Statistics
D1(MP)	0.1181*	4·04
	(0.0292)	
D2(TND)	0.0944*	4·60
	(0.02)	
D3(AP)	-0.1233	-0·59
	(0.0207)	
D4(RAJ)	-0.0455**	-2·06
	(0.0206)	
D5(KAR)	-0.0425**	-2·008
	(0.0212)	
D6(GUJ)	0.20494*	10·05
	(0.0203)	
CONST.(BHR	0.5904*	7·94
	(0.0742)	

Iron and Steel

Dummy	Estimates	T Statistics
D1(AP)	0.1344*	-3.37
	(0.04)	
D2(BHR)	-0.0461	-1.27
	(0.0362)	
D3(GUJ)	0.1395*	3.49
	(0.0399)	
D4(HAR)	0.1902*	4.8
	(0.0395)	
D5(KAR)	0.0856**	2.3
	(0.0372)	
D6(MAH)	0.0596***	1.59
	(0.0373)	
D7(MP)	-0.1313*	-3.51
	(0.0373)	
D8(ORS)	0.0866**	2.4
	(0.0369)	
D9(RAJ)	0.0962**	2.38
	(0.0388)	
D10(TND)	0.0647***	1.69
	(0.0381)	
D11(UP)	0.0735**	1.88
	(0.0389)	
CONSTANT(W	0.7786	2.63
	(0.2957)	

Note:

1. Figures in the pare'ntheses indicate assymtotic standard error of estimates
2. * indicates estimates are significant at 1 % Level
3. ** indicates 5 % level of significance
4. *** indicates 10 % level of significance

The presence of significant dummies indicate there is considerable price variation across states which the data is unable to capture. In the process it reflects considerable regional differences in the choice of techniques of production.

Elasticity of Substitution

The estimates of elasticities of substitution between the pairs of inputs for both the models are presented in Table 5.3.

For an assessment of the significance of individual partial elasticities of substitution we assume, following Lynk (1983), that significant off diagonal B_{ij} $(i \neq j)$ indicates significant σ_{ij} $(i \neq j)$.

Capital-labour

Model I : Capital and labour emerge as substitutes for all industries but the extent of substitutability is limited except in Cement Industry. In Cement Industry we have observed very high substitution possibilities between capital and labour. However, the co-efficient estimates for all industries are, in general, statistically insignificant, although for Cotton Textile and Chemical the estimates are found to be significant only at 10 percent level.

Model II- In Model II we find limited substitution between capital and labour for all four industries. The estimates

TABLE 5.3

ESTIMATES OF ALLEN-UZAWA PARTIAL ELLASTICITY OF SUBSTITUTION (1976-83)

	COTTON TEXTILE		CHEMICAL		IRON AND STEEL		CEMENT	
	Model I	Model II	Model I	Model II	Model I	Model II	Model I	Model II
σ_{KL}	.48***	.42**	.54***	.71***	0.845	0.853	2.033	0.378
σ_{EL}	0.39*	.44*	1.434	.62***	1.025	0.719	.46***	.64***
σ_{KE}	-1.47*	0.30	.339*	2.83**	.150*	2.68**	1.36	1.63
σ_{LL}	-2.42	-2.31	-5.37	-4.03	-4.91	-4.25	-7.22	-4.77
σ_{KK}	-1.95	-3.34	-2.46	-5.58	-2.69	-5.63	-5.58	-4.82
σ_{EE}	-0.61	-3.61	-3.34	-4.99	-2.81	-4.87	-2.89	-3.21

1. Model II estimates based on estimated gross fixed capital stock at constant prices as the measure of capital input.

2. Estimates are computed at the mean of the exogeneous variable

* Indicates co-efficient estimates significantly different from zero at 1% level of significance

** Indicates significance at 5% level

*** Indicates significance at 10% level.

are statistically significant for Cotton Textile Industry at 5 percent level and for Chemical at 10 percent level.

Labour-Energy

Model I: Labour and Energy are found to be substitutes across all four industries. Estimates are statistically significant at 1 percent level for Cotton Textile and at 10 percent level for Cement. Substitution is found to be limited in Cotton Textile and Cement while in Iron and Steel and Chemical labour and energy are observed to be highly substitutable.

Model II: Labour and energy are found to be weak substitutes in all four industries. Estimates are statistically significant for Cotton Textile at 1 percent level, Iron and steel at 5 percent level and for Chemicals and Cement at 10 percent level only.

Capital-Energy

Model I: Capital and energy are found to be strongly complementary in Cotton Textile and the estimate is statistically significant at 1 percent level. But the relationship is one of substitutability in the other three industries, the estimates being statistically significant for Iron and Steel and Chemicals at 1 percent level. For Iron and Steel and Chemicals these two inputs emerge as weak substitutes while substitution is stronger in Cement though the estimate is statistically insignificant.

TABLE 5.4

ESTIMATES OF PRICE ELASTICITIIES OF DEMAND FOR INPUTS : (1976-83)

	COTTON TEXTILE		CHEMICAL		CEMENT		IRON AND STEEL	
	MODEL I	MODEL II	MODEL I	MODEL II	MODEL I	MODEL II	MDOEL I	MODEL II
E_{KL}	0.25	0.24	0.11	0.18	0.33	0.06	0.21	0.22
E_{EL}	0.20	0.25	0.28	0.15	0.08	0.11	0.25	0.18
E_{LL}	-1.25	-1.34	-1.10	-1.00	-1.18	-0.78	-1.19	-1.10
E_{KE}	-0.26	0.06	0.11	1.12	0.73	0.84	0.06	1.05
E_{LE}	0.07	0.09	0.44	0.25	0.25	0.33	0.39	0.28
E_{EE}	-0.11	-0.72	-1.08	-1.96	-1.16	-1.66	-1.06	-1.91
E_{LK}	0.15	0.09	0.26	0.26	0.61	0.12	0.32	0.30
E_{EK}	-0.45	0.07	0.16	1.02	0.41	0.52	0.06	0.94
E_{KK}	-0.59	-0.75	-1.16	-2.01	-1.66	-1.54	-1.02	-1.98

Notes :

1. Estimates are computed at the mean of the exogeneous variable

2. Model II estimates are based on estimated gross fixed capital stock at constant prices.

Model II: Capital and energy emerge as substitutes across all four industries. But the relationship is found to be weak in Cotton Textile (estimate is statistically insignificant) as compared to the other three industries where it is quite strong. Estimates are also statistically significant (at 5 percent level for all three industries).

Own price Elasticities of Demand

The estimated own price elasticities of demand are presented in Table 5.4. Own price elasticity measures the relative demand response of each input to relative changes in its own price. In both models all own price elasticities of demand have shown correct signs consistent with the cost minimization behaviour.

The estimates of own price elasticity of energy demand varies between 0.6 and 1.08 in Model I. In Chemical , Cement and Iron and Steel energy demand is sufficiently price responsive but for Cotton Textile Industry, energy demand is found to be extremely price inelastic (0.11)

The estimates have a wider range of variation in Model II varying between 0.7 and 1.91 across the four industries. Energy demand is again found to be inelastic in Cotton Textiles. But for the other three industries estimates indicate high price responsiveness.

Capital and labour are also found to be highly price responsive in both the models.

In the light of these results presented above we observe that the two models highly confirm each other in terms of the sign of the estimates and reveal, substitutability to be the dominant pattern of relationship among inputs. Results differ only in respect of Cotton Textile industry where Model II yields energy-capital substitution and Model I yields energy capital complementarity. Our results are in contrast to the assertion of Field and Grebenstein (1980) that while 'value-added' approach should yield energy-capital substitution, the 'service price' approach should yield energy-capital complementarity. Thus our results also show that energy interacts differently with working capital but the relationship as opposed to the Field and Grebenstein results is substitutable with physical capital while complementary with respect to working capital.

A possible explanation for getting different results in our value added formulation could be due to the effects of pooling. It needs to be emphasised at this point that there is no apparent economic logic why the substitutability of energy with physical capital and working capital should be of any particular type. Of course as technology changes, the relationship between the fixed and variable capital also changes and accordingly substitutability results will be affected.

On the basis of the results discussed above, we conclude that, in general, the post '73 period exhibits :

1) Substitution to be the dominant pattern of relationship among inputs in all four industries under consideration;

2) Potential for substitution is limited between capital-labour and labour - energy as confirmed by both the models ;

3) As regards capital-energy relationship no definite conclusion can be reached regarding the extent of substitutability. Iron and Steel and Chemicals exhibit strong substitution possibilities in Model II as against limited substitution in Model I. Cement industry shows high substitution possibilities in both the models. Cotton Textiles shows divergent results.

4) Energy demand is found to be highly price elastic except in Cotton textile industry. Capital and labour also exhibit high price responsiveness in all four industries.

5) In general, the structure of technology reflected in the elasticity estimates do not vary much across Iron and Steel, Chemical and Cement. But the Cotton textile industry shows a pattern which is quite distinct from the others. In Model I this is the only industry which shows energy-capital complementarity and in Model II it shows very limited substitution between capital and energy (6_{KE} :0.301) as against significantly high substitution possibilities in the other three industries. (6_{KE}: 2.83 for Chemical, 6_{KE}: 2.68 for Iron and Steel and (6_{KE} : 1.63 for Cement). Energy demand is also found to be extremely price inelastic in Cotton

Table 5.5 (a)

IZEF PARAMETER ESTIMATES OF THE KLE TRANSLOG MODEL

COTTON TEXTILE : 1968-71

	Cost share equation for labour :(SL)			Cost share equation for energy : (SE)	
DF	Estimates	T-Stat. 35	DF	Estimate	T-Stat. 35
a_L	0.677 (0.123)	5.47*	a_E	0.076 (0.165)	0.46
B_{KL}	0.142 (0.054)	2.62*	B_{KE}	0.028 (0.027)	1.03
B_{EL}	-0.032 (0.018)	-1.73**	B_{EL}	-0.032 (0.018)	-1.73**
D1 (MP)	-0.89 (0.030)	-2.95*	D1 (MP)	-0.004 (0.012)	-0.31
D2 (TND)	0.134 (0.036)	3.72*	D2 (TND)	0.047 (0.015)	3.17**
D3 (UP)	0.003 (0.029	0.128	D3 (UP)	-0.033 (0.012)	-2.69*
D4 (WB)	0.176 (0.090)	5.87*	D4 (WB)	0.025 (0.012)	2.02**
D5 (AP)	0.096 (0.030)	3.12*	D5 (AP)	0.007 (0.012)	0.60
D6 (ORS)	0.214 (0.036)	5.91*	D6 (ORS)	0.008 (0.015)	0.56
D7 (RAJ)	0.028 (0.029)	0.97	D7 (RAJ)	-0.013 (0.012)	-1.07
D8 (KAR)	0.091 (0.029)	-3.1*	D8 (KAR)	-0.014 (0.012)	-1.15
D9 (KER)	-0.041 (0.029)	-1.39***	D9 (KER)	0.039 (0.012)	3.18*
D10 (GUJ)	0.104 (0.029)	3.49*	D10 (GUJ)	0.11 (0.012)	0.95
D11 (MAH)	0.023 (0.029)	-0.81	D11 (MAH)	-0.010 (0.012)	-0.87
R^2	0.76		R^2	0.76	
S.S.E.	0.06		S.S.E.	0.06	
S.E	0.04		S.E	0.01	
DW.	2.23		DW	2.27	

1. Estimates are based on estimated gross fixed capital stock at costant prices as measure of capial input

2. Values in the parentheses indicate asymptotic standard error

* Indicates significant co-efficient estimate at 1 % level of significance

** Indicates significance at 5% level

*** Indicates significance at 10% level

textile industry while in the other three industries it exhibits high price responsiveness.

Our findings of limited substitutability and price inelasticity in Cotton textile industry seem to be quite interesting in view of the fact that this is one of the oldest industries of the country with enormous variations in the type of techniques /technology being used in various states of the economy. It therefore deserved a more elaborate and careful study. We have therefore chosen to study the textile industry for the pre '73 period using the same estimating models. We then provide a comparison of the results for the two period for examining if at all there has been any directional change in the nature of input substitution in textile industry.

Cotton Textile Industry : 1968-71

We have estimated elasticities for the period (1968-71) for Cotton Textile Industry following our Model II approach (taking into account only physical capital, estimated at constant prices). Table [5.5(a)] presents the co-efficient estimates and Table [5.6] and [5.7] presents the estimate of AES and price elasticities of factor demand respectively.

The model has been checked for 'well behavedness' and monotonicity and concavity conditions have been found to be satisfied. Presence of negative own price elasticities of demand for factors is again an indication that concavity condition may have been satisfied.

Table 5.6

ESTIMATES OF PARTIAL ELASTICITES OF SUBSTITUTION COTTON TEXTILE : (1968) and (1976-83)

	Model I (1) 1968-71	Model II (2) 1968-71	1976-83
σ_{KL}	1.898*	0.575*	0.419**
σ_{EL}	0.606**	1.320	0.438
σ_{KE}	1.801	6.045	0.301
σ_{LL}	-2.964	-2.174	-2.313
σ_{KK}	-7.284	-5.165	-3.346
σ_{EE}	-8.198	-14.256	-3.611

1. Estimates are computed at the mean of the exagenous variable.
2. Model I estimates for 1968-71 are based on estimated gross fixed capital stock at constant prices as measure of capital input
3. Model II estimates for 1968-71 are based on the assumption that price of capital is unity
4. Estimates for 1976-83 are based on estimated grass fixed capital stock as measure of captial input.

* Indicates β_{ij} parameter is significant at 1% level of significance.

**i ndicates significance at 5% level.

Principal results are summarized below :

All factors are found to be substitutes again. Capital-labour emerge as strong substitutes (co-efficient statistically significant at 5 percent level). Energy is found to be slightly substitutable with labour (co-efficient estimate is statistically significant at 5 percent level) and strong substitute with respect to capital (co-efficient estimate statistically insignificant).

The estimates of own price elasticities of demand for all the three factors are much higher than their corresponding estimates for the post '73 period. Specially labour and capital are found to be highly price responsive in this period.

Comparing these results with the results for the post '73 period (1976-83), we find that the oil price shock of 1973 has not affected the basic relationship among energy and non-energy inputs in the textile industry. The sign of the estimates of elasticity of substitution remaining unaltered in the two sample periods. The only change has been in terms of magnitude. Substitutability has definitely declined for capital with respect to both labour and energy and inputs demand have become more price inelastic during the post '73 period. The magnitude of the changes becomes apparent from the elasticity estimates presented in Tables [5.6] and [5.7].

We now turn to a hypothesis testing for structural shifts in Cotton Textile Industry to verify whether or not

Table 5.7

ESTIMATES OF PRICE ELASTICITIES OF DEMAND IN COTTON TEXTILE : (1968-71 and 1976-83)

	(1) 1968-71 Model I	(2) 1976-83)	(3) 1968-71 Model II	(4) 1968-71 Apte's model
E_{KL}	1.14	0.24	-0.33	-0.41
E_{EL}	0.37	0.25	0.76	0.62
E_{LL}	-1.78	-1.34	-1.26	-0.013
E_{KE}	0.24	0.06	1.09	-1.79
E_{LE}	0.08	0.09	0.24	0.17
E_{EE}	-1.11	-0.72	-2.58	1.594
E_{LK}	0.50	0.09	-0.14	-0.220
E_{EK}	0.47	0.07	1.46	-3.43
E_{KK}	-1.91	-0.75	-1.24	2.16

1. Estimates are computed at the mean of the exogeneous variable

2. Model I estimates in Co.1 estimates are based on estimated gross fixed capital stock at constant prices as the meausre of capital input.

3. Model II estimates in col.3 estimates are based on the assumption price of capital is unity.

4. Column 2. estimates for 1976-83 are based on estiamted gross fixed capital stock as measure of capital input

5. Col. 4 results are for P.C. Apte's model.

the parameters of the cost share equations have shifted over time. This was carried out by using the 'F' test within the IZFF framework[6].

The 'F' values for the energy and labour equation derived from this test are respectively 2.80 and 8.32 and these are statistically significant at 1 percent level at the relevant degrees of freedom. Thus we reject the hypothesis that the parameters of the cost share equations have been stable in the two sample periods and hence we conclude in favour of structural shifts in the cotton textile industry.

This substantiates our findings that the magnitude of the elasticity estimates have declined over the sample periods. This provides another interesting scope for further study of the textile industry as regards its failure to respond positively to energy price hike as one would expect that the structural shift should have been in the direction of substituting other inputs for energy. Perhaps we need to provides some economic explanation for such shift in perverse direction. A possible explanation for such perverse technological change could be existence of distorted input price structure. However, before we draw any strong conclusion of this kind we must look into this problem more carefully.

Another interesting observation that follows from our findings is that our results for the period 1968-71 do not support the results obtained by P.C. Apte (1983) for Cotton

TABLE 5.5(b)

IZEF PARAMETER ESTIMATE OF THE KLE TRANSLOG MODEL COTTON TEXTILE IN (1968-71)

(ON THE ASSUMPTION OF PRICE OF CAPITAL TO BE UNITY)

	Estimate	T (statistic) (DF-35)		Estimate	T statistics (DF-35)
α_L	0.8377	3.51*	α_E	1.81	1.23
	(0.5537)			(1.46)	
β_{KL}	-0.2192	-3.54*	β_{KE}	0.22001	0.8687
	(0.0618)			(0.25325)	
β_{EL}	0.0335	0.4710	β_{EL}	0.0335	0.4710
	(0.0756)			(0.0756	
D_1	0.32687	4.32*	D_1	0.35543	-5.79*
	(0752)			(0.61298)	
D_2	0.1768	2.28**	D_2	-0.3973	-6.15*
	(0.0772)			(0.0646	
D_3	0.2658	3.61*	D_3	-0.4295	-7.22*
	(0.0735)			(0.0594	
D_4	0.3864	5.36*	D_4	-0.38209	-6.4119*
	(0.0720)			(0.0595)	
D_5	0.2432	3.27*	D_5	-0.42393	-6.89*
	(0.0742)			(0.06150)	
D_6	0.1964	2.63*	D_6	-0.43544	-7.0143*
	(0.0744)			(0.06207)	
D_7	0.2922	4.04*	D_7	-0.41948	-7.15*
	(0.0722)			(0.0586)	
D_8	0.1969	2.72*	D_8	-0.3994	
	(0.0723)			(0.0585)	-6.82*
D_9	0.2369	3.27*	D_9	-0.39486	
	(0.0723)			(0.0585)	-6.74*
D10	0.3494	3.27*	D10	-0.38219	
	(0.0723)			(0.0585)	-6.52*
D_{11}	0.1958	2.66*	D_{11}	-0.17409	
	(0.0753)			(0.05949)	-2.92*
R^2	0.5759		R^2	0.7525	
S.S.E	0.2978		S.S.E	0.19530	
S.E.	0.0935		S.E.	0.0757	
D.W.	1.60		D.W.	1.47	

1) estimate are based on the assumption that price of capital = 1.

2) figures in parenthesis indicated asymptotic standard error

*) indicates estimates were significantly different from zero at 1% level of significance

**) indicates significant at 5% level.

Textile Industry for the same period. This is striking because both the models have been estimated using a pooled data base. In contrast to energy capital substitutability in our model Apte reports energy and capital complementarity. In order to search for an explanation as to this discrepancy in results we tried to bring our model as close to Apte's model by assuming price of capital to be unity and obtaining cost share of capital as residual[7]. But the results were markedly different from Apte's result again. [Refer to Table 5.5 (b), 5.6 and 5.7].

Labour-energy are found to be substitutes in this model too. But unlike in the earlier model, capital and labour are found to be complementary which corresponds to Apte's results and the parameter estimate is also statistically significant. Capital and energy are found to be strong substitutes again, (in fact, estimate of AES is much higher than the earlier estimate) but the coefficient is statistically insignificant. What explains this divergence is an interesting issue and needs further empirical investigation. The difference may stem from different ways of constructing variables even though we have tried to be as close as possible with Apte's way of measuring inputs. With respect to the measure of capital input to which empirical results are found to be most sensitive, our measure of capital is exactly identical with Apte's. We, however, believe that the major factor for different results should be the exclusion of materials as a fourth input in our model. One can investigate into this issue by extending our model to include material as another input in the production process. This is a possible line of extension of our study.

A Comparison with the findings of the existing studies for Indian Manufacturing

To begin with, our study is methodologically our Model II is close to Goldar and Mukhopadhaya (GM)'s study. While GM uses time series industry data in case study, we have used pooled data in our study. As GM's study is based on the book value of capital we therefore compare the results of our Model II with the GM results. We have three comparable industries with GM's study e.g. and Cotton Textile, Cement and Iron and Steel.

For Cotton Textile and Cement industries GM study also finds capital-energy to be substitutable confirming our post '73 results, but their estimates are statistically insignificant. On the other hand for Iron and Steel industry our results are at variance with GM results of capital-energy complementarity. We find in our study capital-energy substitution. As regards Capital and labour for cotton textile industry GM study shows complementarity between these two inputs (significant co-efficient estimates) against our finding of substitutability. But for the other two industries both studies confirm substitutability between capital and labour. Labour and energy are found to be substitutes across all three industries we are getting similar results as GM by confining ourselves to the post '73 period.

Comparing our results for cotton textile industry for the pre '73 period with the existing studies relating to this period we find our results of input substitution are confirmed by both Lynk (1983) and Williams and Laumas (1981). Our results are at variance with Apte's results, as has been mentioned before. As results on price elasticity of energy input our result of high price responsiveness of energy is confirmed by both Williams and Laumas and P.C. Apte.

For Cement, Iron and Steel and Chemical we have not estimated the models for the pre '73 period. Therefore we attempt to provide a comparison of results with the existing studies for the pre '73 period. But we cannot draw any conclusion on the basis of such comparison because of different model specifications. For Chemical industry we only have Williams and Laumas study for comparison they find weak substitution between capital and energy in the product group 31 (Chemicals) compared to our results of high substitutability for the post '73 period. Capital labour and labour energy are also found to be substitutes confirming our results.

In cement and Iron and Steel, Lynk finds capital energy complementarity as oppose to our post '73 result of capital energy substitution. Labour-energy also exhibit complementarity in Lynk against substitutability in our study. Capital-labour are found to be substitutes in both the studies in compliance with our results.

P.C. Apte also finds capital-energy and capital-labour complementarity for Cement industry as oppose to our results of substitutability. Labour and energy found to be substitutes confirming our results.

Comparison with International Studies

Comparing our results with the results obtained from the other studies on input substitution for countries, we observe that most of these studies find capital-labour and labour energy to be substitutes in conformity with our results.

As for capital and energy, there exists a divergent set of results. Our results are in compliance with the results of Griffin and Gregory (1976) and Pindyck (1978) indicating capital-energy substitution. It should be mentioned that methodologically our model is similar to theirs' in the assumption of separability of materials and in the use of pooled data.

Our results are at variance with those of Berndt & Wood (1975), Hudson Jorgenson (1974), Fuss (1977) and Magnus (1979) all of whom report energy-capital complementarity.

Of the more recent studies, Gorfalo and Malhotra (1984) and Alamada. J and A. Mann (1985) have carried out almost similar exercise as ours by estimating substitution elasticities among energy and non-energy inputs for the pre and post oil shock era separately.

Methodologically, our model is similar to Gorfalo and Malhotra's three input translog (KLE) model which is based on pooled time series cross section data, pooled across different regions of the US economy, and makes separability assumption, but our results are at variance with their post '73 results because they find capital-energy complementarity in the post oil shock era as opposed to capital-energy substitution in our model.

Alemada. J. and A. Mann have estimated two three input (KLE) time series models for the period 1959-72 and 1973-82 for Puerto Rico and obtained results similar to ours for the post '73 era. Capital-energy are found to substitutes in their post'73 model.

One possible explanation for this variation in result could be that the Indian economy like Puerto Rico, is a small open developing region heavily dependent on imported oil.

Since our model is based on pooled data we can conclude, following Griffin and Gregory (1976) and Pindyck (1978) that we have actually estimated long run estimates of elasticity for the industries covered in our study. Perhaps this also explains the high estimates of own price elasticities of factor demand indicating increasing price responsiveness of energy demand in the long run and greater effectiveness of energy pricing as a policy parameter.

The short run estimates should be much lower indicating relatively inelastic demand and limited adjustment possibilities through' the use of price mechanism.

Our results regarding substitution elasticities among energy and non energy inputs thus indicate that in the long run future economic growth may not be constrained by high priced energy and may be facilitated by affecting price induced substitution.

CHAPTER VI

CONCLUSION

The purpose of this study was to determine the extent of energy substitution possibilities in the Indian Manufacturing Sector for the period following the oil shock of '73. We believe that the post '73 period being marked by very steep hike in energy prices should be treated separately for studying the effects of price rise on energy substitution. We have estimated the elasticities of substitution among the three inputs of energy, labour and capital for the period (1976-83) using data pooled across states.

The translog cost function has been employed to estimate the model. We have actually estimated two models using alternative definitions of capital cost in order to examine the extent to which empirical results relating to capital-energy substitution are sensitive to the way capital cost is being defined (Field and Grebenstein : 1980). Our Model I adopts the 'value added' approach and Model II uses the 'service price' approach to measure capital cost.

We have also estimated the model for the period (1968-71) for cotton textile industry to determine the direction of change in the nature of input substitution between the pre-oil and post-oil shock periods.

To strengthen the validity of our findings we have formally tested for the hypotheses of structural shifts over the two sample periods, preceding and following the '73.

MAJOR FINDINGS

We summarize our principal findings as follows:-

1) 'Substitution' emerges as the dominant pattern of relationship among inputs in the post '73 period in all four industries studied.
2) Substitution possibilities between capital-labour and labour energy are found to be very limited across all four industries.
3) As regards capital-energy relationship the extent of substitutability varies across industries. Iron and Steel and Chemicals exhibit strong substitution possibilities in one model as against limited substitution in the other. Cement industry shows high substitution possibilities in both the models. Cotton Textiles shows divergent results.
4) Input demand is generally found to be highly price responsive except in Cotton Textile industry.
5) Cotton Textile industry shows a pattern of input substitution quite distinct from the other three industries.
6) Our data do not support the belief that empirical results are sensitive to the way the capital cost is being defined.

7) The pre '73 results for Cotton textiles industry show that the oil price shock of the '73 has affected, if at all, only the strength of the substitution relationship among inputs. Surprisingly, our results show that substitutability has declined in the post oil shock period and energy demand has become more price inelastic.

We also find evidence of structural shift over time when we treat pre-73 and post-73 period samples separately. This justifies our presumption that the post '73' period should be considered as a separate sample for Cotton textile industry.

POLICY IMPLICATIONS

Our findings for the post '73 period has certain implications for energy policy. The results indicate that higher energy prices may not be a constraint to future economic growth, since energy is bound to be substitutable with other non-energy inputs in the production process.

In India the thrust for energy planning has mostly been on interfuel substitution, especially of oil by electricity and coal, oil shock being the cry of the day. But our findings show that there is substantial scope for energy saving in the manufacturing sector through substition of energy input. Multi sector energy planning should consider this aspect of energy conservation.

Besides, the high price sensitivenss of energy demand indicates that energy pricing can be an effective policy instrument. This also points out that the energy demand studies based on fixed energy-GNP ratio approach may be misleading.

In general we can suggest the following guidelines for future policy :

Judicious pricing policy for optimal input choice is necessary not only with respect to energy price but also with respect to the prices of other inputs. The rise in energy price will definitely bring about a fall in the relative prices of the other inputs but such a 'fall' in relative price has to be sufficient in the relevant range of technical choice to bring about price induced substitution of other non-energy inputs for energy. Since extent of substitutability varies across industries resource allocation should be shifted towards industries showing higher energy substition possibilities.

Since energy intensity also varies across industries resources should be allocated in favour of relatively less energy intensive industry.

The development implications of some of our findings on input substitution possibilities is not very clear. For example it can be argued that substantial energy saving can be achieved in a relatively labour intensive industry by substituting labour for energy if labour-energy substitutability is found to be high. The fact that we find very limited substitution of labour for energy in a relatively more labour intensive industry like cotton textiles makes it difficult to prescribe any clear cut policy measure on the basis of such evidences on factor substitutability.

LIMITATIONS OF THE STUDY

Our study has certain major shortcomings which we discuss as follows :

(1) Our assumption of weak seperability of materials may not be valid; Williams and Laumas (1981) find that for the two digit manufacturing industries in India the weak seperatbility of production technology is rejected. Following him we should have conducted a test for separability

2) Due to the non-availability of state-wise price data we have used All India Whole Sale price indices in constructing the price indices of fuel and capital goods. AS a result regional variations are lacking to some extent. We accept this as a limitation of our study.

3) Our 'service price' measure of capital cost is also subject to criticism. Our method of estimation of

capital stock has the following limitations : (i) We assume an uniform 2 percent rate of discarding of all industries due to lack of any information on industrywise discarding. (ii) The capital stock is arbitrarily multiplied by a factor two to get the gross capital stock and constant prices for the bench mark year, 1976. (iii) In construction of capital goods price index we have not taken care of the regional variation in the prices of investment goods.

4) The value added definition of capital cost also has its limitations. For a consisting study with time series data on value added we should have estimated value added at constant prices not just by deflating the value added figure by output price alone but by first deflating materials, fuels etc. by their respective prices to arrive at the true estimate of value added. This is known as the double deflation method. This way of measuring value added might have given us different estimates of cost shares and consequently different elasticity estimates.

In the light of the above limitations of our study we may provide certain suggestions for future research.

i) Extension of our model by including material as an input in the production process and conducting the test of separability.

ii)(a) Use of actual state-wise data on prices of fuel and investment goods items taking into consideration the differences in regional tax structure is desirable.

(b) Another possible line of research is to compute an appropriate rate of discarding for each industry and reestimate capital stock in order to get more reliable estimates of cost shares based on this measure of capital input.

(c) It is also desirable to find out to what extent the results get affected if we take consideration the effect of time element and deflate our value added measure by using the 'double deflation method' explained above.

The above modifications may result in entirely different estimates of cost shares in the two models and may even change our conclusion regarding the sensitivity of empirical results to 'service price' and 'value added' definitions of capital cost. Hence the need for further research with more reliable data is felt to be necessary.

iii) Like our analysis of textile industry, it is possible to extend similar studies for other industries to see if we arrive at similar conclusions of structural shifts between pre '73 and post '73 periods.

NOTES :

1. Homothecity assumption implies that in a production function exhibiting neutral technical change the factor ratio is independent of the level of output and of the neutral type of technical progress. It simply depends on the marginal rate of substitution or relative factor prices.

2. Recently Burgess (1975) and Applebaum (1978) have assessed the sensitivity of the empirical results regarding a choice between the TLog production and cost function and arrived at significantly different inferences. Thus empirical results are found to be sensitive to the choice between the cost and production function and this is due to the fact that the translog form is not 'self-dual'.

3. The regional dummies can be looked at in two alternative ways which are computationally equivalent. One is to assume that the co-efficient of linear terms of the cost function vary across regions or we can assume that the regional differences are stochastic so that the error terms are composed of region specific component and an overall component. The covariance estimation procedure in its dummy variable form has an identical formulation.

4. Otherwise, the variables would exhibit perfect multicollinearity. This is refered to as 'Dummy variable trap'.

5. The book value results are being reported in the Appendix. For the purpose of further analysis we have used the results based on estimated value of capital stock at constant prices. We obtain almost identical estimates of cost shares from our book value measure of capital and the measure of capital stock estimated at constant prices. The reason perhaps is the assumption of too low rate of discarding in estimating capital stock.

In assuming d = .02 in our estimate of 'service price' of capital computed as $P_k = (r + d)\ q_k$. Th rate of depreciation (d) obtained from the reported figures in ASI is much higher for all four industries. This has overestimated the cost of capital computed on the basis of book value. That is why, even though our measure of capital input has more than doubled after estimating it at constant prices the estimated cost shares based on the two measures are not much divergent.

6. This test, popularly known as Chow test, is defined as follows:

$$F = \frac{RRSS - URSS / (K + 1)}{(K + 1,\ n_1 + N_2 - 2k - 2)\ URSS/(n_1 + n_2 - 2k - 2)}$$

Where RRSS denotes the restricted residual sum of squares for the entire sample period pooled together and URSS the unrestricted residual sum of squares computed as the sum of squared residuals obtained frame the sub samples by estimating the equations separately for each period. Each of the residual sum of squares obtained from the sub samples has degrees of freedom (n_1 - k - 1) and (n_2 - k - 1) where n_1 and n_2 denotes the number of observations in the two sub samples of k denotes the number of variables.

The restricted residual sum of squares obtained from pooled data has degrees of freedom (n_1 + n_2 - k - 1). In our case, we did not have a continuous time series, our pre'73 period being extended till 1971. We have a period break between 1971 and 1976 primarily because of non availability of data for these years. In this interval, ASI data was available only for 1973. But to perform a chow test what is needed is a continuous time series which can be divided in to two sub samples without any period break.
Therefore, we have attempted to bridge the gap by computing the cost shares for the intervening years as moving averages of the earlier available shares.

7. Apte assumes price of capital to be unity.

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APPENDIX I

ESTIMATES OF COST SHARES IN MODEL I AND MODEL II : 1976-83

	Cotton Textile			Chemical			Iron & steel			Cement		
	Mod.I	Mod.II	Mod.II*	Mod.I	Mod.II	Mod.II*	Mod.I	Mod.II	Mod.II*	Mod.I	Mod.II	Mod.II*
S_K	0.30	0.22	0.18	0.47	0.36	0.31	0.37	0.35	0.27	0.29	0.31	0.19
S_L	0.51	0.57	0.60	0.20	0.24	0.26	0.24	0.25	0.28	0.16	0.16	0.19
S_E	0.17	0.19	0.20	0.32	0.39	0.42	0.37	0.39	0.43	0.53	0.51	0.60

1 The estimated cost shares are reported at their mean value

2. Model II* indicate estimates are based on book value of capital as a measure of capital input

Source : ASI, Census Sector.

APPENDIX II

IZEF PARAMETER ESTIMATES OF THE KLE TRANSLOG MODEL : MODEL II
(1976-83)

	Cotton Textile		Chemical		Cement		Iron & steel	
	Estimates	T-Stat.	Estimates	T-Stat.	Estimate	T-Stat.	Estimate	T-Stat
DF		83		65		41		71
a_L	1.43*	8.08	0.51*	7.49	0.32*	2.06	0.48*	8.97
	(0.17)		(0.06)		(0.15)		(0.05)	
B_{KL}	-0.04**	-2.18	-0.02***	1.73	0.02	0.79	0.004	0.38
	(0.02)		(0.01)		(0.03)		(0.01)	
B_{EL}	-0.07*	-4.17	-0.02***	-1.62	-0.06*	-3.06	-0.04*	-2.87
	(0.01)		(0.01)		(0.02)		(0.01)	
a_E	0.42*	-3.02	0.08	0.91	0.008	-0.05	0.28*	2.58
	(0.014		(0.09)		(0.15)		(0.11)	
B_{KE}	-0.03**	-2.00	-0.02	0.83	0.15*	3.46	-0.001	-0.25
	(0.01)		(0.02)		(0.04)		(0.03)	
R^2(SL)	0.67		0.93		0.88		0.60	
R^2(SE)	0.72		0.85		0.80		0.59	
S.S.E. (SL)	0.11		0.10		0.01		0.28	
S.S.E. (SE)	0.04		0.22		0.07		0.44	
S.E (SL)	0.03		0.03		0.02		0.06	
S.E (SE)	0.02		0.05		0.04		0.07	
LLF	451.98		262.03		215.15		234.12	

1. Estimates are based on 'book value' of capital as measure of capial input

2. Values in the parentheses indicate asymptotic standard error

* Indicates significance of co-efficient estimate at 1 % level

** Indicates significance at 5% level

*** Indicates significance at 10% level

APPENDIX III

ESTIMATES OF ALLEN-UZAWA PARTIAL ELASTICITY OF SUBSTITUTION (1976-83) : MODEL II[1]

	Cotton Textile	Chemicals	Iron and Steel	Cement
σ_{KL}	0.597**	1.35	1.05	1.67
σ_{EL}	0.390*	0.73***	0.675*	0.464*
σ_{KE}	0.026**	1.18***	0.919	2.25*
σ_{LL}	-2.322	-4.83	-4.04	-5.13
σ_{KK}	-3.95	-4.73	-4.52	-10.63
σ_{EE}	-3.14	-3.32	-1.32	-2.87

1. Model II estimates based on book value of capital as the measrue of capital input.

2. Estimates are computed at the mean of the exogeneous variable

* Indicates co-efficient estimates significantly different from zero at 1% level of significance

** Indicates significance at 5% level

*** Indicates significance at 10% level.

APPENDIX IV

Estimates of Price Estimates of Demand : Model II [2]

	COTTON TEXTILE	CHEMICAL	IRON & STEEL	CEMENT
E_{KL}	0.36	0.35	0.33	0.30
E_{EL}	0.24	0.19	0.9	0.19
E_{LL}	-1.40	-1.26	-1.00	-1.16
E_{KE}	0.01	0.50	1.37	0.40
E_{LE}	0.08	0.31	0.28	0.29
E_{EE}	-0.66	-1.41	-1.75	-1.32
E_{LK}	0.11	0.43	0.33	0.30
E_{EK}	0.0004	0.37	0.44	0.26
E_{KK}	-0.74	-1.49	-2.09	-1.26

1. Estimates are computed at mean of the exageneous variable.
2. Estimates based an book value of capital.

Appendix A

International Studies on Energy Substitution : A Brief Survey

	Country	Period	Nature of Data	Level of Aggregation	No. of Inputs	Functional form	Method of Estimation	Results	
								Capital & Energy	Labour & Energy
1.Berndt and Wood (1975)	USA	1947-71	Time Series	Aggregate Manufacturing Sector	Four K,L,E,M	Translog	Iterative three stage least square	Complementarity	Substitutes
2.Hudson and Jorgenson(1974)	USA	1947-71	Time Series	Aggregate Manufacturing Sector	K,L, 5 types of E,81 types of material inputs Aggregate (KLEM) model for nine industrial sectors in short. Two other submodels -energy and material	Translog	Malnivaud's minimum distance estimator	Complementarity	Substitutes
3. Griffin and Gregory (1976)	Nine OECD Countries	1955,1966 1965,1969	Pooled Time Series Cross Section	Aggregate Manufacturing Sector	Three K,L,E seperately assumed	Translog	Iterative (IZEF)	Substitutes	Substitutes
4. Griffin (1977)	Twenty OECD Countries	1955,1966 1965,1969	Pooled Time Series	Electricity	Five K,L and three E coal, gas and oil	Translog	IZEF	Substitutes	Substitutes
5. Robert S. Pindyck (1978)	Ten Industrialised Countries	1959-73	Pooled Time Series	Manufacturing Sector	Six K,L and four types of E inputs	Translog	IZEF	Substitutes	Substitutes
6. Fuss (1977)	Canada	1961-71	Pooled Time Series Cross Section (five regions of Canada)	Aggregate Manufacturing Sector	Nine K,L,M and six types E	Translog	Malnivaud's minimum distance estimator	Complementarity	Substitutes
7. Magnus	Netherland	1950-76	Time Series	Aggregate Manufacturing Sector	Three K,L and E (assuming seperability of M)	Extended Generalised Cobb-Douglas and Translog	Method of Maximum Maximum Likelihood	Complementarity	Substitutes

contd....

Appendix A

International Studies on Energy Substitution : A Brief Survey

	Country	Period	Nature of Data	Level of Aggregation	No. of Inputs	Functional form	Method of Estimation	Results: Capital & Energy	Results: Labour & Energy
8. Field and Grebenstein Grebenstein(1980)	USA	1971	Cross Section State Level	Ten Two Digit Manufacturing Industries	Four L,E, working K and Physical K	Translog	IZEF		
9. A.L Waltar (1981)	USA (Middle Atlantic Region)	1950-73	Time Series	Two Digit Manufacturing Industries	Five K,L,M and two types of energy (electric and fasil)	Translog	IZEF	Comple. bet. physical capital and energy but subs. bet. working cap. and energy	Substitutes
10. Alamada Arther A and Mann	Puerto Rico	1956-72 and 1973-82	Time Series	Aggregate Manufacturing Sector	Three K,L and E	Translog	IZEF	Comple. in 73 era subs. in post 73 era	Substitutes
11. B.C. Field and Harper Caroline (1983)	USA	1971-73	Pooled Time Series and Cross Section (across States divided into three Regions)	Two Digit Manufacturing Industries	Four K,L,E and M	Translog	IZEF	inconclusive elas. estimates are distributed on both sides of zero and are very small	Substitutes
12. Gerfalo and Malhotra Malhotra(1984)	USA	1963-66 and 1974-77	Pooled Time Series and Cross Section (nine census Regions)	Manufacturing Sector	Three K,L and E	Translog	IZEF	For the post oil shock period (1974-77) K & E are comple. but for 1963-66 KE substitutes	Substitutes

Note: IZEF stands for Iterative Zellner Efficient Method of Estimation

Appendix B

Studies on Energy Substitution in Indian Manufacturing Sector: A Survey

	Nature of Data	Period	Industry Definition	No. of Inputs	Functional form and Method of Estimation	Specification of Functional form	Results
1. Edward Lynk (1984)	Time Series	1952-71 (CMI,ASI)	14 Industries 4 Digit	Four K,L,E,M	Generalised Lientief (GLS)	Non-Homothetic	K E substitution/LE Substitution
2. P.C. Apte (1983)	Pooled T. Series (States: Units of Cross Section)	1968-71 (ASI)	5 Industries 3 Digit	Four K,L,E,M Sub-Model: Three Fuels Solid, Liquid and Elec.	Translog (IZEF) Iterative Zelluer Estimation	Non-Homothetic	K E by and large Complementary LE Substitutes
3. William & Lauwas (1983)	Cross Section	1968	8 Industries 2 Digit	Four K,L,E,M	Translog(IZEF)	Homthetic	KE fairly good substitutes LE complementarity for some of the inds.
4. Vashit D.C. (1984)	Time Series	1960-71	Total Mfg.	Three K,L,E Separability with respect to M Sub Model:Inter Fuel [Coal,Oil,Elec.]	Translog(IZEF)	Homthetic	KE tends to be complementary in the short run (Estimates insignificant) LE substitutes
5. V. Goldar and Mukhopadhyay(1991) (1991)	Time Series	1951-82 (CMI,ASI)	5 Industries 3 Digit	Three K,L,E Separability with respect to M	Translog(IZEF) Cost Price approach	Homthetic	:KE subs. for Cotton text.,Chem.,Cement & Paper, Comple. in Iron & Steel LE subs. in all five industries (but most of the results are insig.) cost price results: LE substitution: KE no consistant pattern foun
6. Murty, Paul and Jha (1990)	Time Series	1960-83	5 Industries 3 Digit	(K,L,EM) E M taken Jointly	Translog(IZEF)	Non-Homothetic Incorporating bised tec.ch.	K& FM :complementarity in cotton text.,iron & steel subs. in gas & elec. and cement. L & EM are subs. in all 4
7. Murty(1986)	Time Series	1960-77 (ASI,Fac.Sec.)	All Mfg.	Four K,L,E,M K,L,E,M Sub Model:Inter Fuel [Coal,Oil,Elec.]	Translog(IZSLS)	Non-Homothetic	KE subs. LE complementary

Note: IZEF stands for Iterative Zellner Efficient Method of Estimation

Appendix B

Studies on Energy Substitution in Indian Manufacturing Sector: A Survey

	Nature of Data	Period	Industry Definition	No. of Inputs	Functional form and Method of Estimation	Specification of Functional form	Results
1. Edward Lynk (1984)	Time Series	1952-71 (CMI,ASI)	14 Industries 4 Digit	Four K,L,E,M	Generalised Lientief (GLS)	Non-Homothetic	K E substitution/LE Substitution
2. P.C. Apte (1983)	Pooled T. Series (States: Units of Cross Section)	1968-71 (ASI)	5 Industries 3 Digit	Four K,L,E,M Sub-Model: Three Fuels Solid, Liquid and Elec.	Translog (IZEF) Iterative Zelluer Estimation	Non-Homothetic	K E by and large Complementary LE Substitutes
3. William & Lauwas (1983)	Cross Section	1968	8 Industries 2 Digit	Four K,L,E,M	Translog(IZEF)	Homthetic	KE fairly good substitutes LE complementarity for some of the inds.
4. Vashit D.C. (1984)	Time Series	1960-71	Total Mfg.	Three K,L,E Separability with respect to M Sub Model:Inter Fuel [Coal,Oil,Elec.]	Translog(IZEF)	Homthetic	KE tends to be complementary in the short run (Estimates insignificant) LE substitutes
5. V. Goldar and Mukhopadhyay(1991) (1991)	Time Series	1951-82 (CMI,ASI)	5 Industries 3 Digit	Three K,L,E Separability with respect to M	Translog(IZEF) Cost Price approach	Homthetic	:KE subs. for Cotton text.,Chem.,Cement & Paper, Comple. in Iron & Steel LE subs. in all five industries (but most of the results are insig.) cost price results:LE substitution:KE no consistant pattern found
6. Murty, Paul and Jha (1990)	Time Series	1960-83	5 Industries 3 Digit	(K,L,EM) E M taken Jointly	Translog(IZEF)	Non-Homothetic Incorporating bised tec.ch.	K& FM :complementarity in cotton text.,iron & steel subs. in gas & elec. and cement. L & EM are subs. in all 4
7. Murty(1986)	Time Series	1960-77 (ASI,Fac.Sec.)	All Mfg.	Four K,L,E,M K,L,E,M Sub Model:Inter Fuel [Coal,Oil,Elec.]	Translog(IZSLS)	Non-Homothetic	KE subs. LE complementary

Note: IZEF stands for Iterative Zellner Efficient Method of Estimation

Appendix C

Notes on ASI data

Principal source of Industrial Statistics in India. The ASI is being regularly conducted under Collection of Statistics Act 1953, the results are published in two stages. The ASI replaced both the CMI and SSMI which were conducted previously.

(A) Provisional Summary Results furnishing information on important characteristic in two volumes. (B) Detailed Final Results are produced in two volumes. Volumes II to V contains industry tables giving statewise information on capital, employment, emoluments, itemwise consumption of raw materials , fuels etc. and itemwise production - Vol-I gives certain summary information taking all industries into consideration.

Coverage of ASI extends to the entire factory sector comprising of all industrial units (called factories) registered under the Factories act, (1948), wherein a factory is defined as "any premise.

(1) Where in 10 or more workers are working with the aid of power.

(2) 20 or more workers are working without the aid of power.

Referring Period : The data related to the respective accounting years of the factories closing accounts an any day clearing April 1 to March 31.

This concept of accounting year was introduced since ASI '66. Upto '65 Calander year was used.

Census and Non-Census Sector : The ASI is carried out of two different level units employing 50 or more workers and operating with power and those employing 120 or more workers and operating without power from the first level are covered on complete enumeration basis under Census Sector.

Factories categorized as non-census sector are surveyed on the basis of 50% sample in order to cover the entire non-census sector.

More than 1/5th of the registered factories falling under ASI belong to the Census Sector.