ENERGY MANAGEMENT IN THE INDIAN MANUFACTURING SECTOR: 1970 - 1990

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I hereby affirm that the reseach for this dissertation titled, ***"Energy Management in the Indian Manufacturing Sector: 1970-1990"***, being submitted to the Jawaharlal Nehru University for the award of the Degree of Master of Philosophy was carried out entirely by me at the Centre for Development Studies, Thiruvananthapuram.

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Certified that this dissertation is the bonafide work of Supriya Satyanarayana, and has not been considered for the award of any other degree by any other University.

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Chapter 1

INTRODUCTION

Economics of energy management received due attention only in the last quarter of the twentieth century. The special place of energy as an input in the production process had to be acknowledged due to its three peculiar characteristics: first is its pervasiveness, which makes it critical to all economic activity; second is its inability to be recycled; and, third is its low elasticity of substitution vis-a-vis the other factors of production.

Energy management gained further significance after the oil embargo of 1973 imposed by the 'Organization of Petroleum Exporting Countries'. This, accompanied by the rising scarcity of other fuels with corresponding increase in their prices, led to a 'general energy crisis'. The shocks of 1973 and 1979 exerted a major de-stabilising pressure on oil importing countries of the world. It brought into sharp focus the immediate dependence of economic activity on energy supplies and reinforced the anxieties regarding the long term prospects of energy availability raised by the Meadow's Report (1972). The possibility that shortage of energy may become the limiting factor in economic growth came to be widely recognised.

One of the vital issues for the net energy importing countries like India was, whether or not these economies would be able to sustain the momentum of growth in the face of galloping energy prices. The crisis infact had implications far beyond the commercial sectors of these economies as it entailed a massive transfer of precious foreign exchange reserves to oil exporting nations. Moreover while the developmental objectives will increase their dependence on commercial energy, these nations will never have access to cheap and infinite fuel supplies. The post 1973 era has accordingly witnessed a growing awareness that energy sources are finite, and an exponential growth in energy consumption has come to an end.

Thus, due to the developments of the last few decades in the global energy scenario, energy management has become imperative for developing economies. The urgency of the issues related to energy can be understood when one considers the complete energy situation of these nations. Different facets of this include, the rising demand for commercial forms of energy like coal and oil, the relative supply status of these fuels, the continuing rise of energy bill, and efficient energy management measures taken to tackle the crisis in these nations.

Bearing this in mind, the energy scenario in India shall be critically examined. This will provide the background for the need of energy management in the Indian context.

1.1. The energy scene in India:

In India, reliance is shifting from traditional sources of energy like firewood and dung cakes to modern commercial forms of energy like coal, oil, gas and electricity. According to the Prasad Working Group study, during the period 1953-54 to 1975-76, commercial energy consumption had quadrupled from 60 million tons of coal replacement (mtcr) to 353 mtcr. Over the period it registered a growth of 7 percent per annum, while non-commercial energy expanded at a slower rate of a mere two percent per annum.

Further, the share of commercial energy in total energy has gone up from 32 percent to 64 percent during the same period. In 1994-95 it averaged around 60 per cent (CMIE, June 1994).

Among the commercial energy's major consuming sectors, in 1990-91 industry accounted for the lion's share of 50.40 per cent, while transport took 24.50 per cent. The household sector consumed 13.80 per cent and the rest, 11.30 per cent was attributed to the agricultural sector and others (Eighth Plan Document).

The different forms of primary commercial energy sources in India are, coal, oil, natural gas, hydro and nuclear power. The indigenous production of commercial energy in India registered a growth of 10.7 per cent per annum over the period 1970-94, increasing from 47.77 million tones of oil equivalent (mtoe) in 1970-71 to 178.45 mtoe in 1993-94, (CMIE *op.cit*). A noteworthy feature is the impressive rise in the share of natural gas in total energy supply, which increased from 2 to 8 per cent during the same period. Coal accounted for as much as 60 per cent of total energy, though the 1990's have seen its share declining to 58 per cent. It however continues to remain the major fuel for the economy, registering a growth rate of 5.3 per cent between 1970-1994. Generation of power registered a growth rate of 7.98 per cent per annum between 1970-94. Over the same period, share of hydro capacity in total utilities (the power generated from all sources) fell from around 43 per cent to nearly 27 per cent, while that of thermal increased from 54 to 71 per cent and that of nuclear declined marginally, from 2.9 to 2.6 per cent.

Being a net oil importer, India's balance of payments situation was severely affected by the unprecedented hikes in international oil prices during the 1970s. Between 1970 to 1980 the import value of petroleum, oil and lubricants increased from a mere 9 per cent to 78 per cent. Few years of respite was experienced in the mid 1970s due to the discovery of Bombay High. However, after the closure of over-worked oil wells at Bombay High, indigenous production of crude oil as percentage of total availability, which had averaged around 65 per cent over 1985-90, fell to 47 per cent in 1993-94. On the other hand, net crude oil and petroleum product imports increased from 12 million tones in 1970-71 to 39 million tones in 1993-94, meeting over 40 per cent of the demand for oil. Thus India is highly susceptible to future turmoil in the global oil market.

Commercial energy prices in India rose by more than ten folds, from an index of 100 in 1970-71 to 1120.91 in 1994-95. The price indices for various fuel types (Chandhok, 1990) show that, for the period of 1970-94, furnace oil shows an average annual rise of 16.73 per cent. This fact is strengthened by a trend analysis of different energy product prices in India by Sarkar and Kadekodi (1988). Their analysis shows that, the petroleum products as a single group have shown a price increase at a trend rate of 15.91 per cent between 1970-71 and 1985-86. Much of this increase has been contributed by an increase in crude oil prices (at a rate of 20.26 per cent) and equally sharp increase in the prices of furnace oil (19.09 per cent) and light diesel oil (17.05 per cent). Coal (the major fuel type for the Indian economy) prices remained fairly low and steady in India before nationalisation of the coal industry. The period after nationalisation in 1973 saw a stage of fast rising coal prices at a rate of 17.20 per cent per annum between 1973-74 and 1985-86. Over the whole period for 1970-71 to 1994-95 coal registered an average annual rise in prices (12.86 per cent). During the same period price of electricity registered the slowest annual rise of 10.37 per cent. It is to be noted here that, electricity prices in India vary substantially across users and states. For instance, it is the lowest for agriculture [30 paise per kilo watt hours (ppkwh)] and highest for commercial establishments (136.61 ppkwh) in 1991-92.

From the above facts it can be broadly concluded that in India while on the one hand energy prices are rising sharply, on the other hand domestic energy supply is not adequate to meet energy demanded. This renders energy imports imperative for the economy, causing heavy foreign exchange loss. The overall energy situation in India seems to be closing on to a critical stage. In the final analysis it is apt to touch upon the concerns raised by the Advisory Board on Energy (1986). The Board estimated the total domestic investment required for meeting the demand for fuels at Rupees 450,000 crores over the next 20 years. If the present demand and supply scenario is maintained, then by 2000 AD the oil import bill is expected to be of the order, Rupees 20,000 crores per annum. Meeting the future energy needs of the nation is going to be a major concern of the planners.

This calls for efficient energy management by the Indian economy. Energy management strategies as pointed by Pachauri (1980), have a timeframe. The immediate and short run strategy seeks out measures of increasing energy efficiency and measures to conserve the available energy, the middle run strategy questions as per the existence of substitution possibilities (inter-input and inter-fuel), whereas the long run strategy looks for alternative cheaper sources of energy. In this regard the eighth plan document notes that,

> "The strategy for energy development forms an integral part of the overall economic development strategy. Efficient use of resources and long-term sustainability are the two important objectives of economic planning. . . strategies. . . have to reckon with the available resources and the technological constraints prevalent in the system."

Thus while the long run option of affordable unlimited supply of energy in the form of nuclear and solar options need to be explored, this involves a long gestation period. Therefore the immediate approach must be to tackle the energy shortages through short and medium term policy objectives. These must be framed on lines of strict vigilance as to where the commercial energy flows and how efficiently it is used. Besides concentrating efforts on conservation of available fuels, the substitution opportunities between energy and non-energy inputs and between fuel types need to be investigated as a cost reducing option. The former is referred to as inter-factor substitution and deals with substitution between energy and other factors of production like capital, labour and materials. The latter is referred to as inter-fuel substitution and involves substitution among different fuel types like coal, gas, oil and electricity.

While the importance of managing energy cannot be denied for all sectors of the economy, the need is urgent especially in the manufacturing sector of India, since this sector has the distinction of being the major commercial fuel consumer (more than 40 per cent of the total). Also the share of energy bill in total cost of production for this sector has gone up from 3.9 per cent to 6.2 per cent between 1970-71 and 1990-91. Moreover the intensity of energy use has been steadily rising (Report of the Working Group on Energy Policy, 1979). This study is an attempt to examine a few facets of energy management with reference to the manufacturing sector in India. The issues generally included under energy management are energy efficiency, energy conservation and the factor and fuel substitution possibilities.

With the foregoing discussion at the backdrop, the specific objectives of the present study can now be stated. Before that, however, a critical review of selected literature may be in the order of analysis. The review has been subdivided so as to deal with the different aspects of energy management with special reference to the Indian manufacturing sector, namely, (a) energy efficiency and energy conservation studies and, (b) factor and fuel substitution studies.

1.2 Review of select literature: energy management in Indian manufacturing sector:

1.2.a Energy efficiency, and conservation studies:

The Indian Oil study in Pachauri (ed, 1980) points out the possibility of increasing energy efficiency in industry and estimates a saving of Rupees 24 crores per annum (pa) (1980 figures). Similarly conclude a few other studies like, the United Nations study (1984), the Advisory Board on Energy study (1986) and others. The U N study claims that there is scope for the saving of significant amounts of energy at relatively low cost by simple changes in the production process. It notes that unlike the industrial countries which have shown substantial reduction in use of fuels, India has been showing a reverse trend (due to rapid automation). It also concludes that a number of measures for improving efficiency are present, especially where technological improvements are concerned. The Advisory Board on Energy (1986), has along the same lines pointed out the need to conserve fuel in face of serious energy shortages. It notes the attempts by certain developed countries like Japan, France and United Kingdom towards conservation. It also gives the example of ten Indian industries which have proved exemplary in the field of conserving energy. Some of them are, Arvind Mills, Ahmedabad, Bharat Petroleum Corporation, Bombay and so on.

While the above studies point out towards the existing possibilities of improving energy efficiency in Indian industries, there exist a plethora of World Bank literature on the question of energy efficiency in particular industries, with reference to the developing countries. To mention a few, the studies by Mogens and Kishore (1983) for the cement industry, Meunier and Oscar (1984) for the steel industry and Andrew (1985) for the paper and pulp industry.

On the one hand, for all developing nations they have suggested various measures for improving energy efficiency on the lines of the experience of the developed world, for example, energy consumed per ton of paper declined by 10 per cent in the United States. The measures suggested are, re-use of energy, optimal plant size, introduction of energy audit, improving design technology, operation environment, skills, price management and so on. Andrew (1985) estimated a return of 20-30 per cent in form of energy saving as a result of in-plant improvements. Similarly Meunier and Oscar (1984) for the Steel industry quote the example of Japan and claim a saving of 10-15 per cent energy consumed by the developing countries on adoption of efficiency measures. Along the same lines conclude Mogens and Kishore (1983) that there exist substantial potential for reducing energy consumption in the developing nations and suggest various short and long term measures.

On the other hand (and more importantly), one disturbing factor pointed out by these studies is that, Indian industries are the least energy efficient when compared to those of other industrial and developing nations; for instance, for the cement industry, India shows 0.163 tones of oil equivalent (toe) of fuel consumption per ton of output, whereas the same stands at 0.090 toe for Federal Republic of Germany and at 0.108 toe and 0.161 toe for Turkey and Pakistan respectively. For paper and steel industries in India similar conclusions are drawn, that they display the least energy efficient production. As pointed out by the same studies, plant size, technology and operational environment may be the reasons underlying the occurrence of this phenomenon.

Another very interesting study is that by Parikh (1990). She uses the Cobb-Douglas production function for five most energy utilising Indian industries (classifying the industries on the basis of cost), viz., basic metals and alloys, chemicals, non-metallic minerals, textiles and food products. The study concludes that during the period 1973 to 1984, efforts have been initiated with limited success for energy conservation in these industries, a 14 per cent reduction over 1973 value in real energy cost per output was seen. Large price elasticities but output elasticities close to unity seem to indicate 'soft' changes, and overall output elasticities of 0.72 for all industries seem to indicate changes of the long term nature. She also indicates that the response to price changes of energy requires a lag of 2 to 3 years.

These studies clearly show that there is not only a need to conserve fuel and improve efficiency in the Indian industries but there also exists ample opportunities to do so.

1.2.b Factor and fuel substitution studies:

As a prelude to the review of literature regarding substitution between pairs of factor inputs and between pairs of fuel types, an introductory note on these studies is pertinent.

The earlier studies on production structures assumed negligible substitution opportunities between energy and material inputs vis-a-vis the capital and labour inputs. Since energy and materials costs constitute a significant portion of the production cost, their exclusion may alter the estimates of substitution, scale economies, technical change and lead to sub-optimal output. This reasoning coupled with the 'energy crisis' led the economists to investigate the possibilities of substituting energy with less scarce (or less expensive) inputs. The role of factor and fuel substitution possibilities in conserving energy and reducing the energy bill for the economy is now widely acknowledged. Today there is a plethora of studies treating energy and materials as inputs on par with capital and labour. These studies are popularly referred to as the 'KLEM studies' (where K, L, E, and M stand for, capital, labour, energy and materials respectively). Substitution elasticities were obtained between aggregate energy and other factors of production. Some studies also estimate an energy sub-model to obtain the substitution possibilities among the various fuel types; inter-fuel substitution.

Inter-factor substitution elasticities become important parameters in analysing the impact of a rise in price or shortage of energy. For example, if substantial substitution possibilities among the energy and non-energy inputs are present then a rise in energy prices can be absorbed without affecting the output levels too adversely. Firms can mitigate the effect of energy price hike by substituting other factors in place of energy. However, the opposite result may as Brendt and Wood (1975) note, make adjustment by the industry to high energy prices difficult, unit cost may rise, output levels may fall or alternatively shift may be seen in the composition of output in favour of less energy intensive products and drastic changes may be called for in the technology structure. Thus the extent of impact energy shortages will have on the economic activities depends crucially on the elasticities of substitution between energy and non-energy inputs. The own and cross price elasticities of demand for factor inputs are immensely important for the economy. These elasticities gain prominence especially if there exist a wide price differential among the various factors of production. Here own elasticities quantify the change in the use of a factor input in face of its own price change. The estimated cross elasticities quantify the change in relative quantities of inputs used in response to their relative price changes.

Similarly, the inter-fuel substitution elasticities also play a vital role in analysing the impact of alternative policy decisions regarding fuels. The rate of extraction, import and pricing of a fuel depend crucially on the nature of its relationship with the other fuels. For instance, if coal and oil are strong substitutes then a rise in international price of oil can be countered by using more coal. The own and cross price elasticities of demand for the various fuels gain prominence in the light of the well known Ramsey's consumption efficiency rule, which requires the price of a public good to be inversely related to its price elasticity.

The implication of factor and fuel substitution existing along with the magnitude of elasticities cannot be undermined for an energy importing country like India. The extent of adjustment required in the face of energy crisis will be clear only when such information is available and reliable. Moreover, according to the Fuel Policy Committee (1974), energy policy failed to evolve a satisfactory pricing structure in the absence of the knowledge of the demand responsiveness of the consumers to price changes[1]. Herein lies the importance of estimating own and cross price elasticities of demand for the various factor and fuel inputs.

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[1] The importance of such a price structure has been recognised by the working Group on Energy Policy (1979) in the following words, `A structure of energy prices that encourages the inter-fuel substitution and a degree of economy in energy use would make it easier to implement the energy plan outlined in the earlier chapters.'

In order to familiarise oneself with the methods available for quantifying the factor and fuel substitution possibilities, a critical assessment of selected literature in that area is to be taken up here. For convenience the studies have been classified into those focusing on, (i) factor substitution and (ii) fuel substitution. Sub-section (iii) is devoted to the Indian studies dealing with input demand. Finally sub-section (iv) is a discussion on certain critical assumptions made by majority of the studies.

i. Factor substitution:

Majority of the studies in the area of factor demand and substitution have been taken up for the industrialised nations. For instance, inter-input substitution possibilities have been examined for the U S manufacturing by Brendt and Wood (1975), Halvorsen and Ford (1978), Field and Grebenstein (1980) and others; for the Canadian manufacturing by Fuss (1977); for the manufacturing sector of Netherlands by Magnus (1979), Magnus and Woodland (1987) and so on. Some studies have come up recently for less developed countries (other than India) like, Saicheua (1987) for manufacturing sector of Thailand, Khawaja (1994) for manufacturing sector of Pakistan and others. While these studies pertain to one country, Griffin and Gregory (1976), Pindyck (1979) estimate the substitution elasticities using international time series data.

The studies of energy demand and substitution were facilitated by the introduction of generalised and flexible functional form into applied production analysis. These functional forms are flexible in the sense that they place minimum a priori restrictions on the estimates of factor and fuel substitution elasticities while admitting several factors of production into the analysis. While there are many functional forms that meet the conditions of flexibility, it is the translog cost function form which has been the most frequently used in the KLEM studies[2].

All the studies reviewed here agree that factors of productions are in general responsive to changes in their own prices. In particular, demand for energy is seen to be more elastic in studies using cross section data. For instance, using cross section U S manufacturing data Halvorsen and Ford (1978), and Field and Grebenstein (1980), found own price elasticity of demand for energy of -1.61 and -1.24 respectively. Although the other studies find this elasticity to be less than unity, it is nevertheless significantly different from zero. This implies that given sufficient price change, the amount of energy demanded will undergo a change (this fact must be accounted for in any long term forecast of energy demand).

With respect to the substitution elasticities between energy and other non-energy inputs, most studies are in substantial agreement that these are non-zero. In these studies the apparent contradicting evidence regarding substitution possibilities between energy and capital has led to an interesting debate. A number of studies using time-series data have found complementarity between them. For instance, Berndt and Wood (1975) test a four input

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[2] For further information regarding the various flexible functional forms see chapter 3.

(KLEM) translog cost function with U S manufacturing time series data for the period 1947-71, find the relationship between energy and capital to be one of complementarity. Fuss (1977) also concludes similarly for the Canadian manufacturing sector using pooled time series (1961-71) cross section (5 regions) data. Similar results have been reported by Magnus (1979) for Netherlands.

On the other hand, there are some studies that show substitutability between energy and capital. For example, Griffin and Gregory (1976) report then to be substitutes while estimating three input (KLE) translog cost function from pooled cross section data for the manufacturing sector of nine industrialised Organisation for Economic Corporation and Developement (OECD) countries, at five year intervals from 1955-1969. Pindyck (1979) applies similar function to pooled cross section time series data for the industrial sectors of ten countries (7 European countries, Canada, Japan and the U S) during the period 1963-73, and shows that energy and capital are substitutes. The study by Halvorsen and Ford (1978) uses cross-section data for eight two-digit U S manufacturing industries and finds energy and capital to be substitutes. Similar results are reported by Khawaja (1994) for seven manufacturing industries of Pakistan and by Saicheua (1987) for a three input (KLE) model for five industries of the manufacturing sector of Thailand for the period 1974-77.

Brendt and Wood (1979) while commenting on the contrasting results of studies relating to energy-capital relationship, conclude that the econometric studies finding evidence of energy-capital substitutability are apparently supported by engineering analysis of energy conservation potential due to energy-capital substitution. Moreover, detailed engineering studies have estimated increase in energy efficiency available by increasing investment either through new engineering designs or by adjusting existing plant and equipment.

The divergent results with regard to the nature of relationship between energy and capital have different implications for policy decisions. Suppose energy-capital are complements then this would imply that higher priced energy will ceteris paribus dampen the demand for new plant and capital equipment. This in turn may slow down the rate of productivity growth. Any attempt to provide incentive to investment would cause an increase in the demand for energy too. In an era of rising energy prices this conflicts with the objective of energy conservation. Therefore, investment becomes less attractive. On the other hand, suppose energy-capital substitutability exist then, higher energy prices may depress overall output levels, thereby reducing demand for all the factors, the substitution effect may to some extent offset the depressive effect on investment. Moreover, a policy of encouraging higher energy prices would satisfy the objective of energy conservationist since capital could be substituted for the more expensive energy.

Conflicting evidence from econometric studies regarding energy capital relationship might be explained by a number of reasons including different data sets and approaches to measuring input quantities and prices, varied treatments of excluded inputs and distinction between short and long term elasticities.

Strengthening the last explanation, Griffin and Gregory (1976) claim that short-run cost functions with time-series data are likely to show energy and capital to be complements. As the energy efficiency of capital is essentially fixed in the short run and therefore increased use of capital is accompanied by increased energy use. Energy and capital however become substitutes if estimation is based on cross-section data which better reflects long term adjustment possibilities because they tend to exhibit greater relative factor price variations (especially between countries) which have persisted for a long period of time.

However, studies like Fuss (1977) using pooled data which have concluded energy-capital complementarity. Reconciling such contrasting results Brendt and Wood (1979) argue that although energy capital are gross substitutes they are also net complements. They base this argument on the observation that those studies finding energy capital substitutability considered only capital, labour and energy. By omitting materials, one obtains only a gross elasticity. The net elasticity which allows for the additional substitution between the capital, labour, energy aggregate and materials can indicate energy-capital complementarity.

Field and Grebenstein (1980) trace one of the reasons for divergent results to the definition of capital employed. They show that reproducible capital (fixed capital) and energy are complements whereas working capital and energy are largely substitutes in production. The study argues that, a value-added approach to capital cost would be expected to show capital energy substitutability [like in the studies of Griffin and Gregory

(1976), Pindyck (1979), and Fuss (1977)] as the cost of capital would be dominated by the presence of working capital. A service approach on the other hand would show complementarity between the two inputs [as in Brendt and Wood (1975)].

In the final analysis it must be noted that any reconciliation remains to be partial and this debate of energy-capital relationship is yet to be resolved satisfactorily.

Regarding the nature of relationship between energy and other non-energy inputs and between other pairs of inputs there emerges a broad agreement among most of the studies. Even though the absolute size of the estimated elasticities may vary, almost all the studies reviewed agree that the relationship between energy and labour and between capital and labour is that of substitutability. A few studies that include intermediate materials in their analysis find that the relationship between energy and materials is predominantly that of substitutability. Also material input exhibits a largely substitutable relationship with other factors of production.

ii. Fuel substitution:

Inter-fuel substitution includes the process whereby shifts in relative fuel prices lead to changes in the degree of utilisation of individual fuels. The extent to which inter-fuel substitution may be possible can be deduced by examining the own price and cross-price elasticities of demand, and the elasticity of substitution for individual fuels.

Among the studies reviewed Fuss (1977), and Pindyck (1979), have estimated disaggregated models which provide estimates of derived demand elasticities for energy inputs as well as for aggregate energy. For this purpose, they use a two stage optimisation procedure. Here the mix of fuels that make up the energy input is optimised in the first stage, generally referred to as the energy sub-model. In the second stage, the optimal quantities of aggregate factor inputs are chosen. On the other hand, Halvorsen (1977), Magnus and Woodland (1987) and others focus exclusively on the substitution possibilities between fuel types and estimate a single stage inter-fuel substitution model.

A fundamental assumption that has been made in these studies is that, the production function is 'Homothetic Weakly Separable' in the major categories of energy and non-energy inputs[3]. This provides the necessary as well as sufficient condition for a consistent two stage optimisation process (Fuss, 1977).

Almost all the studies on inter-fuel substitution cited here, consider four standard types of energy inputs: oil, gas, coal, and electricity.

A review of these studies shows that, although there may be considerable divergence in the size of the estimated price elasticities, changes in fuel prices have had significant effects on energy consumption patterns. All studies agree that electricity is the least responsive among all energy types to fuel price changes. Electricity is a much more expensive fuel on a thermal

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[3] See Chapter 3 for a formal treatment.

basis than any other fuel, and is used only when there is little possibility of using an alternative fuel. This fact is reflected by the low own price elasticity of demand for electricity obtained by most studies.

With regards to own price elasticities of demand for other fuels viz., coal, oil and gas, Halvorsen (1977) finds them to be greater than unity, for each U S two digit manufacturing industry for the year 1971. Elastic demand for these fuels has been obtained by Pindyck (1979) for a sample of ten countries, and by Fuss (1977) for Canadian manufacturing. Using annual time series data for six manufacturing industries in the Netherlands, Magnus and Woodland (1987) show that the own price elasticities for coal and oil are particularly high. However, the elasticity for oil besides that of electricity is low, mostly in the inelastic range.

With respect to the cross- price elasticities, majority of the studies show that all the fuels are substitutes for one another with only a few exceptional cases of complementarity. For instance, Magnus and Woodland (1987) find that coal and oil, also gas and electricity are complements for Netherlands.

Fuss (1977) points out that; "In general the pattern of inter-fuel substitution is acceptable a priori. Those fossil fuels which are used primarily for heating purposes exhibit strong substitutability characteristics. The opposite description is the case for electricity, used primarily for lightening and motive power."

iii. The Indian studies:

It is essential to focus on the Indian studies exclusively as the energy situation in India has a few distinct peculiarities. Unlike coal and electricity, the demand for oil is largely met through imports, which eats into a major portion of India's export earnings. Besides this, there is also the uncertainty regarding the supply and price of energy[4].

In recent years a number of studies have attempted to quantify the price sensitivity of energy demand in India. For instance, Uri (1979), measured the energy substitution effects in five commercial sub-sectors of the Indian economy viz., mining and manufacturing, transportation, domestic sector, agriculture, and commercial, government etc, for the period 1960-71. He found that coal and electricity are significantly substitutable for oil in all the sub-sectors. He concludes that, elements within the commercial sector of India are responsive to price changes while making their energy choice.

The rest of the studies have either looked at the total manufacturing sector (Vashist, 1984 and Murty, 1986), or for a cross section of industries [Williams and Laumas (1981), Lynk (1983), Apte (1983), Goldar and Mukhopadhyay (1991), Jha, Murty and Paul (1991), Kar and Chakraborty (1986), and others]. This focus on the manufacturing sector could be because of the fact that it is the major fuel consuming sector in India.

ee, Parikh and Parikh (1992).

Among these studies some have estimated the possibilities of factor substitution only, while few others obtain both the factor and fuel substitution possibilities, and yet others focus entirely on the inter-fuel substitution possibilities. Williams and Laumas (1981) estimate substitution elasticities between aggregate factor inputs (KLEM) using data for a cross-section of manufacturing industries for 1968. Lynk (1983) tests the factor substitutability for fourteen organised Indian industries for the period 1952 to 1971. Goldar and Mukhopadyay (1991), on the other hand, estimate a three input (KLE) model for four industries for the period 1951 to 1982. Jha et.al (1991) measure the elasticities of substitution between factors (capital, labour, and a combined energy-material input).

As far as inter-fuel substitution is concerned, following Pindyck (1979), Fuss (1977) and others, Apte (1983), Vashist (1984) and Murty (1986) obtain elasticities of substitution between both factors and fuels, using a two stage optimisation procedure, noted earlier.

Apte (1983) analyses the pattern of substitution between the energy and non-energy inputs, and within the energy inputs, (broadly categorised as solid fuels, liquid fuels and electricity) for a set of five industries. He uses a pooled time series (1968-71) and cross section (across states) sample. Murty (1986) on the other hand, estimates the model for the whole of the Indian manufacturing sector for the period 1953 to 1977. Kar and Chakraborty (1986) focus exclusively on the inter-fuel substitution possibilities of eleven manufacturing industries with relatively high energy intensity for the period 1959 to 1973.

Most of these studies dealing with KLEM model employ the translog cost function approach. The two exceptions to this are the studies by Lynk (1983) who uses an adaptation of Diewert's (1971) Generalised Leontief Parameterisation, while the other by Goldar and Mukopadhyay (1991) uses Conrad's (1983) cost price approach. Both studies also present the results for the corresponding translog model for purpose of comparison.

Although the factor substitution studies for India vary in terms of the size of the elasticities estimated, certain broad features emerge. All find that energy demand is quite responsive to a change in its own price. William and Laumas (1981) and Vashist (1984) infact show that the own price elasticity of energy is higher than that of other factors of production. Murty (1986) places it only after the own price elasticity of capital. This is evidence enough to say that the demand for energy will eventually adapt to changes in its price.

According to Jha et.al. (1991) the evidence available suggests that there exists substantial substitution possibilities between factor inputs in the Indian Industries. William and Laumas (1981) find that all factors are fairly good substitutes of energy, with the exception of labour. There is divided evidence with respect to the relationship between labour and energy; they emerge as complements for some product groups and substitutes for the others. With the exception of Murty (1986) who finds complementarity between energy and labour most other studies reviewed find the relationship to be predominantly one of substitutability in the Indian industries.

The debate regarding the nature of the relationship between energy and capital has percolated into the Indian studies also. Lynk (1983), Williams and Laumas (1981), find substitutability between energy and capital for majority of the industries considered in the respective studies. This finding is also supported by Murty (1986) for the manufacturing sector as a whole. Jha et.al. (1991) and Goldar and Mukhopadhyay (1991) also conclude similarly. On the other hand, for four out of the five industries considered Apte (1983) finds energy and capital to display a complementary relationship. Similar result has been obtained by Vashist (1984) for the manufacturing sector.

In the light of the energy conservation potential of energy-capital substitutability (Brendt and Wood,1975), these contrasting results have far reaching implications for the Indian industries. As pointed by a number of engineering studies the average energy efficiency of plant and machinery in the Indian industries is particularly low (Mogens and Kishore, 1983, Meunier and Oscar, 1984, Andrew, 1985, and others). Given substitutability between capital and energy, higher priced energy can lead to energy conservation and increased efficiency, since capital could be substituted for energy.

With respect to the relationship among other inputs, capital and labour turn out to be substitutes in all the studies, while capital and materials, and energy and materials turn out to be complements in some and substitutes in the other studies.

The studies dealing with energy sub-model indicate the presence of substantial own and cross price elasticities. This is sufficient to reject the notion of constant fuel mix while forecasting future energy demand.

While estimating the inter-fuel possibilities the Indian studies have considered only three types of fuels, viz., coal, oil, and electricity. Upon examining the own price elasticities of demand for different fuels obtained by Apte (1983), Kar and Chakraborty (1986) one can conclude that, the demand for each fuel type in the Indian manufacturing is by and large inelastic. Also that demand for electricity appears to have the lowest own price elasticity as in the case of the developed countries[5]. However, Murty (1986) proves to be an exception to both these conclusions. His study reports not only relatively high own price elasticity of demand for various fuels, but also reports coal to be the least price responsive of all the fuels.

The estimates of partial elasticities of substitution obtained by all the studies with the exception of Apte (1983), are positive. This indicates that the relationship between fuel types in the Indian manufacturing is predominantly one of substitutability.

The principal source of data for most of the studies has been the report on the Annual Survey of Industries, published by the Central Statistical Organisation of the Government of India.

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[5] Recollect that, electricity in its use as a source of motive power cannot be readily substituted for by other fuels, while in heating uses such substitution is possible.

iv. Critical assumptions made in factor and fuel substitution studies:

a. Specifications regarding the technological change :

In the factor substitution models the assumption made on technical progress can have an important bearing on the results. Majority of the studies reviewed assume technical change to be Hicks-neutral. These are the ones by, Brendt and Wood (1975), Griffin and Gregory (1976), Fuss (1977), William and Laumas (1981) and Murty (1986), Goldar and Mukhopadhyay (1991) and others. However, a Hicks-neutral technical change specification involves the assumption that the marginal rate of substitution between each pair of factor inputs is independent of technical change.

Hunt (1986) investigates the validity of the assumption of neutral technical change while estimating the substitution possibilities between factor inputs. He estimates a translog KLE function incorporating non-neutral technical change for the industrial sector of U K and finds that the hypothesis of neutral technical progress must be rejected in favour of the non-neutral hypothesis. He also demonstrated that different relationships between inputs are obtained for both types of technical progress. For instance he finds that, for the non-neutral specification all three inputs are substitutes for one another. However, in an earlier study based on neutral technical change assumption Hunt (1984) had found that for the data set capital and energy become complements. This result gives evidence enough to reject the assumption of Hicks-neutral technical change in favour of biased technical change.

The studies that have allowed for a bias in technical change are, Lynk (1983), Jha et.al. (1991) and others. While the principle objective of all the studies is to estimate the inter-factor and/or fuel substitution, they also look into the question of technical bias, non-proportionalities in the use of inputs and economies of scale. Lynk (1983) finds a high capital using technical bias among industries. This is in keeping with the hypothesis of mechanization of the industries. Jha et.al (1991) notes that technical change is biased towards use of labour and energy while it saves capital for certain industries. This he points out is consistent with price induced innovation hypothesis. However, he also obtains exactly opposite results for some other industries. No attempt has been made to explain these contradicting results across industries.

b. Homothetic-weakly separable production function and non-neutral fuel efficiency bias:

A fundamental assumption made in the studies examining the inter-fuel substitution opportunities is that the production function is 'Homothetically Weakly Separable'. 'Homotheticity' of energy aggregate implies that the optimal mix of inputs is independent of the aggregate input of energy. As far as the energy inputs are concerned, 'weak separability' implies that the marginal rate of substitution between individual fuels are independent of the quantities of capital, labour and material inputs. According to Fuss (1977), the 'homothetic separability' assumption provides the necessary as well as the sufficient condition for a consistent two stage optimisation process. This result is extremely useful, since it implies that the substitution possibilities between the various fuel types can be investigated without being concerned about substitution among the aggregate inputs.

Another assumption made by the majority of these studies is that the technical change displays neutral fuel efficiency bias. However, Hall (1986) estimates a range of fuel substitution models allowing for non-neutral fuel efficiency bias, for the non-energy producing industrial sectors of seven major OECD countries. He finds that the specification preferred for all seven countries is the model allowing for the possibility of individual fuel efficiency bias. Unlike other studies he finds little scope for substitution among fuel types.

Certain generalisations:

From the preceding review of literature certain broad generalisations can be drawn with regards to the energy management issues, with specific reference to the Indian manufacturing sector:

(i) It was seen that where energy efficiency was concerned, Indian industries paint a dismal picture. They are less energy efficient not only when compared to the industries in the developed nations but also in the developing nations. However, on the other hand certain conservationist trends are visible, especially in recent years.

(ii) The evidence on the degree of factor and fuel substitution and demand elasticities is mixed, however, certain broad relationships emerge from an examination of selected literature. The principal finding of most studies has been that, factors demanded in the production process are quite price sensitive. Though the size of the elasticities varies across studies and are very small, they are nevertheless non-trivial (statistically). This indicates that factor demand eventually adapts to the change in its price.

(iii) As far as the own price elasticities of factor demand are concerned, it can be seen that energy is significantly sensitive to own price changes; implying that a change in price of energy can induce conservation measures.

(iv) Regarding the substitution possibilities among inputs, the studies agree that substantial opportunities do exist. Some divided results however are noted. The most important controversy concerns the nature of relationship between energy and capital. It is yet to be resolved satisfactorily as to whether the relation between them is that of substitutability or complementarity.

(v) Principally energy and labour emerge as substitutes in the non-Indian studies, however in the Indian studies there is contrasting evidence to be found.

(vi) As far as the inter-fuel substitution possibilities are concerned, there is general agreement that substantial scope exists, implying that price shocks concerning any one type of fuel can be absorbed by substituting one fuel type for the other.

Critical assessment of the literature reviewed:

More importantly the review of the cited studies brings forth the following points to light:

(i) While there are studies dealing with energy use at the industry level, the absence of a comprehensive aggregate study is a significant lacunae. In specific, the issues concerning energy management have not been sufficiently examined for the Indian manufacturing sector as a whole. An aggregate level study is important to the extent that it gives a broader perspective of energy demanded by the sector, especially since the manufacturing sector is the major energy consumer in the economy. Thus the need for a study of this nature cannot be undermined.

(ii) Majority of the factor and fuel substitution studies for India have been carried out for the individual industries (except Vashist, 1984 and Murty, 1986). Though the relevance of these studies cannot be denied, there is a simultaneous need for aggregate level studies. Exploring the possibilities of factor and fuel substitution in the manufacturing sector will provide an understanding of the overall relation prevailing between energy and non-energy inputs and among fuel types. Moreover, the effect of falling energy supply or rising energy prices on the manufacturing sector depends on the flexible nature of energy demanded by the entire sector. The studies for individual industries examining the energy substitution possibilities can then be embedded within this general perspective. There is thus a need for factor and fuel substitution studies conducted at the aggregate level in order to precede and complement the studies for individual industries.

(iii) Most of these studies (both industry level and macro level studies) do not examine the factor substitution opportunities after the first and second oil shock (1973 and 1979). In effect they fail to bring out the shifts that may have taken place in the demand for various factors and fuels, following the rise in the overall energy prices; a period when energy management assumed greater significance. This emerges as a visible and important gap in the literature.

(iv) As far as the estimation of factor and fuel substitution possibilities are concerned, most studies assume a Hicks-neutral technical change. As seen earlier, not allowing for technical bias in the production structure can result in misleading conclusions on substitution possibilities.

In the light of the above facts, this study attempts to fill in some of the gaps in the literature, and attempts to overcome some of the limitations of the previous studies. The overall objective of the study is to examine certain issues related to energy management in the Indian manufacturing sector. As seen earlier, managing energy in this sector is imperative not only because it is a major fuel consumer in the economy but also due to the fact that the energy bill in the sector is rising at a phenomenal rate over the past two decades (almost doubled).

1.3 Objectives of the present study:

The specific objectives of the study can be stated as follows:

(i) This study attempts to examine the energy use (in relation to the output produced) in the Indian manufacturing sector. Towards this purpose, the output-energy ratio in the sector is examined.

The reasons underlying the trend in the ratio are explored and some of the reasons are empirically tested.

(ii) As an important aspect of energy management factor-substitution possibilities for the entire manufacturing sector are quantified by estimating the substitution elasticities between the four inputs, viz., capital, labour, energy and materials. In order to gauge the factor demand response to relative price changes the own and cross price elasticities of demand for individual factors are computed. As an improvement over previous studies the effect of change in scale and technology on the factors demanded are quantified.

(iii) It is attempted to estimate the inter-fuel substitution elasticities for the total registered manufacturing sector. This involves substitution among the three major fuel types viz., coal, oil and electricity. The response of demand for different fuel types to relative price changes is also quantified. For this the own and cross price elasticities of demand are estimated. An attempt is made to examine the effect of a non-neutral technical change on the demand for fuels, again an improvement over the studies reviewed.

1.4 Approach adopted and data sources:

In order to examine the first objective of the study namely, the nature of energy use in the Indian manufacturing sector, simple statistical tools like, ratios, growth rates, percentages have been employed.

For the purpose of quantifying the response of factor and fuel demand to relative price changes in the manufacturing sector, a two stage optimisation procedure is carried out as in Fuss (1977), and Murty (1986). In the first stage, an energy sub-model is estimated, for quantifying the substitution possibilities between the fuel types; coal, oil and electricity. Using the parameter estimates of the sub-model a Divisia price index is constructed for aggregate energy. This index becomes an instrumental variable in the second stage (replacing the price of energy) and is the explicit linking factor between the energy sub-model and the aggregate model. In the second stage, an aggregate 'KLEM' model is estimated dealing with the substitution possibilities between the four factors of production (capital, labour, energy and materials). The complete model is estimated for the period 1970-71 to 1990-91. It covers the time period after the oil shocks so as to capture the pattern of change in the factor and fuel demanded in response to these shocks.

For the purpose of estimation it is required to choose a functional form which places minimal a priori restrictions on the parameters of the production function in general and the elasticities of substitution between factors and fuels in particular. Among the various flexible functional forms available this study has employed the Transcendental Logarithmic functional form introduced by Cristensen, Jorgenson and Lau (1971, 1973).

A study of this nature draws heavily on secondary sources for data. The present study needs data on prices and cost of various inputs. For this purpose while the primary source has been the Central

Statistical Organisation's publication, 'Annual Survey of Industries', Summary Results for the Factory Sector, data has also been drawn from other sources.

1.5 Chapter scheme:

The scheme of the chapters is as follows: Chapter 2 examines the energy use in the Indian manufacturing sector while analysing the reasons behind the same. Chapters 3, 4, and 5 are devoted to quantifying the factor and fuel substitution elasticities in the sector. While Chapter 3 deals with the details of model specification and estimation, a detailed treatment of the various data sources and the construction of variables can be found in Chapter 4. Chapter 5 deals with the results. Finally, Chapter 6 gives the summary and conclusions of the study.

Chapter 2

ENERGY-OUTPUT RATIO IN THE INDIAN MANUFACTURING SECTOR: CERTAIN ISSUES

2.1 Introduction:

In the review of literature it was seen that the energy efficiency of the Indian industries was very low compared with that of the other nations - both developed and developing. Moreover, a comprehensive macro picture of energy management has not been analysed for the manufacturing sector of India, particularly for the post oil shock period. The present chapter attempts to fill this gap.

The outline of the chapter is as follows: To understand the trends in energy use at the macro level first the output-energy ratio (at constant prices) for the manufacturing sector is examined. Next certain hypotheses are put forth in order to explain the observed trend in the ratio, and these hypotheses are duly tested.

2.2 The energy-output ratio in the indian manufacturing sector:

In order to understand the nature of energy use in the total manufacturing sector of India the output-energy ratio has been examined[1]. It is to be noted here that this study defines the manufacturing sector as all industries after deleting 'electricity', 'water works and supply', 'gas and steam', and 'repair works'.

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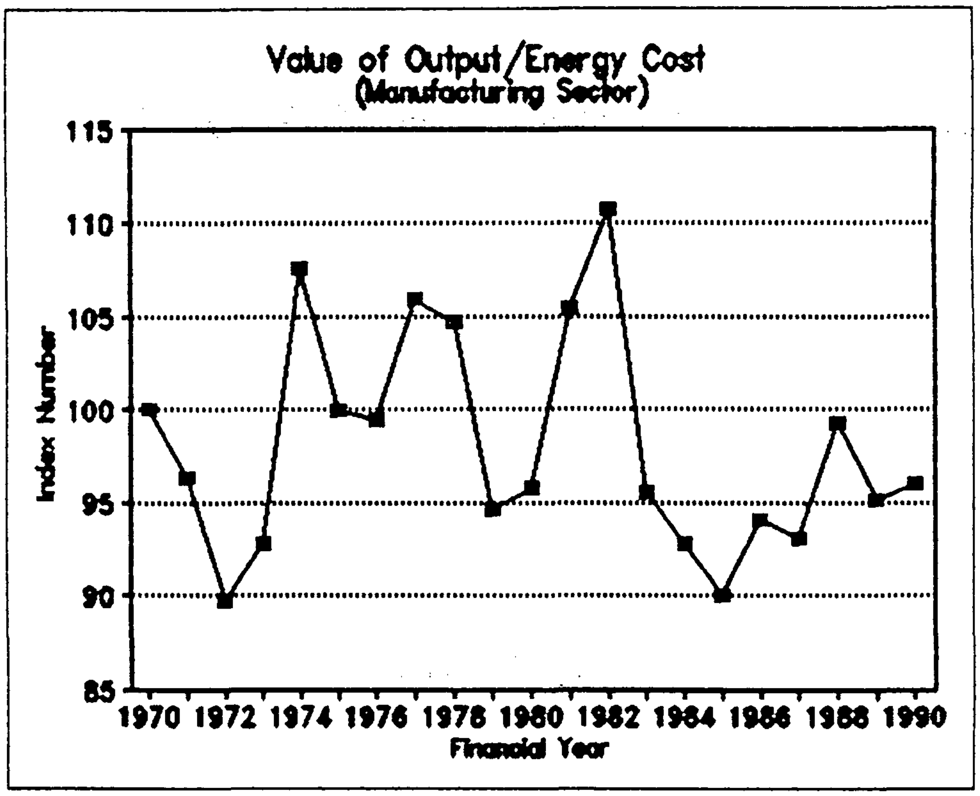
[1] According to 'Productivity' (1991 b), the output-energy ratio is defined as 'Energy Productivity Ratio'.

Figure 2.1 illustrates the output-energy ratio in the manufacturing sector, for the period 1970-71 to 1990-91[2]. Here the value of output and energy cost of the manufacturing sector have been taken at constant prices. The deflator used for output is the Wholesale Price Index (WPI) for 'manufacturing sector', and the deflator used for energy cost is the WPI for 'fuel, oil and lubricants' (base 1970=100)[3].

Figure 2.1



It can be seen that the ratio is highly fluctuating till 1982, after which a sharp decline is seen till 1984. Then onwards however there is a slight upward trend upto 1988, after which it

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[2] In order to estimate data for the year 1972-73 for which the survey report is not available, this study has taken a simple average of 1971-72 and 1973-74.

[3] The WPIs are taken from Chandok (1990) and Index Number of Wholesale Prices in India (1985-90).

falls again. The overall picture that emerges after 1982 is that of a decline in the output-energy ratio in the manufacturing sector.

The sudden and traumatic end of the cheap oil era in 1973 also marked the beginning of a subsequent and all time increase in the prices of all fuel types. Following this general energy crisis, energy conservation gained momentum in many countries. Limiting the focus to industries, in a scenario of rising fuel cost, one would expect (under the assumption of minimizing cost behaviour), the industry to increase its fuel productivity, conserve fuel and thus bring down energy cost incurred. Overall it would be expected that energy is managed more efficiently. However, it can be seen that this has not happened in the Indian manufacturing sector, especially after 1982. It would be interesting to examine the factors responsible for this phenomenon. While there may be many factors responsible for this trend, a few of the important ones are outlined here[4], so as to provide atleast a partial explanation to the observed phenomenon.

i. Redundant capital equipment:

As the machinery employed in the production process gets older, normally there will be more wastage of fuel in producing the same amount of output. This leads to inefficient use of energy and a hike in the energy cost incurred by the industry, leading to a decline in the output-energy ratio.

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[4] The other factors exogenous to the industry can be the energy inefficiency of the given process of production, allocation of energy between public and privately owned industries, and so on. These have not been considered in the present study.

ii. Training of labour:

The labour force, especially that which is directly involved in the production process contributes significantly towards the saving or excessive using of fuels. Appropriate labour training can save substantial amounts of energy and bring down the cost thereof. However, on the other hand, lack of the same can lead to inefficient use of energy by the labour, in turn leading to a hike in the energy cost.

iii. A structural shift in the composition of the manufacturing sector towards more energy utilising industries:

In case the manufacturing sector has undergone a shift towards more energy utilising industries after 1982, then it would be expected that the energy used in the sector during that period would definitely rise, and hence the trend observed.

iv. The technological change in the sector:

If the technological change in the sector has been energy using (opposite to energy saving) over the time period considered then the general energy intensiveness of the industry rises and it uses more energy per unit of output; as a result pushing up the cost incurred on energy and pulling down the output-energy ratio.

v. The factor and fuel substitution possibilities in the manufacturing sector:

As noted in Chapter 1, the role of factor and fuel substitution in reducing the energy bill is widely recognised. If the substitution elasticities between energy and non-energy inputs lie in the inelastic range then, even if price incentives are present non-energy inputs cannot substitute energy, thus eliminating the (downward) flexibility of energy demanded by the sector. This ultimately contributes to the rise in energy use by the industry.

Also, if the inter-fuel substitution elasticities in the sector are very low then the relatively expensive fuel type cannot be substituted with the cheaper one, thus again rendering the energy demand inflexible. In such a situation, the energy input in the manufacturing sector cannot come down.

This raises a question as to which of the above stated reasons are responsible (partially or wholly) for the observed phenomenon of the decline in the output-energy ratio in the manufacturing sector after 1982.

2.3 Empirical testing of the hypotheses stated:

The testing of the first two hypotheses put forth, namely capital redundancy and labour training hypotheses requires detailed micro level data. For instance, testing the capital obsolescence hypothesis requires knowledge about the age of the machinery, the rate of replacement and so on, these are specific to a firm. Similarly, each factory is exclusively responsible for the training of its labour in energy management techniques, and hence the labour training hypothesis is also specific to each firm. Thus, these two hypotheses can be examined only at the firm level. In this context an aggregate level approximation does not seem meaningful. Hence, this being a macro level study, it confines itself to testing the rest of the last three hypotheses, viz.,: (1) A structural shift in the composition of the manufacturing sector towards more energy utilising industries after 1982; (2) The type of technical change the sector has experienced over the time period under consideration, and finally; (3) the factor and fuel substitution possibilities in the sector.

To examine whether the rising energy cost (alternatively the fall in the output-energy ratio) phenomenon after 1982 is because of a structural shift in the composition of the manufacturing sector towards more energy utilising products or industries, the following methodology has been adopted.

The 2-digit level classification provided by National Industrial Classification (NIC 1970) has been used for this analysis[5]. For 1972-73 as the ASI survey report was not available, the method followed at the aggregate level was continued to be followed; a simple average for 1971-72 (preceding year) and 1973-74 (succeeding year) was taken. For industries where data was not available for two consecutive years; 1971-72 and 1972-73, the growth rate between the 1970-71 and 1973-74 was computed. An average of this was assumed over the three year period and the missing figures for the two years were thus estimated. The analysis was carried out for two separate time periods: 1st period from: 1970 to 1982 and the 2nd from: 1983 to 1990. This division of time periods was taken since it is relevant to the issue under consideration: it is only after 1982 that an overall fall in the output-energy ratio in the sector was observed.

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[5] The relevant classification can be found in Annexure II, (Supplement to) ASI, Summary Results for the Factory Sector.

The industries in manufacturing sector are divided on the basis of their energy utilisation[6]. To reach a cut off point for dividing these industries, an average energy cost for the sector on the whole was computed using the following procedure. First the relative share of each industry in the total energy cost for each year has been computed. The computed shares have been averaged for each period. Then, these averages have been summed up across industries and divided by total number of industries (18 in number) to arrive at the average energy cost for the sector. The calculated average energy cost were 5.83 and 5.85 per cent of the total energy cost for the 1st and the 2nd periods respectively.

Using this as the cut off, the industries in both the periods were divided into two broad categories: Category 1 are utilising more than the average energy cost; and, Category 2 are less energy utilising industries, accounting for less than the average energy cost. Within these two categories four groups of industries were identified:

Group 1: More energy utilising industries in period 1970-82.
Group 2: More energy utilising industries in period 1983-90.
Group 3: Less energy utilising industries in period 1970-82.
Group 4: Less energy utilising industries in period 1983-90.

It was seen that five industries belonged to Group 1, and the same five continued to belong to Group 2. Thirteen industries belonged to Group 3, and the same thirteen continued to belong to Group 4.

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[6] As a proxy for energy utilisation, the energy cost has been used.

In conclusion, the industries which were more energy utilising in the seventies continued to be in that category even after 1982. Similarly, the less energy utilising industries did not change their status after 1982. A list of the industries in both the categories is given in Chart 2.1 along with their NIC numbers.

Chart 2.1

Category 1: More energy utilising industries:

NIC Code	Description of the industry
20-21	Food Products
23	Cotton Textiles
31	Chemicals and Chem. Products (except Petroleum and Coal)
32	Non-Metallic Mineral Products
33	Basic Metals and Alloys

Category 2: Less energy utilising industries:

NIC Code	Description of the industry
22	Beverages, Tobacco and Tobacco Products
24	Wool, Silk and Synthetic Fibre Textiles
25	Jute, Hemp and Mesta Textiles
26	Textile Products (including Wearing Apparel other than Footwear)
27	Wood and Wood Products, Furniture and Fixtures
28	Paper and Paper Products, Printing Publishing and Allied Industries
29	Leather, Leather and Fur Products (except repair)
30	Rubber, Plastic, Petroleum and Coal Products
34	Metal Products and Parts except Machinery and Transport Equipment
35	Machinery, Machine Tools and Parts except Electrical Machinery
36	Electric Machinery, Apparatus, Appliance and Supplies and Parts
37	Transport Equipment and Parts
38	Other Manufacturing Industries

While this suggests that there has been no shift in favour of energy utilising industries (new industries have not joined the group) after 1982, it is important to see as to what has happened to the total number of firms/factories in the four groups. Towards this end, with reference to both the time periods, the average number of factories in the manufacturing sector was computed. Next the shares of the more energy utilising and less energy utilising factories in the total number of factories were computed. The results reveal that, while more energy utilising factories had a share of 46.93 per cent of the total number of factories in the sector in the first time period, this share came down to 45.50 per cent after 1982. On the other hand, the less energy utilising factories improved their share in the total over the two periods from 53.07 per cent to 54.50 per cent. This further strengthens the earlier conclusion that there has been no structural shift in the manufacturing sector towards more energy utilising industries. Infact the results show that the less energy utilising factories have increased their share in the manufacturing sector of India.

While it can be concluded that the downward trend in the output-energy ratio in the eighties was not because of any structural shift in favour of more energy utilising industries in the sector, it would be interesting to see how the output and energy parameters behaved within the four group of industries identified earlier.

In order to examine the trend regarding the output, the average output of the sector (in value terms) was computed for both the time periods. The share of more energy utilising industries and the share of less energy utilising industries in the total average output was computed. It was seen that whereas the share of more energy utilising industries in the total output declines from 57.85 per cent to 54.94 per cent from first period to the second; the same for the less energy utilising industries shows a rise from 42.15 per cent to 45.06 per cent. This further strengthens the argument that no structural shift has been noticed in the sector in favour of more energy utilising industries. On the other hand, the shift seems to be more inclined towards the less energy utilising ones[7].

Regarding the trend in energy cost, it was seen that the share of more energy utilising industries in the total average energy cost for both the periods remained more or less unchanged (declined marginally from 79.66 per cent to 78.43 per cent). However, it was noticed that a few of the more energy utilising industries registered an increase in the energy cost incurred as a percentage of the total energy cost to the sector; that is, the energy utilisation of some industries in Category 1 went up further after 1982. These were; Chemical and Chemical Products (31), and, Non-Metallic Mineral Products (32).

The corresponding share of the less energy utilising industries showed a hike from 20.34 per cent of the total energy cost in the 1970s to 21.57 per cent after 1982. This implies that, energy utilisation of the less energy utilising industries is rising in the second period. The industries that increased their energy utilisation in this category after 1982 are: Beverages, Tobacco and Tobacco Products (22), Wool, Silk and Synthetic Fibre Textiles (24), Paper and Paper Products (28), Leather, Leather and Fur Products (29), Rubber, Plastic, Petroleum and Coal Products (30),

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[7] This is with specific reference to its share in output.

and Machinery, Machine Tools and Parts except Electrical Machinery (35).

To get a relative picture of the output-energy trend the same was examined with respect to all the four groups of industries. The average output-energy ratio is computed at constant prices (base 1970=100). With respect to the more energy utilising industries they show a decline in the average output-energy ratio over the two periods, it going down from 18.76 to 16.84. Whereas the average output-energy ratio for the less energy utilising industries is seen to remain more or less stable, at 43.58 in the seventies and 43.62 after 1982[8].

Thus, though there was no shift towards more energy utilising industries in the sector, this result suggests that it was the industries in this category which were mainly responsible for the occurrence of a fall in the output-energy ratio in the manufacturing sector as a whole. This leads one to conclude that the conservation efforts must be concentrated in the energy utilising industries, in order to improve the output-energy ratio.

For quick reference the four groups of industries and the results arrived for each group respectively have been illustrated in Chart 2.2.

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[8] For a detailed 3-digit industry wise Energy Productivity Ratio refer to Productivity (1991 b).

Chart 2.2

Period I (1970-1982)	Period II (1983-1990)
Category 1: More Energy Utilising Industries	
Group 1	Group 2
No. of industries = 5 Share in total factories = 46.93 % Share in total output (value) = 57.85 % Share in total energy cost = 79.66 % The output-energy ratio = 18.76 (at constant prices)	No. of industries = 5 Share in total factories = 45.50 % Share in total output (value) = 54.94 % Share in total energy cost = 78.43 % The output-energy ratio = 16.84 (at constant prices)
Category 2: Less Energy Utilising Industries	
Group 3	Group 4
No. of industries = 13 Share in total factories = 53.07 % Share in total output (value) = 42.15 % Share in total energy cost = 20.34 % The output-energy ratio = 43.58 (at constant prices)	No. of industries = 13 Share in total factories = 54.50 % Share in total output (value) = 45.06 % Share in total energy cost = 21.57 % The output-energy ratio = 43.62 (at constant prices)

Note: The horizontal divide represents the average energy cost cut off point (5.8 per cent of the total energy cost).

Having ruled out the possibility of a shift in the manufacturing sector towards more energy utilising industries, it becomes imperative to analyse the other possible factors which could underly the decline in the output-energy ratio in the manufacturing sector of India after 1982. Towards this direction the chapters to follow examine the last two hypotheses set out in this chapter, viz., the technical change and the factor and fuel substitution elasticities in the sector.

Chapter 3

THEORETICAL MODEL AND ESTIMATION

3.1 Introduction:

In the previous chapter it was seen that after 1982 the Indian manufacturing sector witnessed a fall in the output-energy ratio. This set the stage for analysing the reasons behind the phenomenon. The possible reasons put forth were: the nature of technological change in the sector being energy using and the possibility of low inter-factor and inter-fuel substitution elasticities in the sector. The first possibility causes a hike in energy use in the sector with technical progress. While the second renders substitution between energy and non-energy inputs or between pairs of fuel types impossible, again causing the energy use to rise in the sector. This chapter aims to empirically examine these hypotheses, in other words it quantifies the type of technological change and the possibilities of inter-factor and inter-fuel substitution in the Indian manufacturing sector. Towards this end the following two stage optimisation procedure is used[1]: (1) In the first stage an energy sub-model is estimated, dealing with the elasticities of substitution among the three fuel types viz., coal, oil, and electricity. The parameter estimates of the sub-model are used to compute a Divisia price index for aggregate energy. This index is used as an instrumental variable in the second stage, and is the explicit link between both the models. (2) The second stage involves the estimation of an aggregate 'KLEM' model where, K stands for capital, L for labour, E for energy and M for materials. It quantifies the effect of technical change on factor proportions. This model is also used for understanding the inter-factor

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[1] Following Fuss (1977) and Murty (1986).

substitutability and price elasticities of factor demands in the Indian manufacturing sector. The period of study is from 1970-71 to 1990-91.

The chapter is divided into the following sections: Section 2 discusses the two assumptions of 'homotheticity', and 'functional separability' in production structure, essential for the two stage optimisation procedure undertaken by this study; Section 3 presents the complete deterministic model, under two sub-sections, the first dealing with the demand for aggregate factors (KLEM model), and the second dealing with the demand for energy components (energy sub-model). The final section deals with the estimation procedure adopted for estimating the complete model, along with the relevant stochastic specifications.

3.2 Homotheticity and separability in production structure:

3.2.a Homotheticity and non-homotheticity:

A homothetic production function displays unchanging distributive shares with changes in scale (increase or decrease in the level of output), ceteris paribus. Factor proportions therefore, depend only on factor price ratios and are independent of the level of output. On the other hand, in a non-homothetic production structure, pure scale changes would alter relative marginal products and thus affect factor proportions and factor shares, independent of factor prices[2].

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[2] See Chambers (1988) for further details.

3.2.b Separability in production structure:

The production function

$$Y = y(K_1 \ldots K_K,\ L_1 \ldots L_L,\ E_1 \ldots E_M,\ M_1 \ldots M_N)$$

is weakly separable in the K, L, E, M aggregates if it can be written as,

$$Y = y[K(K_1 \ldots K_K),\ L(L_1 \ldots L_L),\ E(E_1 \ldots E_M),\ M(M_1 \ldots M_N)]$$

where $K(K_1 \ldots K_K)$, $L(L_1 \ldots L_L)$, $E(E_1 \ldots E_M)$, and $M(M_1 \ldots M_N)$ are aggregate functions and K, L, E, and M are aggregate inputs of capital, labour, energy and materials, respectively. The marginal rate of substitution between E_i and E_j is independent of the quantities of K_k, L_l and M_n demanded, $i,j = 1 \ldots E$; $k = 1 \ldots K$. $l = 1 \ldots L$; $n = 1 \ldots N$. For instance, the optimal choice[3] of the energy mix is independent of the capital mix and the level of the capital aggregate even though the aggregate E is not.

Fuss (1977) points out that, imposition of separability constraint yields two important results. First, only under weak separability do aggregates exist. Second, the existence of aggregates which are homothetic in their components implies an underlying two-stage optimisation procedure: optimise the mix of components within each aggregate and then optimise the level of each aggregate. The former justifies the separate construction of a sub-model in the energy components. The latter result justifies the construction of a model in the aggregates alone.

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[3] Cost-minimising or alternatively profit-maximising.

3.3 The Deterministic Model:

3.3.a The aggregate 'KLEM' Model:

Weak separability as stated above allows the modelling to proceed in two stages. It is convenient to begin with the construction of the model in the aggregates alone. Assume that there exists in the Indian manufacturing a twice differentiable aggregate production function of the form,

$$Y = y(K, L, E, M, T) \tag{3.1}$$

It summarises the underlying technology where, Y denotes total output, K denotes capital, L stands for labour, E for energy, M for materials and T denotes time used as a proxy for technological change. Assuming perfect competition in the factor markets, the factor prices and the output levels are exogenously determined. The 'duality theory'[4] then implies that, given the cost minimising behavior corresponding to such a production function there exist a cost function reflecting the same technology employed. In its general form it is written as,

$$C = c(P_K, P_L, P_E, P_M, Y, T) \tag{3.2}$$

here C is the total cost, P_K, P_L, P_E and P_M are the input prices of K, L, E and M respectively. For purposes of empirical estimation it is necessary to specify an explicit functional form for C. It is desirable to choose a functional form which is flexible, in the sense that it places minimal a priori restrictions on the

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[4] Duality theory: A fundamental result of the duality theory is that, given certain regularity conditions there exist production and cost functions which correspond (are dual) to each other. It implies that, the technology of a firm (or any producing unit) employing several factors to produce a single output can be represented by a relationship between inputs and output (a production function) or equivalently by a relationship between input prices and cost (a cost function). This result was proved and its importance in econometric application was first brought to light by Shephard (1953) and Uzawa (1962).

characteristics of the production function, and in particular on the elasticities of substitution. Over time, the forms suggested in applied production analysis have made concessions for greater flexibility regarding the elasticity of substitution and marginal products. Among such functional forms are the generalised Cobb-Douglas - discussed in Diewert (1973), generalised square root quadratic function introduced by Diewert (1971, 1973, 1974), generalised Leontief, again discussed in Diewert (1971) and the transcendental logarithmic (translog) function introduced by Christensen, Jorgenson and Lau (1971, 1973).

Among them however, the translog cost function has the distinction of being the most often used functional form in the studies on factor and fuel consumption. The true advantages in using a translog function are: (i) The translog production and price frontiers can include multiple products and multiple inputs; (ii) It is flexible, in the sense that it permits the technology to exhibit an arbitrary set of partial elasticities of substitution between pairs of inputs at a given point in input price (or quantity space); (iii) The translog is parsimonious; it has the minimal number of free parameters required to have the flexibility property; and (iv) The translog function results in derived demand equations for the inputs which are linear in unknown parameters. This makes it a functional form which is easy to compute, (Dargay, 1983).

Accordingly, the translog approximation to the cost function has been employed here as a description of the underlying production technology. It can be viewed as a second order approximation to an arbitrarily twice differentiable cost function. It is expressed as a quadratic function in the logarithms of input prices and output. For the four input structure the translog cost function corresponding to (3.2) can be written as,

$$\begin{aligned}\ln C = {} & \ln\alpha_0 + \alpha_K \ln P_K + \alpha_L \ln P_L + \alpha_E \ln P_E + \alpha_M \ln P_M + \alpha_Y \ln Y + \alpha_T \ln T \\ & + 1/2\ \gamma_{KK}(\ln P_K)^2 + \gamma_{KL}\ln P_K \ln P_L + \gamma_{KE}\ln P_K \ln P_E + \gamma_{KM}\ln P_K \ln P_M \\ & + 1/2\ \gamma_{LL}(\ln P_L)^2 + \gamma_{LE}\ln P_L \ln P_E + \gamma_{LM}\ln P_L \ln P_M + 1/2\ \gamma_{EE}(\ln P_E)^2 \\ & + \gamma_{EM}\ln P_E \ln P_M + 1/2\ \gamma_{MM}(\ln P_M)^2 + 1/2\ \gamma_{YY}(\ln Y)^2 + \gamma_{KY}\ln P_K \ln_Y \\ & + \gamma_{LY}\ln P_L \ln Y + \gamma_{EY}\ln P_E \ln Y + \gamma_{MY}\ln P_M \ln Y + 1/2\ \gamma_{TT}(\ln T)^2 \\ & + \gamma_{KT}\ln P_K \ln T + \gamma_{LT}\ln P_L \ln T + \gamma_{ET}\ln P_E \ln T + \gamma_{MT}\ln P_M \ln T + \gamma_{YT}\ln Y \ln T \end{aligned} \tag{3.3}$$

The cost function thus written allows for non-homotheticity and non-constant returns to scale of the production structure[5]. A measure of non-neutral or biased technical change has been incorporated in the function[6]. The proxy for technical change has been included in the logarithmic form here, thus imposing a rate of technical change which varies overtime in a particular way. Alternatively, a simple time trend, implying a smooth exponential growth in technology overtime could be taken. Infact both models

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[5] The translog cost function corresponds to a 'homothetic' production function structure, if and only if, it could be written as a separable function of output and factor prices; if, $\gamma_{iY} = 0$ for all i, where i stands for all the four inputs. In the terms of a cost function it implies that the cost minimising input mix is determined solely by input prices and is independent of the level of production. A homothetic production structure is further constrained to be 'homogeneous' if the elasticity of cost with respect to output is constant. That is, if $\gamma_{YY} = 0$. The cost function is linearly homogeneous and the underlying technology is characterised by constant returns to scale, if $\gamma_{iY} = \gamma_{YY} = 0$ and $\alpha_Y = 1$.

[6] This is in keeping with the studies of Lynk (1983), Jha, Murty and Paul (1991).

were estimated and the model with the logarithmic 'T' term was found to be superior. This model alone has been reported.

The structure of the production process[7] can be analysed by estimating the cost function (3.3) directly. However, the number of parameters to be estimated is very large and multicollinearity among the exogenous variables may pose a threat to the precision of the estimates. In order to minimise this problem, empirical estimates are based not on the cost function but on the derived demand equations. They can be obtained by using Shepard's Lemma.

Shephard's Lemma[8] implies that, the factor demand are the partial derivatives of cost function with respect to input prices; $\partial C/\partial P_i = X_i$, where X_i stands for the cost minimising quantity demanded of the i^{th} input. Then,

$$\partial \ln C/ \partial \ln P_i = (\partial C/ \partial P_i).(P_i/C) = (P_iX_i)/C = S_i$$

here S_i represents the share of the i^{th} input in the total cost of production. The factor demand functions, in terms of cost shares, for the four inputs take the form,

$$\begin{aligned}
S_K &= \alpha_K + \gamma_{KK}\ln P_K + \gamma_{KL}\ln P_L + \gamma_{KE}\ln P_E + \gamma_{KM}\ln PM + \gamma_{KY}\ln Y + \gamma_{KT}\ln T \\
S_L &= \alpha_L + \gamma_{KL}\ln P_K + \gamma_{LL}\ln P_L + \gamma_{LE}\ln P_E + \gamma_{LM}\ln P_M + \gamma_{LY}\ln Y + \gamma_{LT}\ln T \\
S_E &= \alpha_E + \gamma_{KE}\ln P_K + \gamma_{LE}\ln P_L + \gamma_{EE}\ln P_E + \gamma_{EM}\ln P_M + \gamma_{EY}\ln Y + \gamma_{ET}\ln T \\
S_M &= \alpha_M + \gamma_{KM}\ln P_K + \gamma_{LM}\ln P_L + \gamma_{EM}\ln P_E + \gamma_{MM}\ln PM + \gamma_{MY}\ln Y + \gamma_{MT}\ln T
\end{aligned} \quad (3.4)$$

where, S_K, S_L, S_E and S_M refer to the share of capital, labour,

[7] The structure of the production function specifies the technical relation existing between the inputs and the outputs at a given time period. It also incorporates information on the elasticity of substitution, marginal product, etc.

[8] For detail discussion, see Diewert (1971).

energy and materials respectively. In order that the system of equations (3.4) satisfy the adding up criterion ($\Sigma S_i=1$), and the underlying production function satisfies the properties of neo-classical production theory, the conditions of 'symmetry' along with that of 'linear homogeneity in prices' must be satisfied by (3.3)[9]. The condition of symmetry imposes the following restriction on the parameters of the share equations,

$$\gamma_{ij} = \gamma_{ji} \qquad \text{where, } i \neq j \qquad i,j = K,L,E,M \tag{3.5}$$

Linear homogeneity in factor prices on the other hand means that for a given level of output, a proportional increase in all factor prices should result in a proportionate increase in the production cost. This condition further implies the following restrictions on the parameters of (3.4),

$$\begin{aligned}
\alpha_K + \alpha_L + \alpha_E + \alpha_M &= 1\\
\alpha_{KK} + \alpha_{KL} + \alpha_{KE} + \alpha_{KM} &= 0\\
\alpha_{KL} + \alpha_{LL} + \alpha_{LE} + \alpha_{LM} &= 0\\
\alpha_{KE} + \alpha_{LE} + \alpha_{EE} + \alpha_{EM} &= 0\\
\alpha_{KM} + \alpha_{LM} + \alpha_{EM} + \alpha_{MM} &= 0\\
\alpha_{KY} + \alpha_{LY} + \alpha_{EY} + \alpha_{MY} &= 0\\
\alpha_{KT} + \alpha_{LT} + \alpha_{ET} + \alpha_{MT} &= 0
\end{aligned} \tag{3.6}$$

It can be seen that majority of the parameters of the cost function in (3.3) can be determined by estimating the system in (3.4).

In order to test the hypothesis that the technical change in the manufacturing sector is (partially) responsible for the rise in the energy demand in the sector, information on this facet of the production process can be obtained from the share equations specified.

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[9] See Christensen et.al (1973).

According to Binswanger (1974), measure of technical change can be obtained by differentiating the cost function twice with respect to the input price and the level of technology. Thus, $\gamma_{iT} = (\partial^2 \ln C)/(\partial \ln P_i \, \partial T)$. The parameter γ_{iT} which appears as co-efficient of time in the share equations denotes the bias in the technical change. It signifies how dynamic factors affect the choice of individual inputs. If $\gamma_{iT} > 0$, then the technical change displays a positive bias for the input i, and the technology is said to be input i using. The cost share associated with the ith input goes up with a change in technology. On the other hand, if it is negative, then the technology is input i saving. Finally if $\gamma_{iT} = 0$, it implies neutral technical change and the cost function remains unaffected by technological change.

Besides this the scale effect can be analysed with the help of the co-efficient of output γ_{iY} in the share equations which indicates the effect of a 1 per cent change in output on the cost share of an input. It signifies the extent of disproportionalities in the use of inputs as an effect of the change in scale. If it is equal to zero it signifies constant returns to scale, if on the other hand it is negative it implies that the cost share of the i^{th} input has been going down with an increase in the output (economies of scale are implied). If on the other hand it is positive then diseconomies with regards to that particular input is implied.

The testing of the next hypothesis involves examining the nature of relationship among inputs. At an individual co-efficient level, the γ_{ij} in the share equations indicate the effect of a 1 per cent change in the price of factor j on the cost share of the input i[10]. These estimates can be used to study the nature of the relationship between the inputs (factor substitution) and price responsiveness of the inputs.

Given two inputs say E_1 and E_2 and their prices U_1 and U_2, the Hicksian elasticity of substitution between inputs is, $(\hat{E}_2 - \hat{E}_1)/(\hat{U}_1 - \hat{U}_2)$, where circumflexes '^' denote the percentage change[11]. Mundlak (1968), generalises this result to N-dimensional case and provides three alternative measures[12] of substitutability between the inputs E_i and E_j: (1) The one-factor, one-price elasticities of substitution (OOES) are those that are expressed as, $\hat{E}_i/\hat{U}_j$. This 'partial' measure comes to rescue in overcoming the difficulty arising in quantifying elasticity of substitution for a general N-factor case. It defines the elasticity of substitution between factors i and j as, the response of a change in the price of the j^{th} factor on the amount demanded of the i^{th} factor, when all the other factor prices are held constant; (2) The two-factor, one-price elasticities of substitution (TOES) take the form, $(\hat{E}_i - \hat{E}_j)/\hat{U}_j$. This measures the change in the input ratio between i and j in response to a change in the price of j^{th} input; (3) Finally the two-factor, two-price elasticities (TTES) are written as, $(\hat{E}_i - \hat{E}_j)/(\hat{U}_j$

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[10] Also if all $\gamma_{ij} = 0$, the translog cost function dissolves into a Cobb-Douglas one.

[11] Following which elasticity of substitution is the percentage change in the relative amount of factors employed resulting from a given percentage change in the relative prices. Alternatively, it can be interpreted as the elasticity of an input ratio with respect to an input price ratio.

[12] Alternative measures of elasticity are based on the intuitive reasoning that a ratio (say a/b) can change in several ways. The value of `a' alone can change, or the value of `b' can change, or both `a and b' can change simultaneously.

$- \hat{U}_i$). The TTES shows the percentage adjustment in input ratios to changes in the factor price ratios. As such they are closest to Hick's definition of elasticity of substitution[13].

All elasticities specified are evaluated at constant output. Inputs are classified as substitutes if the elasticity of substitution is positive and as complements if the elasticity is negative. Unfortunately this classification of inputs is not independent of the choice of elasticity measure, as shall be shown below.

The Allen-Uzawa partial elasticity of substitution, (henceforth referred to as AES) is consistent with OOES[14]. Brent and Wood (1975) have shown that for a translog cost function the AES can be calculated as,

$$\sigma_{ii} = (\gamma_{ii} + S_i^2 - S_i)/ S_i^2,$$

$$\sigma_{ij} = (\gamma_{ij} + S_i S_j)/(S_i S_j), \qquad i \neq j$$

$$i,j = K,L,E,M \qquad (3.7)$$

These AES are not constrained to be constant but may vary with the level of factor prices (as the elasticities are a function of the

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[13] The theoretical framework employed for the discussion on the three measures of elasticity is adopted from Chambers (1988), pp: 93 to 100.

[14] AES, (Allen, 1938) defines the elasticity of substitution between factors i and j as the normalised response of a change in the price of the j^{th} factor on the amount demanded of the i^{th} factor, when all the other factor prices and output are held constant, however the quantities of all other factors are allowed to vary. Uzawa (1962) has derived the Allen partial elasticities of substitution between input i and j, as $\sigma_{ij} = (C\, C_{ij})/(C_i\, C_j)$ where, $C_i = \partial C/\partial P_i$, and $C_{ij} = \partial^2 C/(\partial P_i\, \partial P_j)$, and by definition, $\sigma_{ij} = \sigma_{ji}$. For a detailed treatment see Allen R G D (1938) and Uzawa (1962).

cost shares) and with the level of output (since the function is non-homothetic).

For understanding the price responsiveness of inputs the price elasticity of demand (E_{ij}) is estimated. It can be defined as,

$$E_{ij} = \partial \ln X_i / \partial \ln P_j, \qquad i \neq j$$

where output quantity and all other input quantities are fixed. This measure gives the change in the demand of i^{th} input in response to a change in the price of the j^{th} input. Allen (1938) has shown that the AES are analytically related to the price elasticities of demand for factors of production in the following manner,

$$E_{ij} = S_i \, \sigma_{ij} \qquad i \neq j$$

$$i = K,L,E,M \qquad (3.8.a)$$

by looking at the term E_{ii}, the influence of own price change on the i^{th} input can be known, this can be written as,

$$E_{ii} = S_i \, \sigma_{ii} \qquad i = K,L,E,M \quad (3.8.b)$$

Due to symmetry condition even though $\sigma_{ij} = \sigma_{ji}$, in general $E_{ij} \neq E_{ji}$.

Even though the AES measures input responsiveness to input price changes, it is somewhat limited since it only measures how single input adjusts to single factor price changes. It yields little information on relative input adjustments to factor price change. The TOES because of its inherent nature takes into account the relative input adjustment to factor price changes. The elasticity consistent with TOES is the Morishima elasticity of substitution (henceforth referred to as MES), and is written by Koizumi (1976) as,

$$\sigma_{ij}^{M} = S_j(\sigma_{ij} - \sigma_{jj}) = E_{ij} - E_{jj} \qquad (3.9)$$

(The superscript 'M' denotes MES). The MES measures how input ratios respond to single input price changes. Note that though the AES measure is symmetric, ($\sigma_{ij} = \sigma_{ji}$), the MES is not. As the MES measure is not sign symmetric the classification of inputs i and j as substitutes or complements depends critically on which input price changes (i or j). Also note that if, $\sigma_{ij} < 0$ but that, $|\sigma_{jj}| > |\sigma_{ij}|$. Since concavity of the cost function implies that, $\sigma_{jj} < 0$ it follows that $\sigma_{ij}^M > 0$. Thus, there may be instances where inputs are substitutes according to MES but complements according to AES, (Ball and Chambers, 1983).

The third and the last measure of elasticity is the TTES, corresponding to which is the shadow elasticity of substitution or the McFadden elasticity of substitution (henceforth referred to as SES). It is evaluated at constant average cost and shows the percentage adjustment in input ratios to changes in factor price ratios. It is[15],

$$\sigma_{ij}^S = [(S_i \; S_j)/(S_i + S_j)] * (2\sigma_{ij} - \sigma_{ii} - \sigma_{jj}) \qquad (3.10)$$

(Here the superscript 'S' differentiates SES from the other measures). Since both MES and SES are derived from the AES they too can vary with the output (due to the non-homogeneity of the cost function). Note that this TTES is in fact symmetric ($\sigma_{ij}^S = \sigma_{ji}^S$), in addition to providing a more complete measure of relative input responsiveness to relative price changes.

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[15] Alternatively the SES can be written as, $\sigma_{ij}^S = [S_i/(S_i + S_j)] * \sigma_{ij}^M + [S_j/(S_i + S_j)] * \sigma_{ji}^M$. It means the SES is also the weighted average of two MES where the weights are given by the relative cost shares.

Chambers (1988) notes that, different elasticity measures giving differing results highlights the difficulty in defining a meaningful measure of substitution elasticity in the many-input case, and any work on applied production analysis must have occasion to show interest in all the three measures. The present study attempts to see how the energy and non-energy inputs respond in the face of a price change. Suppose only the price of energy changes, then to capture the degree of response of other inputs in terms of elasticities, the AES measure would be sufficient. Alternatively if, change in input ratio between energy and a non-energy input as an effect of a change in price of one of the inputs is to be captured then the best measure would be MES. However, one can also envisage a situation where the prices of all inputs or atleast a few change simultaneously. The interest would then lie in looking at the relative input response to the relative price change. Therefore one also needs to look at the elasticity as given by SES. This study attempts to look at all the three elasticities prescribed in the literature, and in this light to try and understand the nature of the relationship between inputs.

Besides symmetry and linear homogeneity in prices, there are other conditions that the cost function must satisfy, so that it is well behaved[16]. These are: (i) its input demand functions must be strictly positive (to ensure that monotonicity is satisfied); and (ii) it should be concave in prices. The tranlog cost function belongs to the family of flexible functional forms which do not

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[16] Thus satisfying the requirements of cost minimising demand theory, and to ensure that the underlying production function satisfies the properties of neo-classical production technology. See Brendt and Wood (1975).

globally (for all possible factor prices) satisfy the conditions required for it to be well behaved. It becomes imperative then to check for the well behavedness of the model atleast in the sample region. The first condition of strictly positive input demand functions is satisfied if the fitted cost shares are positive at each one of the observations. The second condition of concavity requires that the Hessian matrix of the second order derivatives are negative semi-definite at every data point. A less stringent test however is applicable, which requires the estimated own price elasticities of demand for factors to be negative, thus satisfying the condition of concavity.

3.3.b The energy sub-model:

Aggregate inputs consist of a number of components. A firm will select that mix of components which minimise the cost of each input, subject to the constraints imposed by the production technology. Therefore, the price of an aggregate input is more correctly specified as an endogenous variable, even when the prices of individual components are assumed exogenous. While this logic can be extended to all inputs, the present study concentrates on introducing the components of energy into the model.

Consider the case where a firm can choose from among various energy types, E_i, $i = 1,\dots n-1, n$. The production function can then be written as,

$$Y = y(K, L, E_1, \dots E_{n-1}, E_n, M, T) \qquad (3.11)$$

Imposing the assumption of homothetic weak separability in the energy input, the production function becomes,

$$Y = y[K, L, E(E_1, \dots E_{n-1}, E_n), M, T) \qquad (3.12)$$

where E, the total energy measure is the appropriately chosen homothetic aggregator function.

Using the theory of duality of cost and production it can be shown that corresponding to (3.12) there exist a weakly separable cost function,

$$C = c[P_K, P_L, P_E(P_{E1}, \ldots P_{En-1}, P_{En}), P_M, Y, T] \qquad (3.13)$$

Here P_{Ei} refer to the price of the fuel types. In this study the fuel types considered are coal, oil and electricity (referred to as C, O and E). P_E is also an aggregator function, referred to as the aggregate price index. Since it is the price per unit of energy, it also dually represents the cost per unit to the cost minimising/profit maximising firm. This cost can be expressed by an arbitrary unit cost function. For reasons specified earlier the chosen (unit) cost function is in the translog form written as[17],

$$\begin{aligned} \ln P_E = {} & \ln\beta_0 + \beta_C \ln P_{EC} + \beta_0 \ln P_{E0} + \beta_E \ln P_{EE} + 1/2\ \beta_{CC}(\ln P_{EC})^2 \\ & + \beta_{C0}\ln P_{EC}\ln P_{E0} + \beta_{CE}\ln P_{EC}\ln P_{EE} + 1/2\ \beta_{00}(\ln P_{E0})^2 \\ & + \beta_{CE}\ln P_{EC}\ln P_{EE} + 1/2\ \beta_{EE}(\ln P_{EE})^2 + 1/2\ \beta_{TT}(T)^2 \\ & + \beta_{CT}\ln P_{EC}\ T + \beta_{0T}\ln P_{E0}\ T + \beta_{ET}\ln P_{EE}\ T \end{aligned} \qquad (3.14)$$

This cost function refrains from imposing the constraint of technological change being neutral in fuel efficiency bias and towards this end specifies a proxy for technological change in the linear form. Alternatively it could have taken a logarithmic form (by allowing a lnT instead of the simple T term to denote the time trend). Both models were in fact estimated and the one with simple

[17] Following Fuss (1977), Murty M N (1986).

T as time trend was found to be a better fit. Hence only this model has been specified.

Cost minimising behavior implies that by employing the Shephard's Lemma, the demand functions for the individual energy type in terms of shares (S_{Ei}) in the cost of aggregate energy take the form,

$$S_{EC} = \beta_C + \beta_{CC}\ln P_{EC} + \beta_{CO}\ln P_{EO} + \beta_{CE}\ln P_{EE} + \beta_{CT} T$$
$$S_{EO} = \beta_O + \beta_{CO}\ln P_{EC} + \beta_{OO}\ln P_{EO} + \beta_{OE}\ln P_{EE} + \beta_{OT} T$$
$$S_{EE} = \beta_E + \beta_{CE}\ln P_{EC} + \beta_{OE}\ln P_{EO} + \beta_{EE}\ln P_{EE} + \beta_{ET} T \qquad (3.15)$$

Here S_{EC}, S_{EO} and S_{EE} denote the cost shares of coal, oil and electricity in the aggregate cost on energy input respectively. In the share equations the parameter estimates have a specific interpretation. β_{ij} indicates the change in the cost share of the ith fuel type resulting from a 1 per cent change in the j^{th} fuel price. β_{iT} denotes the influence of technological change on the cost shares of fuels, for example, if $\beta_{iT} > 0$ reflects the ith fuel using bias, $\beta_{iT} < 0$ reveals the ith fuel saving bias and finally $\beta_{iT} = 0$ shows that the technological change is neutral in its fuel efficiency bias.

Again in order to satisfy the adding up criterion ($\Sigma S_{Ei} = 1$) and the properties of the neo-classical production function, the restrictions of 'symmetry' and 'linear homogeneity in prices' have to be imposed on the parameters. Symmetry implies,

$$\beta_{ij} = \beta_{ji} \qquad \text{where } i \neq j \text{ and } i,j = C, O, E. \qquad (3.16)$$

while linear homogeneity requires,

$$\begin{aligned}
&\beta_C + \beta_O + \beta_E = 1 \\
&\beta_{CC} + \beta_{CO} + \beta_{CE} = 0 \\
&\beta_{CO} + \beta_{OO} + \beta_{OE} = 0 \\
&\beta_{CE} + \beta_{OE} + \beta_{EE} = 0 \\
&\beta_{CT} + \beta_{OT} + \beta_{ET} = 0
\end{aligned} \qquad (3.17)$$

The last restriction on (3.14) has been necessitated by the assumption of non-neutral fuel efficiency bias.

The inter-fuel substitution elasticities can be measured using all the three measures of elasticity, viz., AES, MES, and SES, and the price elasticities of factor demand can be measured as in the case of the KLEM model. The only difference that needs to be noted is that, these elasticities are independent of the level of output as the unit energy cost function is homothetic.

Finally as was in the case of the aggregate model well behavedness of the unit energy cost function requires that, the fitted fuel cost shares be positive at every observation (to satisfy the condition of monotonicity). For the condition of concavity in input prices the estimated own price elasticities of demand have to be negative for each fuel type.

Estimation of the complete model is accomplished via the following two stage optimisation procedure:

(1) In the first stage, the system of equations (3.15) are estimated subjected to the constraints of symmetry (3.16) and linear homogeneity in prices (3.17). The parameter estimates help estimate the elasticities of substitution between the energy types and the price elasticities given any set of relative energy prices.

In addition to this by substituting the parameter estimates into (3.14), an estimate of the aggregate energy price, P_E^* (upto an arbitrary scaling factor β_0) can be obtained. This serves as an instrumental variable in the second stage of estimating the aggregate model.

(2) Second stage estimates the system of equations (3.4) subject to the constraints of symmetry (3.5) and linear homogeneity (3.6) replacing the P_E by the instrumental variable P_E^*.

3.4 Estimation procedure:

The justification for using P_E^* as the appropriate instrumental variable for P_E in the aggregate model is provided here. The aggregate energy price in the aggregate model P_E is endogenous even though the energy components prices P_{Ei} are exogenous. This might lead to simultaneous equation bias in the estimation of the aggregate KLEM model. In order to avoid this bias and to restrict the number of components entering the estimation procedure, Divisia index, (a discrete approximation to the continuous Divisia index) is commonly computed. Diewert (1976) has shown that the Divisia index has a number of desirable properties[18]. This index is supposed to be exact for a translog model, and its greatest advantage lies in its ability to measure changes accurately over time (Diewert, 1975). The continuous Divisia aggregate energy price index in its differential form can be written as,

$$d \ln P_E = \sum_i S_{Ei} \, d \ln P_{Ei} \qquad (3.18)$$

[18] For details see, Christensen et.al (1973), Brent and Wood (1975), Fuss (1977) and Murty (1986).

A discrete approximation for this is,

$$\ln P_E - \ln P_E^0 = \sum_i 1/2\ (S_{Ei}^0 + S_{Ei})\ (\ln P_{Ei} - \ln P_{Ei}^0) \qquad (3.19)$$

The superscript '0' indicates base period normalisation values. Suppose the base period normalisation values set all energy type prices equal to 1. β_0 in (3.14) is also set equal to 1 since the aggregate energy price is unique upto a scalar multiple. Then from (3.15) we have $S_{Ei}^0 = \beta_i$. The Divisia approximation becomes,

$$\ln P_E = \sum_{i=1}^{n} 1/2\ (\beta_i + S_{Ei})\ \ln P_{Ei}$$

$$= \sum_{i=1}^{n} 1/2\ [\beta_i + (\beta_i + \sum_j \beta_{ij} \ln P_{Ej} + \beta_{iT})]\ \ln P_{Ei}$$

$$= \sum_{i=1}^{n} \beta_i \ln P_{Ei} + 1/2 \sum_i \sum_j \beta_{Ei} \ln P_{Ei} \ln P_{Ej} + 1/2 \sum_i \beta_{iT} \ln P_{Ei}\ T \qquad (3.20)$$

The replacement of β_i, β_{ij} in (3.20) by the estimates from the energy sub-model provides the means of computing the instrumental variable. Given: (1) the stochastic specification usually assumed for multivariate models; (2) the exogenous nature of the P_{Ei}, P_K, P_L, P_M and Y; and (3) homothetic weak separability, the instrumental variable construction in (3.20) can be used to obtain consistent parameter estimates for the sub-model and the aggregate model. The two stage procedure outlined in section 3.3.a and 3.3.b provides a consistent estimate of the price index of aggregate energy and avoids simultaneous equation bias in the estimation of parameters of the aggregate model (Fuss, 1977). With the translog specification of the unit cost function for energy as in equation (3.20), the system (3.15) can be estimated subject to the constraints (3.16) and (3.17). The parameter estimates thus obtained can be substituted in (3.20) to arrive at the aggregate price index for energy. This Divisia index is used as an instrumental variable in the second stage, the estimation of the aggregate 'KLEM' model.

The statistical treatment of the model specified in the preceding sections requires it to be embedded in a stochastic framework. It is assumed that deviations of the actual cost shares from the logarithmic derivatives of the translog cost function are the result of random errors in the cost minimising process. Subsequently to each cost share in (3.4) an additive disturbance term is appended. The system of cost shares specified in (3.4) now take the stochastic form,

$$S_i = \alpha_i + \Sigma\, \gamma_{ij} \ln P_j + \gamma_{iY} \ln Y + \gamma_{iT} \ln T + \varepsilon_i, \qquad i,j = K,L,E,M$$

On similar lines the fuel cost shares in (3.15) take the stochastic form,

$$S_{Ei} = \beta_i + \Sigma\, \beta_{ijj} \ln P_{Ej} + \beta_{iT}\, T + \mu_i, \qquad i,\ j = C,O,E$$

Here ε_i and μ_i are vectors of error terms.
These disturbances capture the random errors in the cost-minimising behavior which are a result of explanatory variables not accounted for.

In each of these models, the disturbance from one of the equations is arbitrarily dropped and it is specified that the column vector of the disturbance terms in the remaining equations is independently and identically normally distributed with mean vector zero and non-singular covariance matrix.

When the disturbance covariance matrix is singular and non-diagonal the standard estimation procedure adopted is to delete one of the equations arbitrarily from the system equations and employ an estimation procedure which will result in estimates that are invariant to which equation is deleted.

Barten (1969) showed that Maximum Likelihood estimates of a system of share equations with one equation deleted are invariant with respect to which equation is dropped. Kmenta and Gilbert (1968) have shown that iteration of the Zellner estimation procedure converges to the Maximum Likelihood estimates.

Accordingly, one equation is arbitrarily dropped from the system of the share equations in (3.4) and (3.15), and the remaining equations are jointly estimated as a multivatriate regression system, using the Zellners ISUR method[19]. The materials share equation was dropped in the aggregate model and the electricity share equation dropped in the sub-model. The parameters of the dropped share equations can be computed using the estimates of the parameters of the other share equations, by imposing the symmetry and the linear homogeneity constraints.

The next chapter takes up the task of constructing the variables involved for the estimation of the 2 stage optimisation procedure outlined in this chapter.

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[19] The software package used for the purpose of estimation is Micro Time Series Processor (MicroTSP) version 7.0, developed by Lilien M David (1983-1990).

Chapter 4

DATA AND CONSTRUCTION OF VARIABLES

4.1 Introduction:

Within the framework of energy management, the study makes an attempt to estimate the type of technological change and the possibilities of factor and fuel substitution in the manufacturing sector of India. For the same, a two stage optimisation procedure has been specified in the previous chapter. The estimation of the aggregate 'KLEM' model requires information on the cost shares of various factor inputs (capital, labour, energy, and materials) in the total cost of production and their respective price data. The estimation of the energy sub-model requires information on the cost shares of the various fuels (coal, oil, and electricity) in the total energy cost as well as the data on their prices.

In this chapter, a description of the methodology employed in order to obtain the cost and prices of various factor and fuel inputs is presented. The plan of the chapter is as follows: Section 2 presents a brief overview of the main source of data - the 'Annual Survey of Industries'. The third section deals with a description of the methodology adopted to obtain the cost and prices of the various factor and fuel inputs. In the final section preliminary analysis of the data is taken up. In this section, the trends in the value of output, prices, costs of the various factor and factor inputs in the manufacturing sector are analysed in detail.

4.2 A note on the data sources:

The present study has used the 'Annual Survey of Industry' (ASI), Summary Results for the Factory Sector, published by the Central Statistical Organisation as its main source of data. Data has also been drawn from the Reserve Bank of India Bulletins, the Index Number of Wholesale Prices in India, published by the Office of the Economic Adviser (Government of India), Chandhok and the Policy Group's (1990) India data base: The economy, the Centre for Monitoring Indian Economy publications, 'Productivity' (1991), a publication of the National Productivity Council, and others. A brief note on the prime data source- the ASI is presented below.

The present study draws data from the Factory Sector, Summary Results of the ASI[1]. For reasons stated earlier the period covered by the study is from 1970-71 to 1990-91. The reference year for the ASI is the accounting year of the factory ending on 31st March. The survey provides detailed information on matters like, fixed capital, working capital, invested capital, number of workers, number of employees, wages to workers, total emoluments, fuels consumed, materials consumed, other inputs, total inputs, value of output, depreciation and so on. All this data is provided in value terms, (in lakh of rupees), except where it is specified to be in numbers. Upto the year 1973-74, detailed information on the quantities of fuels and materials components were reported along with their values. However, after 1973-74 these inputs were published only in value terms. Moreover, as the ASI has not published the survey report for 1972-73, to maintain continuity, the study takes a simple average of 1971-72 and 1973-74. The definition of the manufacturing sector remains as stated in Chapter 2.

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[1] Besides the summary volumes detailed factory sector results are published in 10 volumes. The `factory sector' of the ASI includes the survey of registered factories. It has been further divided into the `census sector' and the `sample sector'. For details see the summary volume of the ASI.

4.3 Construction of variables:

This section shall take up the task of building variables using the ASI and other previous mentioned sources of data, for the purpose of estimation of the complete model. Measurement of output is discussed first, followed by measurement of costs and prices of capital, labour, energy and materials. While measuring energy the cost shares and prices of three fuel types viz., coal, oil, and electricity have been discussed.

4.3.a Measurement of output:

For measuring output most of the earlier production function studies have used the value added approach. However, this measure excludes intermediate materials including energy. In view of the fact that this study attempts to focus on the role of energy as an input in the production process, gross value of output at constant prices is preferred to value added as a measure of output.

The value of output of the manufacturing sector as provided by the ASI are deflated using the Wholesale Price Index (WPI) for the manufacturing sector (1970-71 = 100), in order to obtain the gross output at fixed prices.

4.3.b Measurement of capital:

A knowledge of capital stock is required as a measure for capital input. After the pioneering study by Goldsmith in 1951, many studies have used the 'Perpetual Inventory Method' (PIM) for estimating capital stock. This technique is defined as, summation of different vintage of capital assets, across the years, of service lives. It needs data on acquisition of machinery, usable life span of capital stock, base year ('bench mark') prices, and price deflators. A number of studies have employed this technique for capital estimation with reference to India[2].

The present study has employed the estimates as computed by the study of Balakrishnan and Pushpangadan (1994). A detail discussion of the methodology employed by them can be found in the Appendix 3 of their paper. These estimates are given in constant prices (base 1960-61=100). To convert this capital stock to current prices, the WPI for machine and machine tools as given by the same study has been used. Moreover, the capital stock estimates were reported only upto 1988. In order to compute the capital stock for the year 1989-90 and 1990-91, the investment figures for those years had to be computed (using the formula specified by the same study) and duly added on to the capital stock estimate of the respective preceding years. The estimates of stock by BalaKrishnan and Pushpangadhan (at 1960-61 prices), the WPI for machine and machine tools (1960-61 = 100), and the converted capital stock at current prices are given in the Appendix 4 B, Table 4.1. These stock figures at current prices are used as the capital input.

The price of capital, is computed using the method suggested by Griliches and Jorgenson (1966)[3]. They state that, in the absence

[2] See Goldar (1986), Ahluwalia (1991) and Balakrishnan and Pushpangadan (1994).

[3] In estimating capital flow, often a distinction is made between capital stock and capital service. To truly reflect the flow, stock data requires that the ratio of capital service to capital stock be identical for all assets, and also the asset prices (used as weights for measuring stock) need to be proportional to service prices. However, this is not so in reality. The present study has treated service of capital as the function of production, and used the method suggested by Grilliches

of direct taxation, the asset price q_k and the service price p_k of the k^{th} type of capital good would be related through the following equation:

$$p_k = q_k \; [r + \sigma_k - \dot{q}_k/q_k]$$

where,

p_k = service price of k^{th} capital good

q_k = asset price of k^{th} capital good

r = the rate of return on all capital

σ_k = the rate of replacement of k^{th} type of capital good

and, $\dot{q}_k/q_k$ = the rate of capital gain in this type of capital good

Following Murty (1986), Goldar et.al (1986), Jha et.al (1991) and others, the effect of capital gain on the price of services of capital is ignored, and the price of services of a rupee worth capital is estimated as '$(r+\sigma_k)$'. However, as Murty (1986) points out that, if the capital gain term is not duly deducted then this will lead to overestimation of the cost of capital services, for in India the capital goods price index has been rising continuously.

For estimating 'r', 'the yield on preference shares' has been taken from the various issues of the Reserve Bank of India Bulletins. This data is available upto 1978. For the remaining years, upto 1990, the rate taken is the 'yield on preference shares and convertible preference shares' as given by the 'Basic Statistics Relating to the Indian Economy', various issues (a 'Centre for Monitoring the Indian Economy' publication). The rate of depreciation 'σ_k' is computed using the depreciation and fixed capital figures for each year provided in the ASI. For the thus computed 'rate of depreciation' and the 'rate of return on capital' see Table 4.2, Appendix 4 B.

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and Jorgenson (1966), thus overcoming this problem.

The price index number of capital services are estimated by multiplying the price of a rupee worth of capital '$(r+\sigma_k)$' for each year with the weighted average of the WPI for machinery and transport equipment and the WPI for building material. This was computed from the relevant WPIs given in Chandhok (1990). These were available upto 1987. For the last three years of the study these WPIs were estimated by assuming that the growth rate they experienced were equal to the average annual growth of the preceding years (from 1970 onwards). This weighted average is in keeping with the components of capital investment[4].

The annual cost of capital services for the manufacturing sector is then computed by multiplying the price of a rupee worth of capital services '$(r+\sigma_k)$' with the capital stock estimates at current prices (earlier estimated from Balakrishnan and Pushpangadhan's study).

4.3.c Measurement of labour:

The ASI data on 'total number of employees', has been used as a measure of labour input in the present study, as done by Jha et.al (1991). This includes'workers', involved in the production process directly as well as the 'persons holding position of supervision or management or employed in confidential positions'[5]. This measure has an implicit assumption that workers and employees other than workers are substitutable, this is acknowledged as a limitation of labour measured.

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[4] See appendix 4 A for definition of fixed capital.

[5] See appendix 4 A.

The other measures of labour given by ASI are 'mandays' (for workers and employees), 'number of workers' and 'number of employees'. This study has refrained from using mandays as a labour measure because several studies have argued that computation of mandays in the ASI has been done by multiplying the number of workers in a shift by 8 (and not the actual duration of the shift) and then aggregating it across factories (Goldar, 1986). Taking 'workers' or 'employees' alone as a measure for labour has also been decided against, as the distinction between 'workers' and 'persons other than workers' is rather vague and unacceptable in the view that for efficient production a balance of both is essential.

The cost of labour is taken as 'total emoluments' paid to employees which includes according to ASI, 'wages,salaries and other benefits'. The price of labour is then derived by dividing 'total emoluments' by the 'total number of employees'. The data so obtained is then converted into index numbers with the base 1970-71.

4.3.d Measurement of energy:

The energy input measure has to be the amount of energy that is consumed by the manufacturing sector in quantity terms[6]. 'Productivity' (1991, page 650, table 2), has given estimates of the total energy input in Million Tons of Coal Replacement (MTCR),

[6] The ASI cannot be used here for as stated earlier the ASI stopped reporting quantity break up of energy components from 1973 onwards.

for both the mining and the manufacturing sectors combined[7]. It also gives the energy consumption by three types of energy inputs, viz., coal in Million Metric Tons (MMT), oil in MTCR and electricity in Million Kilowatts Hours (MKWH). The period covered is from 1953 to 1988. The conversion factor adopted by them is as follows,

MTCR = 1.5 MMT of coal

$$MTCR = \frac{MKWH}{1000}$$

To derive the energy consumption by manufacturing alone the consumption of the mining sector had to be separated from these estimates. This task was taken up for each individual fuel. For coal, the data on 'Offtake of Coal by Major Consumers' is published by the CMIE (June 1994, page 171). The offtake by the mining sector (Colliery) is given from 1982 TO 1994. The growth rate for this 12 year period was assumed for the earlier period and coal consumption by the mining sector was estimated for 1970 to 1990. This was then deleted from the combine (mining and manufacturing) consumption estimates, in order to arrive at the consumption of coal by the manufacturing sector alone. For electricity again CMIE (June 1994, page 18) gives data on sector wise 'Power Utilisation'. This has been used to compute the MKWH

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[7] The other source which gives the quantity data is the, `Report of the Energy Working Group' (1979). It was observed that the data provided by this source under the heading, "Energy Consumption by the Industries", corresponded with the data given by the Productivity (1991), which has been given for mining and manufacturing both. Using these estimates directly will overestimate the energy intake of the manufacturing sector and may result in misleading conclusions. However this source has been used by previous studies (Murty (1986). It will be shortly seen that the present study makes an effort (in no terms sufficient) to take care of this shortcoming.

of electricity consumed by the manufacturing sector for the concerned period[8]. Where consumption of oil by the mining sector is concerned estimates were available from 1988 onwards. It was observed that for these years (after 1988), the consumption of oil by mining as a percentage of the joint consumption by both mining and manufacturing was negligible (4 per cent, on an average). In light of this fact, the task of separating the oil consumption by manufacturing sector was not carried out and the estimates as given by 'Productivity' (1991) (for both sectors jointly) were used. The coal and oil consumption by the manufacturing sector for the years 1989 and 1990 were computed by assuming the annual growth in those years to be equal to the average annual growth over the period 1953 to 1988. All fuel quantities are then converted into MTCR. Table 4.3, Appendix 4 B gives the estimated quantities of all the three fuel types, along with the total energy input in the manufacturing sector and that of the mining and manufacturing together (this brings out the magnitude of the flaw in using the 'Productivity' (1991) data, without subtracting the consumption of the mining sector).

For the price of these energy types, their respective price indices were taken as given by "Chandhok" (1990), and CMIE (April, 1994), with the base year 1970-71.

In order to obtain the cost incurred by the manufacturing sector on various energy types, data on the price of coal per ton was used

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[8] The figures thus obtained are lower than the estimates given by the `Productivity' for the combined consumption (of mining and manufacturing), except for a five year period in the early 80's. The study has taken the lower estimates.

from the CMIE publication (June, 1994). The quantity of three types of fuels consumed by manufacturing sector were converted into Metric Tons (measure for coal), using the conversion factor. The cost of individual energy types is obtained by taking the product of the per ton coal price and quantities in tons. The total energy cost is the sum of cost incurred on each energy item. The cost share of each item is then computed by dividing the cost of that item by the total energy cost. The information on prices and cost shares of various fuels is used to estimate the energy sub-model.

In order to obtain the price of aggregate energy, the Divisia index has been extensively used in the KLEM studies. As specified in the earlier chapter this index is computed by the present study using the parameter estimates of the energy sub-model. Besides constructing this index the price of aggregate energy has been computed using data on the cost incurred by the manufacturing sector on fuels ('fuels consumed')[9] as given in the ASI volumes and dividing it by the quantity of total energy (as estimated). This cost has then been converted to the base of 1970-71. As for the cost of aggregate energy, the figures on aggregate fuel cost provided by the ASI have been taken.

4.3.e Measurement of materials:

The price index of the raw materials (base 1970-71=100), for the manufacturing sector as computed by the study of Balakrishnan and Pushpangadhan (1994), has been employed in this study. For the cost incurred on the material inputs by the manufacturing sector, the 'material cost' as given by the ASI has been used.

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[9] See appendix 4 A.

The total cost of production is computed by adding the cost incurred on each of the four inputs (K, L, E, and M). The cost shares of all the inputs have been obtained by dividing the cost on each input by the total cost of production.

4.4 Inputs costs and prices: certain trends

This section aims at conducting a preliminary analysis of the above constructed variables. It examines the trends in the cost and prices of various factor inputs, the value of aggregate output and the trends in the cost and prices of the various energy inputs. For this purpose average annual growth rates have been computed and presented in percentage terms, for the whole period of 1971-90 and for the sub-periods of 1971-80 and 1981-90.

To begin with growth in prices of the aggregate inputs, for the whole period and for the sub-periods are presented in Table 4.1.

Table 4.1

AVERAGE ANNUAL GROWTH RATES OF FACTOR PRICES INDICES (1970-71 = 100) (figures in percentage)

PERIOD	CAPITAL	LABOUR	ENERGY	MATERIALS
1971-90	10.53	10.53	12.59	9.56
1971-80	10.89	9.08	14.75	14.18
1981-90	10.18	11.97	10.43	4.93

The Table 4.1 clearly shows that between 1971-1990, average annual growth of energy price was the highest (12.59 per cent), followed by capital and labour prices. Material prices registered the lowest growth of 9.56 per cent for the period. As expected the price of energy grows faster in the decade of 1970, reflecting the crisis of 1973, and 1979. Labour prices registered the fastest growth in the 1980's and the materials input recorded the slowest growth, a mere 4.93 per cent. The input prices growing at different rates present another reason for examining the possibilities of factor substitution in the manufacturing sector of India, for reducing the cost of production.

Average growth rates in the costs of four inputs, total cost, and the growth of the gross output of the manufacturing sector are reported in the Table 4.2. The variables are at constant prices (1970-71 = 100).

Table 4.2

AVERAGE ANNUAL GROWTH OF FACTOR COSTS AND OUTPUT IN THE INDIAN MANUFACTURING SECTOR (figures in percentage)

PERIOD	CAPITAL	LABOUR	ENERGY	MATERIALS	TOTAL COST	OUTPUT
1971-90	6.13	4.23	7.42	6.99	6.43	7.14
1971-80	4.72	5.06	6.17	2.77	3.49	5.58
1981-90	7.55	3.41	8.67	11.20	9.37	8.71

Note: Cost and output variables measured at constant prices (1970-71 = 100).

As seen in Table 4.2, both the total cost of production and the value of output at constant prices in the manufacturing sector register a higher growth in the 1980s than the 1970s. However, a disturbing factor is the faster growth of the former in the 1980s (9.37 per cent). Among the components of total cost it is seen that, for 1971-90, the energy cost grew the fastest at 7.42 per cent. This is despite the fast growth in its price (as shown by Table 4.1). It perhaps reflects the inelasticity of energy demanded to own price changes. Two other interesting observations are the slow growth of material prices in the 1970s and of labour in the 1980s, both seem to be a direct affect of the rise in their respective prices, during the concerned periods. Further comment on price responsiveness of inputs requires the estimation of own and cross price elasticities of demand for factors.

Table 4.3 gives the average cost shares of inputs in the Indian manufacturing sector for 1970-91.

Table 4.3

AVERAGE OF FACTOR COST SHARES IN THE TOTAL COST OF PRODUCTION IN THE INDIAN MANUFACTURING SECTOR (1970-91)
(figures in percentage)

FACTOR INPUT	SHARE IN TOTAL COST
CAPITAL	21.80
LABOUR	9.57
ENERGY	5.66
MATERIALS	62.97

The Table 4.3 captures the importance of each of the input in the total cost of production in the manufacturing sector. Material cost forms the major cost component in the total cost, followed by capital, labour and then energy. Worth noting is the fact that materials and energy together constitute almost 70 per cent of the total cost. Thus the earlier production analysis approach of looking at capital and labour as the only inputs, and therefore examining the substitution possibilities between the two only, comes under serious question. It is clear that, materials and energy inputs cannot be disregarded while estimating derived demand for inputs.

Table 4.4 reports growth in price indices of the three fuel types. For the whole period (1971-90), it can be seen that the price of oil registered the fastest growth rate (16.43 per cent). It is followed by growth in prices of coal and electricity which show a growth rate of 12.64 and 9.40 per cent respectively. For the sub-periods of 1971-80 and 1981-90, an outstanding feature is the rise of oil prices in the 1970s, perhaps a direct repercussion of the oil embargo, so crucial to that decade. The prices of other fuels also display a high rate of growth, signifying the advent of 'general energy crisis'. In 1980s, while the prices of other fuels rose as before, that of oil displayed a low growth rate mainly because of the controlled oil prices after 1985.

Table 4.4

AVERAGE ANNUAL GROWTH RATES OF FUEL PRICE INDICES
(1970-71 = 100)
(figures in percentage)

PERIOD	COAL	OIL	ELECTRICITY
1971-90	12.64	16.43	9.40
1971-80	13.85	27.63	9.27
1981-90	11.42	5.23	9.52

An interesting observation is that, the prices of various fuel types are rising at varying rates, implying changing relative prices. This presents a case for examining the fuel substitution in the manufacturing sector as a cost reducing option.

Table 4.5 gives the annual average growth in the quantities of three fuel types consumed by the manufacturing sector during the reference period.

Table 4.5

AVERAGE ANNUAL GROWTH RATES OF FUEL QUANTITIES CONSUMED IN THE INDIAN MANUFACTURING SECTOR
(figures in percentage)

PERIOD	COAL	OIL	ELECTRICITY
1971-90	6.49	2.09	6.07
1971-80	7.25	-0.44	5.20
1981-90	5.73	4.62	6.95

The Table 4.5 reveals that Coal dominates the picture for the period as a whole, while electricity follows closely. Oil is way behind with only 2.09 per cent growth for 1971-90. It can be seen that oil actually registered a negative growth during the 1970s, perhaps in response to the phenomenal rise in oil prices experienced by the industry. This points towards the highly responsive nature of oil to own price changes. Estimating the own and cross price elasticities of demand will aid in further understanding the response of fuels demanded to changes in fuel prices.

The average cost shares of energy types in total energy cost for the period 1970-1991 is presented in Table 4.6.

Table 4.6

AVERAGE COST SHARE OF FUEL TYPES IN TOTAL ENERGY COST IN THE INDIAN MANUFACTURING SECTOR (1970-1991)
(figures in percentage)

ENERGY TYPE	SHARE IN TOTAL ENERGY COST
COAL	44.42
OIL	10.22
ELECTRICITY	45.36

It is clear from the Table 4.6 that, for the period electricity and coal account for around 90 per cent of the total energy cost in the Indian manufacturing sector. The domination of coal is explained by the fact that, till recently the administered prices for this fuel were infact lower than its cost of production (CMIE, June 1994). Oil registered the highest growth in price, this perhaps explains the lower dependence of the sector on the same.

The analysis of trends in the variables points out that substantial differences do exist in the relative factor and fuel prices. This necessitates the estimation of substitution possibilities among the factors of production and the fuel types. Also while energy was seen to be inelastic to own price changes, the opposite was observed in the case of labour and materials inputs and oil (among the fuel types). This further brings out the importance of estimating the price elasticities of demand. With this preliminary analysis the next chapter takes up the task of interpreting the estimated elasticities (through the model specified in the previous chapter).

Chapter 5

TECHNOLOGICAL CHANGE, FUEL AND FACTOR SUBSTITUTION IN THE INDIAN MANUFACTURING SECTOR: EMPIRICAL RESULTS AND INTERPRETATION

5.1 Introduction:

To empirically test the hypotheses that technical change and the low factor and fuel substitution elasticities in the manufacturing sector could (partially) explain the decline in the output-energy ratio in the sector after 1982, a model was set out in Chapter 3 for which the variables were constructed in Chapter 4. In this chapter the empirical results obtained by estimating the model are presented. Specifically, the effect of technological change on factor and fuel proportions, with special reference to the energy input is quantified. Also the computed values of elasticities of substitution between the energy and non-energy factors of production and between various pairs of fuel types are reported together with the factor and fuel price elasticities. The interpretation of estimates and related policy implications are given alongside.

The division of the chapter is as follows: The next section deals with the aggregate KLEM model, presents the coefficient estimates, biased technological change parameters, substitution and price elasticities and interprets their implications; The third section deals with the energy sub-model. It reports and interprets the parameter estimates computed through the share equations, the findings regarding the technical change, the substitution and the price elasticities.

5.2 *The aggregate `KLEM' Model:*

The parameter estimates of the energy sub-model (estimated in the previous chapter) will enable the estimation of the Divisia aggregate energy price index number for the Indian manufacturing sector. The translog specification of per unit energy cost (price) as elaborated in equation (3.14) of section of the Chapter 3 is employed for the same. This index number is in turn used as an instrumental variable in the estimation of the aggregate model for the manufacturing sector by the present study. This helps in avoiding the simultaneous equation bias in the parameter estimation of the aggregate model.

The parameter estimates provide insight into the underlying production technology involving the aggregate inputs of capital, labour, energy and materials. They are obtained by estimating the translog system of share equations in (3.4) subject to the constraints of symmetry (3.5) and linear homogeneity in input prices (3.6). The parameter estimates of the share equations for capital (K), labour (L), energy (E) and other intermediary inputs (M) along with their estimated asymptotic t-statistics (in the parentheses), R^2 and D-W statistic are reported in (5.1).

As far as the coefficients of price variables are concerned, in the capital share equation the coefficients on energy and material prices are significant at 1 per cent level while that of labour price at 10 per cent level. However, the coefficient on own price is not significant. The labour share equation shows that while coefficients on capital and material prices are significant at 10 per cent, that on price of energy is significant at 1 per cent.

Again the own price coefficient is not significant. For the energy cost share equation all coefficients on price variables are significant at 1 per cent level. The share equation of material input coefficients on all price variables are significant at 1 per cent level except that on $\ln P_L$ which is significant at 10 per cent level.

$$S_K = \underset{(3.4741)}{0.9467} + \underset{(1.2594)}{0.0512} \ln P_K + \underset{(1.7981)}{0.0763} \ln P_L + \underset{(2.1276)}{0.0646} \ln P_E - \underset{(-5.1982)}{0.1921} \ln P_M - \underset{(-2.7568)}{0.1234} \ln Y + \underset{(1.8457)}{0.0290} \ln T$$

$R^2 = .82 \quad D\text{-}W = 1.62$

$$S_L = \underset{(4.0927)}{0.4994} + \underset{(1.7981)}{0.0763} \ln P_K - \underset{(-0.9065)}{0.0343} \ln P_L - \underset{(-4.0416)}{0.0610} \ln P_E + \underset{(1.6654)}{0.0190} \ln P_M - \underset{(-3.1219)}{0.0626} \ln Y - \underset{(-0.7220)}{0.0048} \ln T$$

$R^2 = .97 \quad D\text{-}W = 1.89$

$$S_E = \underset{(1.7812)}{0.0909} + \underset{(2.1276)}{0.0646} \ln P_K - \underset{(-4.0416)}{0.0610} \ln P_L - \underset{(-5.9034)}{0.0183} \ln P_E + \underset{(3.2427)}{0.0147} \ln P_M - \underset{(-1.2847)}{0.0086} \ln Y + \underset{(1.7498)}{0.0064} \ln T$$

$R^2 = .97 \quad D\text{-}W = 1.49$

$$S_M = - \underset{(-2.3311)}{0.5370} - \underset{(-5.1982)}{0.1921} \ln P_K + \underset{(1.6654)}{0.0190} \ln P_L + \underset{(3.2462)}{0.0147} \ln P_E + \underset{(5.3449)}{0.1584} \ln P_M + \underset{(5.1380)}{0.1946} \ln Y - \underset{(-2.2746)}{0.0306} \ln T$$

$R^2 = .78 \quad D\text{-}W = 1.61$

(5.1)

With regards to the co-efficient on output it is significant at 1 per cent level for all share equations except for the energy equation. The coefficient on time variable (a logarithmic time trend is taken as a proxy for technological change), is significant at 5-10 per cent level for the share equations of capital, energy and materials. However, for the labour share equation it is not significant.

The (R^2) being high for all the four share equations indicates that the four share equations in the aggregate model are a good fit.

Nearly 82 per cent of the variations in cost share of capital in the Indian manufacturing sector can be explained by the fitted model, while almost 97 per cent of labour share variations in total cost can be explained by the estimated equation. Nearly 97 per cent and over 78 per cent of the variations in the shares of energy and materials respectively can be explained by the aggregate KLEM model estimated in this study. The D-W statistic at 1.62, 1.89, 1.49 and 1.61 respectively for the four share equations indicates that there is no serial auto-correlation among the error terms.

5.2.a Biased technical change and non-homotheticity:

One of the reasons for the observed fall in the output-energy ratio in the sector after 1982 may have been the effect of technical change on aggregate inputs in the sector. This hypothesis noted in Chapter 1 can be tested through the estimates of the `KLEM' model. The present study has therefore employed a non-neutral and non-homothetic translog cost function, assuming that a change in the technology and in the output levels do affect the input proportions independent of the price effects[1]. This also allows for the testing of changes in the proportion of inputs with changes in scale, in short the scale effects. This again is an improvement over the previous studies for as noted in Chapter 1, not many studies (especially at the aggregate level) have allowed for the technical change to be non-neutral or biased towards factor proportions.

[1] Tests conducted by Lynk (1983), Murty (1986), and Jha et al., (1991), sufficiently establish that both scale and biased technical change have a significant role to play in determining the demand for factors in the Indian manufacturing sector.

The coefficient on logarithmic time term[2] in the factor cost share equations can be interpreted as how technical factors affect the choice of individual inputs, or the bias of technical progress towards the input use. Non-neutral technical bias has been considered in the aggregate KLEM model for the Indian manufacturing sector by the present study. The coefficient of time is negative in the cost share equations of materials, indicating that during the sample period, technical change has been biased towards the saving of materials in the manufacturing sector. This coefficient is positive for capital and energy inputs, implying that the bias in technical change was towards the use of capital and energy inputs; thus perhaps augmenting the cost for both the inputs in the sector over time. It can however be seen that the coefficient of time in the labour equation is very low, so as to be insignificant. This implies that the impact of technical progress on labour use in the manufacturing sector has been neutral during the period 1970 to 1990. As all input prices especially the labour and energy prices registered a high growth rate during the sample period, technical change in the manufacturing sector does not seem to be price induced.

The output coefficient γ_{iY} in the share equations reveals the effect of a one per cent change in output on the cost share of an input. It can be seen from the cost shares (5.1) that the signs of the output coefficient in the cost shares for capital, labour and energy are negative. It means that for the period 1970 to 1990

[2] After experimenting with two specifications of technical progress, a linear and a logarithmic, the latter is reported as it was preferred (using R^2 as a criterion).

there have been significant reductions in the cost shares of capital, labour and energy per unit of output with increases in output in the Indian manufacturing sector. In other words economies of scale exist for these three inputs. However, positive coefficient on output term for the share equation of materials indicates that there have been significant diseconomies in the use of materials in the manufacturing sector during the period 1970 to 1990. The study by Murty (1986) obtains the scale effect as capital and energy using and economies existing in the use of labour and material for the period of 1960 to 1977 in the manufacturing sector of India. Divergent results can be explained by the fact that different time periods have been considered by the two studies, and this study has assumed non-neutral technical progress in the Indian manufacturing sector.

In the final analysis the results tend to suggest that initial fall in the output-energy ratio in the sector after 1982 was perhaps the effect of technological change being in favour of using more energy. However, over time as output expanded the scale effect seems to have overshadowed the technological effect (for a few years in the late 1980s) and this might have resulted in a fall in the energy demanded by the sector; thus bringing about the fluctuation in the output-energy ratio during those years.

5.2.b Inter-factor substitution in the Indian manufacturing sector:

One of the prime concerns of the present study is to examine the inter-input substitution possibilities particularly between the energy and non-energy inputs in the Indian manufacturing sector, and to adjudge whether their low magnitudes are responsible for the inflexibility of energy demanded by the sector, thus leading to an increased energy demand in the sector. In order to examine the elasticities of factor substitution, three measures of elasticities viz., Allen, Morishima and shadow elasticity of substitution have been estimated for selected years during the period 1970-1990. Table 5.1 reports the estimated Allen partial elasticities of substitution (AES) between pairs of aggregate inputs. As stated earlier this partial measure (σ_{ij}) shows how elastic is the demand of factor i to single input price changes. The estimated AES between pairs of inputs reveals a mixed picture for factor substitution between the energy and non-energy inputs in the manufacturing sector.

Table 5.1

ESTIMATED ALLEN'S PARTIAL ELASTICITIES OF SUBSTITUTION BETWEEN FACTOR INPUTS IN THE INDIAN MANUFACTURING SECTOR FOR SELECTED YEARS

YEAR	1970	1975	1980	1985	1990
σ_{KL}	4.30	4.19	4.85	5.02	5.71
σ_{KE}	9.22	6.76	6.28	4.82	5.36
σ_{KM}	-0.50	-0.43	-0.46	-0.31	-0.27
σ_{LE}	-12.20	-9.65	-9.77	-9.89	-13.51
σ_{LM}	1.25	1.28	1.31	1.39	1.44
σ_{EM}	1.58	1.46	1.39	1.34	1.38

As noted in Chapter 1, a lot of debate has been generated in the factor substitution studies regarding the nature of the relationship between energy and capital. This is so because they being substitutes or complements is crucial, both for understanding the impact of rising energy prices on capital investment and on output levels, as well as in designing policies for energy conservation. The debate has however not found an uncontroversial solution.

The estimates of this study show that there is a strong substitutability between capital and energy, the elasticity ranging between 4.82 to 9.23 over the selected years. A point to be noted here is that this elasticity is lower in the 1980s when compared to that in the 1970s, i.e; the elasticity of substitution between energy and capital comes down in the 1980s. This is perhaps a partial explanation to the fall in the output-energy ratio in the sector after 1982 (Chapter 2). The possibility suggested is that, as substitution between energy and capital became relatively less elastic in the eighties (vis-a-vis the 1970s), substituting capital for energy became more difficult, causing the energy demand in the sector to rise.

That energy and capital are substitutes in the Indian manufacturing sector is also supported by Murty (1986)[3]. William and Laumas (1981) have also found them to be substitutes for a cross section of 11 industries. However, there are other studies for the Indian industries which have shown complementarity between then (Lynk, 1983, Jha.et.al.1991, and others).

The substitutable relation between energy and capital obtained in this study is also supported by studies assuming a non-neutral technical change (Hunt, 1986). In so far as, non-neutral technical progress has been incorporated in this study, energy capital substitutability could be explained in terms of this factor. The

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[3] For comparison the factor substitution elasticities for the aggregate Indian manufacturing as estimated by Murty (1986) are reported in Table 5.1, Appendix 5. Also AES alone can be taken up for comparison as MES nor SES have been computed between energy inputs.

result is also supported by engineering studies which analyse the energy conservation potential of energy-capital substitution. As pointed in Chapter 1, these studies have shown that the average energy efficiency of existing plant and equipment in any industry is a fraction of the maximum possible efficiency. This was seen to be particularly true in the case of the Indian manufacturing industries. Given the substitutable nature between energy and capital, a policy of high fuel prices may lead to conservation of energy in the sector, since capital could be substituted for the more expensive energy.

Thus the relationship between energy and capital becomes controversial not only as a result of divergent estimates, but also due to the far ranging policy implications for assessing the long term growth prospects for the Indian industries.

With regards to the AES between energy and labour, it can be seen that it is negative and high for the selected years ranging from -9.65 to -13.51. This implies that energy and labour are complements to each other, indicating that a rise in the price of energy will cause a substantial fall in the ability of the manufacturing sector to absorb labour or vice versa.

Energy-labour complementarity is also supported by Murty (1986), Lynk (1983) and others. However there are studies like Goldar and Mukhopadhyay (1991) which conclude otherwise. Overall it was seen in Chapter 1 that though the studies for industrialised countries displayed only a substitutable relation between labour and energy they were either substitutes or complements in the Indian studies.

Materials as an input is of prime importance to the manufacturing sector. Therefore a separate material input has been included in the aggregate model in this study. The substitution elasticities between material and non-material inputs can help in finding out whether intermediate material shortages can be expected to have adverse effect on the output of the manufacturing sector, or whether offsetting substitution by other inputs is feasible.

The estimates of this study indicate that, labour and materials and energy and materials are substitutes. In the light of a relatively higher rise in prices of labour and energy in the 1980s in relation to the price of materials (Table 4.1, Chapter 4), these high elasticities have far reaching implications for reducing cost in the manufacturing sector of India, by substituting materials for labour and energy. It is also noticed that, while the substitution possibility between labour and materials has been rising over the years, the substitutability between energy and materials has been falling. Specifically, the 1980s saw a relatively lower elasticity of substitution between energy and materials when compared to the 1970s. This implies that, when compared to the seventies the eighties displayed a lower substitution possibility between energy and materials, again providing a possible story towards explaining the rise in energy demanded by the sector in the eighties (and therefore a fall in the output-energy ratio).

The study shows that the relation between capital and materials in the Indian manufacturing sector is one of complementarity. Though in the inelastic range the complementarity between capital and materials found in this study suggests that shortage of material input can be a likely constraint to the long run growth of output in the manufacturing sector.

A comparison with Murty (1986) shows that while he too finds evidence of substitutability between energy-materials and labour-materials, in contrast to the results obtained by this study he finds capital and materials to be substitutes in the Indian manufacturing sector.

It is important to know the extent of substitutability among other inputs, as this has a direct implication for input decisions, cost of production, output level and so on. The estimates between other factors show that, capital and labour are substitutes in the manufacturing sector, the elasticity ranging between 4.19 to 5.71 for the selected years. This is consistent with most studies on factor and fuel substitution (Lynk, 1983, Murty, 1986, Jha et.al. 1991, and others). This finding coupled with that of energy-labour complementarity is suggestive of a two pronged explanation to the fall in labour demand by the manufacturing sector in the 1980s as noted by many studies[4]. The possible explanation is that, on the one hand while the fast rise in labour price itself mitigated labour use, this was accentuated by the possibility of substitution existing between capital and labour in the sector as indicated by the study. This period was also accompanied by equally fast rising energy prices (Table 4.1, Chapter 4). Energy-labour complementarity as shown by this study in such a situation further aided in depressing the labour absorption capacity of the sector. Thus, the falling demand for labour in Indian manufacturing could

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[4] See Ahluwalia (1991), and Nagaraj (1993).

perhaps be explained in the light of the factor substitution possibilities existing in the sector.

In order to examine the relative input adjustments to a factor price change Morishima elasticities of substitution (MES) have been estimated between pairs of factor inputs and reported in Table 5.2. According to the Morishima measure, the evidence of complementarity between inputs is found to be weaker than that for the Allens measure. For instance, consider the relationship between σ_{LE} and σ_{LE}^{M}. In Table 5.1, σ_{LE} indicates that a price rise in energy leads to a decreased utilisation of labour by the sector. On the other hand the associated Morishima elasticity is positive, for all the selected years. This can be interpreted as follows; as price of energy rises, utilisation of labour falls - evidence of complementary behaviour. At the same time, however usage of energy also declines[5] at such a rate that the energy-labour input ratio actually falls. Therefore since energy use declines faster than the decline in labour, to that extent they act as substitutes.

The non-symmetric nature of Morishima measure further highlights the asymmetry in the relation between capital and materials. σ_{MK}^{M} and σ_{KM}^{M} show that whereas materials and capital behave as Morishima substitutes (though the elasticity is in the inelastic range) when the price of capital rises, they behave as Morishima complements when the price of materials rises. The estimates also suggest that materials is more price responsive than capital to changes in either the price of capital or materials. Similar asymmetry is

[5] As required by concavity and reflected in the own price elasticity of energy demand (Table 5.4).

noticed in the relationship between labour and energy for 1970, however for the rest of the years they behave like weak Morishima substitutes.

Table 5.2

ESTIMATED MORISHIMA ELASTICITIES OF SUBSTITUTION BETWEEN FACTOR INPUTS IN THE INDIAN MANUFACTURING SECTOR FOR SELECTED YEARS

YEAR	1970	1975	1980	1985	1990
σ_{KL}^{M}	1.68	1.66	1.73	1.75	1.83
σ_{KE}^{M}	1.79	1.65	1.62	1.53	1.57
σ_{KM}^{M}	-0.21	-0.14	-0.18	-0.06	-0.05
σ_{LK}^{M}	1.40	1.45	1.55	1.75	1.91
σ_{LE}^{M}	0.94	0.80	0.67	0.49	0.40
σ_{LM}^{M}	0.92	0.92	0.95	0.98	1.03
σ_{EK}^{M}	2.37	2.01	1.84	1.70	1.83
σ_{EL}^{M}	-0.25	0.13	0.33	0.57	0.52
σ_{EM}^{M}	1.13	1.03	1.00	0.95	0.99
σ_{MK}^{M}	0.44	0.45	0.45	0.47	0.48
σ_{ML}^{M}	1.32	1.34	1.39	1.46	1.54
σ_{ME}^{M}	1.48	1.38	1.33	1.28	1.32

Shadow elasticities of substitution (SES) corresponding to this technology are reported in Table 5.3. They show the percentage adjustment in input ratios to change in price ratios. Examining the SES show that, when there is a change in the relative input price movements (as against individual price change) the input ratio adjustments indicates that all inputs act as if they were substitutes. Between energy and non-energy inputs the substitution possibilities are particularly strong between capital and energy, and energy and materials. Among other pair of inputs capital and labour and labour and materials also display high substitutability.

Table 5.3

ESTIMATED SHADOW ELASTICITIES OF SUBSTITUTION BETWEEN FACTOR INPUTS IN THE INDIAN MANUFACTURING SECTOR FOR SELECTED YEARS

YEAR	1970	1975	1980	1985	1990
σ_{KL}^{S}	1.57	1.59	1.67	1.75	1.84
σ_{KE}^{S}	1.89	1.72	1.67	1.57	1.62
σ_{KM}^{S}	0.29	0.30	0.30	0.32	0.33
σ_{LE}^{S}	0.64	0.59	0.54	0.53	0.46
σ_{LM}^{S}	1.26	1.28	1.33	1.41	1.49
σ_{EM}^{S}	1.46	1.35	1.30	1.25	1.29

Differing factor substitution elasticities given by different measures used is not the indication of the flaw in the measures, but simply emphasises the need to look at elasticities in the light of single price changes and relative price changes.

5.2.c Price responsiveness of factor demand in the indian manufacturing sector:

The interest of this study also lies in analysing the own and cross price responsiveness of the aggregate inputs besides looking at the possibilities of factor substitution. The price elasticities of derived demand between aggregate factors (K, L, E, and M) in the manufacturing sector have been estimated for selected years over the period 1970-71 to 1990-91 and presented in Table 5.4.

As expected the own price elasticities are negative for all the four inputs, consistent with the theory of factor demand. Labour and energy appear to be the most responsive to own price changes with elasticities ranging between -1.18 to -1.44 and -1.19 to -1.42 respectively. On the other hand, the own price elasticities for capital and materials lie in the inelastic range. The own and cross price elasticities show that, energy has been most responsive to price changes in other inputs than vice versa for the

Table 5.4

ESTIMATED PRICE ELASTICITIES OF DEMAND BETWEEN FACTOR INPUTS IN THE INDIAN MANUFACTURING SECTOR FOR SELECTED YEARS

YEAR	1970	1975	1980	1985	1990
E_{KK}	-0.54	-0.55	-0.55	-0.55	-0.55
E_{KL}	0.50	0.46	0.46	0.40	0.39
E_{KE}	0.37	0.35	0.37	0.34	0.33
E_{KM}	-0.32	-0.27	-0.29	-0.19	-0.17
E_{LL}	-1.18	-1.20	-1.26	-1.35	-1.44
E_{LK}	0.85	0.91	1.00	1.20	1.36
E_{LE}	-0.48	-0.50	-0.58	-0.70	-0.84
E_{LM}	0.81	0.79	0.84	0.85	0.91
E_{EE}	-1.42	-1.30	-1.25	-1.19	-1.23
E_{EK}	1.83	1.46	1.30	1.15	1.28
E_{EL}	-1.42	-1.07	-0.94	-0.78	-0.92
E_{EM}	1.02	0.91	0.89	0.82	0.87
E_{MM}	-0.11	-0.12	-0.11	-0.13	-0.12
E_{MK}	-0.10	-0.09	-0.09	-0.08	-0.07
E_{ML}	0.15	0.14	0.13	0.12	0.10
E_{ME}	0.06	0.08	0.08	0.09	0.09

selected years in the Indian manufacturing sector. Note, however that this elasticity is lower for the 1980s as compared to the 1970s, implying that, energy demand became more rigid or inflexible (downward) in the 1980s, causing a rise in the energy demand, and thus perhaps leading to the output-energy ratio fall in the sector during that period.

Demand for materials appears to be least responsive to factor price changes. This is perhaps due to the high dependence of the manufacturing sector on materials input (it accounts for more than 60 per cent of total input cost).

The cross price elasticities throw further light on the substitution possibilities in the manufacturing sector of India. It confirms the results as obtained by the AES measure.

For reasons of comparison the price elasticities between inputs estimated by Murty (1986) are presented in Table 5.2, appendix 5. It can be seen that according to his estimates capital is the most price responsive to own price changes, whereas the present study finds labour to be most responsive. Own price elasticities for energy and materials lie in the inelastic range similar to the estimates of the present study. Energy is also seen to be more responsive to price changes in the other inputs than vice versa, as is concluded by this study.

5.2.d Well behavedness of the estimated cost function for the 'KLEM' Model:

The translog cost function employed by the present study is a local approximation to a twice differentiable flexible function, and therefore may not satisfy the condition required for well-behavedness. In order to satisfy the condition of monotonicity, the signs on the fitted cost shares have to be positive. The fitted cost shares in the aggregate model for all the four inputs are positive for all observations thus satisfying the positivity condition. The second condition, concavity in input prices is satisfied if all the own price elasticities of the inputs are negative. It can be seen from the estimated elasticities of prices that all inputs have a negative own price elasticity, thus, leading to the conclusion that the KLEM model estimated in the present study is a well behaved one.

5.3 The energy sub-model:

The parameter estimates of the fuel cost share equations in the energy sub-model along with their asymptotic t-statistics (in the parentheses), the coefficient of determination (R^2) and Durbin-Watson statistic are reported in (5.2). These values have been obtained by estimating the system of share equations in (3.15) subjected to the restrictions of symmetry (3.16) and linear homogeneity (3.17).

$$
\begin{aligned}
S_{EC} &= \underset{(27.2069)}{0.3830} - \underset{(-2.6681)}{0.2834}\ \ln P_{EC} + \underset{(7.5836)}{0.2269}\ \ln P_{EO} + \underset{(1.2526)}{0.0565}\ \ln P_{EE} - \underset{(-0.1638)}{0.0008}\ T \\
&\qquad R^2 = .78, \quad D\text{-}W = 1.24 \\
S_{EO} &= \underset{(25.4593)}{0.1700} + \underset{(7.5836)}{0.2269}\ \ln P_{EC} - \underset{(-7.8428)}{0.2832}\ \ln P_{EO} + \underset{(1.2651)}{0.0563}\ \ln P_{EE} - \underset{(-4.5804)}{0.0098}\ T \\
&\qquad R^2 = .87, \quad D\text{-}W = 1.75 \\
S_{EE} &= \underset{(55.2582)}{0.4470} + \underset{(1.2526)}{0.0565}\ \ln P_{EC} + \underset{(1.2651)}{0.0563}\ \ln P_{EO} - \underset{(-1.9415)}{0.1128}\ \ln P_{EE} + \underset{(3.5233)}{0.0106}\ T \\
&\qquad R^2 = .55, \quad D\text{-}W = 1.40
\end{aligned}
\tag{5.2}
$$

As far as the coefficients of the fuel price variables are concerned, the cost share equation of coal shows that the parameter estimates of coal and oil prices are highly significant at 1 per cent level. However, the coefficient of $\ln P_{EE}$ is insignificant. In the share equation of oil, the coefficients of $\ln P_{EC}$ besides that of $\ln P_{EO}$ are significant at 1 per cent level, again the coefficient of $\ln P_{EE}$ emerges insignificant. Finally, the share equation of electricity shows that, except the coefficient of own price, coefficients of other price variables are not significant.

With regards to the coefficient of time, (a linear time trend has been taken as a proxy for technological change) it is seen to be highly significant at 1 per cent level for the share equations of oil and electricity whereas for coal it is insignificant.

The coal equation has a R^2 of .78 this implies that, nearly 78 per cent of variations in the cost share of coal are explained by the estimated equation. For the cost share of oil it indicates that nearly 87 per cent of the variations in the dependent variable are explained by the explanatory variables considered in the estimated equation. The R^2 for the share equation of electricity means that 55 per cent of variations in the share of electricity are explained by the estimated equation. The D-W statistic at 1.24, 1.75 and 1.40 for the three share equations respectively indicates that there is no serial autocorrelation among the error terms.

5.3.a Non-neutral fuel efficiency bias:

In order to test the nature of technological change within the energy sub-sector, this study has aimed at quantifying the effect of a non-neutral technical change on the fuel inputs in the sector. Towards this end the study has estimated the inter-fuel substitution possibilities in the Indian manufacturing sector by using an energy unit cost function that allows for a biased technical change. It is also an improvement over the previous studies for, as pointed in Chapter 1, most studies for India (including Murty, 1986) ignored the influence of non-neutral fuel efficiency bias of technological change on fuel demand.

The proxy for technical change employed in this study is a linear time trend. It can be seen from the cost equations (5.2) that though the size of the estimated coefficient of time for all three share equations is low, it is highly significant at 1 per cent level for the share equations of oil and electricity whereas for coal it is not significant. The coefficient is negative for the coal and oil share equations and positive for the electricity equation. This implies that the technical change in the Indian manufacturing sector during the period 1970 to 1990 has been biased towards the use of electricity, but towards the saving of oil. Alternatively, there has been a shift towards the use of electricity in the sector. This result is supported by the Table 4.5, Chapter 4. It shows a faster growth in the amount of electricity demanded by the manufacturing sector in relation to that of oil. This reflects the attempt to minimise cost by the manufacturing sector, as this period experienced a faster rise in the price of oil vis-a-vis other fuels. Thus the results suggest that the technical change within the energy sub-sector of the manufacturing sector has been in the right direction.

The significance of the estimated coefficient of time in the fuel share equations reflects that non-neutral technical change does have a significant influence on individual fuel cost shares, independent of relative price changes during the twenty year period in the manufacturing sector. This also implies that, absence of some form of technical change in a model on inter-fuel substitution could be an important source of mis-specification. Also since the technical change within the energy sub-sector has not been neutral in its fuel efficiency bias, a change in the fuel substitution elasticities is now possible to contemplate. It is next proposed to check how the change in these elasticities in the 1980s could have contributed to a rise in the energy demand.

5.3.b Inter-fuel substitution in the Indian manufacturing sector:

The elasticities of substitution between pairs of fuels have been estimated using three measures viz., Allens, Morishima and shadow elasticities for selected years during the period 1970 to 1990 for the manufacturing sector.

A look at the Allens partial elasticities of substitution (AES) in Table 5.5, indicate strong substitution possibilities between energy components in the Indian manufacturing sector.

Table 5.5

ESTIMATED ALLENS PARTIAL ELASTICITIES OF SUBSTITUTION BETWEEN FUEL TYPES IN THE INDIAN MANUFACTURING SECTOR FOR SELECTED YEARS

YEAR	1970	1975	1980	1985	1990
$\sigma_{CO}=\sigma_{OC}$	4.60	5.92	6.26	6.61	7.37
$\sigma_{CE}=\sigma_{EC}$	1.33	1.28	1.28	1.27	1.27
$\sigma_{OE}=\sigma_{OE}$	1.73	2.44	2.26	2.42	2.35

A noteworthy feature is that the AES between coal and oil is the highest, being around three times more than the elasticity between other pairs of fuels. The estimates for five selected years during 1970-1990 vary from 4.60 to 7.37, implying significant substitution opportunities between the two fuel types. In an era of rising oil prices, a positive and high σ_{ECO} means that coal could be substituted for the more expensive oil in the sector. Similarly, the AES between oil and electricity is high, the range being between 1.73 to 2.44 over the selected years. The AES between coal and electricity though the lowest is more than unity, again indicating the possibility of substitution. Thus, all pairs of fuels are Allen substitutes in the energy sub-sector of the Indian manufacturing sector, the substitution opportunities between coal and oil being the strongest followed by oil and electricity and coal and electricity. Another point to be noted here is that these elasticities are rising in the 1980s, except for the elasticity between coal and electricity which remains more or less stable over the period.

As discussed earlier, Allens is a partial measure of elasticity, in the sense that it quantifies only single input response to single input price changes. It yields little or no information on relative input adjustments to single factor price changes. For this reason the Morishima (MES) is estimated and presented in Table 5.6. The MES, σ_{Eij}^{M} measures the relative input adjustment to single factor price changes. Here $\sigma_{Eij}^{M} \neq \sigma_{Eji}^{M}$, thus classifying fuels as substitutes or complements depends on which fuel price changes. Comparing Tables 5.5 and 5.6 (while keeping this point in mind) reveals some interesting information. First, Morishima measure also indicates that all the fuels are strong substitutes to each other. The order of substitutability between fuel types is as obtained by the AES. Second, the non-symmetric nature of the MES measure is clearly highlighted, especially in the relationship between oil and electricity. Upon examining σ_{EOE}^{M} and σ_{EEO}^{M}, it is seen that while both act as substitutes in the light of a price change in either of the fuels, electricity is more price responsive than oil to changes in price of oil.

Table 5.6

ESTIMATED MORISHIMA ELASTICITIES OF SUBSTITUTION BETWEEN FUEL TYPES IN THE INDIAN MANUFACTURING SECTOR FOR SELECTED YEARS

YEAR	1970	1975	1980	1985	1990
σ_{ECO}^{M}	3.28	4.47	4.42	4.71	4.90
σ_{ECE}^{M}	1.40	1.39	1.37	1.37	1.36
σ_{EOC}^{M}	3.10	3.99	3.97	4.19	4.36
σ_{EOE}^{M}	1.58	1.87	1.82	1.89	1.90
σ_{EEC}^{M}	1.88	1.71	1.76	1.74	1.79
σ_{EEO}^{M}	2.80	4.15	4.03	4.34	4.47

Table 5.7 reports the shadow elasticities of substitution (SES), which show the percentage adjustment in input ratios to changes in fuel price ratios. From the table it can be concluded that when

Table 5.7

ESTIMATED SHADOW ELASTICITIES OF SUBSTITUTION BETWEEN FUEL TYPES IN THE INDIAN MANUFACTURING SECTOR FOR SELECTED YEARS

YEAR	1970	1975	1980	1985	1990
σ_{CO}^{S}	3.23	4.40	4.34	4.63	4.81
σ_{CE}^{S}	1.67	1.54	1.57	1.56	1.59
σ_{OE}^{S}	2.47	3.73	3.64	3.94	4.10

changes in the price ratio (as against individual price change) are considered, all fuels act as strong substitutes to each other in the Indian manufacturing sector during the period 1970 to 1990. Though the magnitude of the shadow elasticities are higher, the order of substitutability is similar to that obtained by the Allen and Morishima measures.

In the final analysis it can be said that, substitution elasticities between fuel types are high, implying that one fuel can be substituted for the other without much difficulty. Thus there is a possibility that the sector can minimise cost incurred within the energy sub-sector through appropriate inter-fuel substitution. Moreover, overall these elasticities are seen to rise in the 1980s as compared to 1970s. Hence, high inter-fuel substitution elasticities suggest that energy demand is not inflexible (downwards) due to a dearth of substitution possibilities between the fuel types in the manufacturing sector of India.

For the purpose of comparison, Murty's (1986) AES estimates are given in the Table 5.3, Appendix 5. The study indicates strong substitutability between different forms of fuels in the Indian manufacturing industry, this is in broad agreement to the conclusion obtained in this study. However, Murty found that substitution between oil and electricity are strongest, whereas according to the estimates of the present study coal and oil display the strongest substitution possibilities followed by oil and electricity and coal and electricity.

5.3.c Price responsiveness of the demand for fuels in the Indian manufacturing sector:

The price responsiveness of the demand for fuels throws further light on the flexibility of fuels demanded and the fuel substitution possibilities in the sector. In order to analyse the price responsiveness of the individual fuels to own price changes and to price changes of other fuels, own and cross price elasticities have been estimated and presented in Table 5.8.

Table 5.8

ESTIMATED PRICE ELASTICITIES OF DEMAND FOR VARIOUS FUEL TYPES IN THE INDIAN MANUFACTURING SECTOR FOR SELECTED YEARS

YEAR	1970	1975	1980	1985	1990
E_{ECC}	-1.39	-1.09	-1.20	-1.16	-1.25
E_{ECO}	0.78	0.56	0.61	0.58	0.62
E_{ECE}	0.61	0.53	0.59	0.57	0.63
E_{EOO}	-2.51	-3.92	-3.81	-4.13	-4.27
E_{EOC}	1.71	2.90	2.77	3.04	3.11
E_{EOE}	0.79	1.01	1.04	1.09	1.16
E_{EEE}	-0.79	-0.86	-0.79	-0.80	-0.73
E_{EEC}	0.50	0.63	0.57	0.59	0.54
E_{EEO}	0.29	0.23	0.22	0.21	0.20

In the energy sub-model all the estimated own price elasticities are negative, indicating that they are in confirmation with the postulates of factor demand theory. These elasticities indicate that the fuels are highly responsive to own price change. The size of the estimates indicate that during the period 1970 to 1990, demand for oil with an own price elasticity ranging from -2.51 to -4.27 has been the most responsive to own price changes. This finding is supported by the fact that oil consumption of the manufacturing sector was low in response to the oil price hikes of the 1970s (as seen in Table 4.5, Chapter 4). High own price elasticity of demand for oil is followed by that of coal with the estimate varying between -1.09 to -1.39.

On the other hand, demand for electricity appears to be the least responsive to own price changes with an own price elasticity having a range from -0.73 to -0.86. The inelastic demand for electricity in the Indian manufacturing sector could be explained in terms of the fact that it constitutes over 45 per cent of the total cost incurred on energy in the sector (see Table 4.6, Chapter 4). Supporting the inelasticity of the demand for electricity is also the fact pointed in Chapter 1 that, electricity being an expensive fuel in motive energy is generally used when no other alternative is available, and therefore is difficult to cut down upon.

The estimates of price elasticities of demand for fuels are also relevant from the point of view of designing fuel price policy. The consumption efficiency rule or Ramsey's rule[6] for optimal pricing of public sector commodities requires that price be inversely proportional to price elasticity of demand. Since energy inputs are mainly supplied by the public sector in India, any pricing policy for supply of energy inputs must take note of the estimates of own and cross price elasticities of derived demand for them. Estimates of the present study show that, electricity has lower price elasticity of demand than coal and oil. Therefore, consumption efficiency indicates that price cost mark up be high for electricity in relation to coal or oil. Oil on the other hand must have a low price cost mark up in relation to other fuels. In order to achieve consumption efficiency as well as the objective of distributional equity a policy decision in the direction of optimal pricing taking into account the elasticities of demand for fuels is called for.

The cross price elasticities confirms the earlier conclusion that energy prices are substitutes to one another in the Indian manufacturing sector, with the substitution possibilities being very strong between coal and oil.

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[6] See Brown and Sibley (1986).

For purpose of comparison, own and cross price elasticities estimated by Murty (1986) are presented in the Table 5.4, Appendix 5. These estimates broadly support the present study. Murty concludes that fuels are highly responsive to own price changes, oil being the most elastic. As can be seen the cross price elasticities obtained by Murty signify strong substitution possibilities between energy inputs, similar to the conclusion arrived at by this study. A significant difference between the estimates of the two studies is that, according to him coal emerges as the least own and cross price responsive, whereas for the present study the least price elastic fuel type is electricity. However, the finding that electricity is least responsive to own and cross price changes is consistent with majority of the studies on inter-fuel substitution conducted for the industrial sector of both developed and developing countries including India. Among other studies, Uri's (1979) estimates of own and cross price elasticities for coal, oil and electricity for India are lower than those estimated by this study. However, estimates for other countries by studies like Fuss (1977) also reveal high own price elasticities for energy inputs.

5.3.d Well behavedness of the estimated unit energy cost function:
The conditions of monotonicity and concavity, as in the aggregate model are satisfied by the energy sub-model estimated. All the fitted cost shares are positive thus satisfying monotonicity (positivity) at all observations and the estimated own price elasticities of demand for energy inputs are negative, thus satisfying the condition of concavity.

Chapter 6

SUMMING UP

The dependence of economic activities on fuel supplies was fully appreciated after the turn of events in the international oil market in the 1970s. It could no longer be denied that scarcity of energy may become a constraint to growth in net energy importing countries like India. Economists responded to this realisation by attempting to analyse the implications of scarce and expensive fuels on the economy.

In the long run a transition towards the use of non-conventional sources of fuels might be feasible, but this involves a long gestation period. Therefore, most nations while designing the short and medium run policy objectives have recognised the need to manage energy efficiently. Energy management consists of issues regarding: (1) Conserving commercial fuel sources (like coal, oil, gas and electricity) and increasing energy efficiency in production. These two factors contribute towards reducing the general energy intensity of the economy; and (2) Appropriate factor and fuel substitution in order to minimise the energy costs. These substitution possibilities would not only help in shaping the future energy policies, but also explain the changes in the economy, induced by energy price rises or shortages.

The importance of energy management for a developing economy like India cannot be denied. More so since secondary studies tend to suggest that energy efficiency in the Indian manufacturing industries is very low - a matter of concern with wide implications for the growth potential of the economy. This reinforces the need to manage energy efficiently. It is in this context that this study attempts to provide an energy profile for the Indian manufacturing sector - the major commercial fuel consumer in the economy. Specifically, the study has aimed at examining the nature of energy use in the Indian manufacturing setor, to investigate the type of technical change and quantify the substitution possibilities between the energy and non-energy factors of production, and between pairs of various fuel types in the sector. Thus, the study essentially fills in a visible gap in the literature on energy management at an aggregate level. The time period covered by the study is 1970-90. This period witnessed a turmoil in the international oil market with implications for energy used by net energy importing nations like India.

The primary source of data for this study has been the Annual Survey of Industries, Summary Results for the Factory Sector, published by the Central Statistical Organisation of the Government of India. The other sources have been Chandok (1990), CMIE publications, RBI Bulletins, Productivity (various issues) and others.

In order to understand the nature of energy use in the sector, the output-energy ratio in the manufacturing sector was examined. Until the eighties no particular trend was observed, however after 1982 an overall fall in the ratio was noticed. The study then set out to examine the reasons behind this phenomenon. While there are several possible explanations, this study confines itself to examining three issues:

(i) Was there a structural shift in the manufacturing sector towards more energy utilising industries in the 1980s? This would mean an increase in energy used in the sector thus leading to the fall in the ratio.

(ii) Was the technical change in the sector energy-using? If yes, then this would lead to more use of energy in the sector.

(iii) Finally, were the inter-factor and inter-fuel substitution elasticities in the sector very low? This would render appropriate factor and fuel substitution difficult, causing the energy demand in the sector to be inflexible, thus pushing up the energy use vis-a-vis the output, and further leading to a fall in the output-energy ratio in the sector.

The empirical testing of the first hypothesis led to the conclusion that there was no structural shift in the composition of the sector towards more energy utilising industries and that this could not have been the possible reason for the fall in the output-energy ratio in the sector after 1982. However, the results tend to suggest that the more energy utilising industries were largely responsible for the fall in the output-energy ratio in the sector.

For the purpose of testing the next two hypotheses, namely, the nature of technical change and the factor and fuel substitution possibilities in the sector, a two stage optimisation model was estimated. In the first stage a sub-energy model involving substitution possibilities between the three fuel types viz., coal, oil, and electricity was estimated. Using the parameter estimates obtained, a Divisia index for the aggregate price of energy was computed. This was used as an instrumental variable in the aggregate `KLEM' model which deals with the substitution possibilities between the energy and non-energy inputs (capital, labour, and materials.) in the manufacturing sector.

The complete model was estimated for the period 1970-71 to 1990-91. Owing to reasons of sufficient flexibility and minimum a priori restrictions on the factor and fuel substitution elasticities, from the available functional forms the translog form was selected for estimation purpose.

In order to capture the effect of technology and scale on aggregate inputs in the manufacturing sector this study estimated a cost function which displays a non-neutral technical bias and is non-homothetic. Technical bias in the manufacturing sector during the period was seen to be capital and energy-inputs-using, materials-saving and labour-neutral. As all input prices especially the labour and energy prices registered a high growth rate during the sample period, technical change in the manufacturing sector does not seem to be price induced. However, one finds a partial explanation for the fall in the output-energy ratio in the nature of the technical change, as it has been in favour of energy using.

Regarding the scale effect, for the period 1970-90 there have been significant economies of scale for capital, labour and energy. However, significant diseconomies in the use of materials in the manufacturing sector have been seen. The fluctuations observed in the late 1980s in the output-energy ratio in the sector can perhaps be explained in this light. As the technology was energy using, energy use grew faster than the output, but since there are economies of scale present in the use of energy, as output expanded demand for energy input came down causing the ratio to fluctuate.

Substitution elasticities between factors of production in the Indian manufacturing sector are quantified by estimating the aggregate model, using three different measures of elasticities viz., Allens, Morishima and shadow elasticity of substitution. While Allens looks at the change in demand of a single input in response to single price changes, Morishima examines the input ratio adjustment to single price changes, while on the other hand shadows looks at the input ratio adjustment to changes in input price ratio. All elasticities were computed for a few selected years in the 1970s and the 1980s.

In particular with regard to the crucial relation between energy and capital, around which a lot of debate is centered, this study found them to be strong substitutes, implying substantial substitution possibilities between the two inputs in the Indian manufacturing sector. However, this elasticity was seen to come down in the eighties, suggesting that substituting energy with capital became relatively less easier in the eighties. This perhaps led to the inflexiblility of energy demand in the sector, causing a rise in the output-energy ratio.

The substitution possibility between the two inputs has some further implications. For instance, it suggests that by increasing investment in plant, machinery and other fixed assets, improved energy efficiency could be achieved or alternatively, energy consumption of the sector can be brought down. This implies that, in an era of rising energy prices the adverse effect on production can atleast partially be offset by substitution of capital. Also, a policy of high energy prices for the manufacturing sector may lead to conservation of the same, as capital can be substituted with minimal effect on the output levels.

Energy and labour emerge as complements, suggesting that, a hike in energy prices will cause a fall in the ability of the manufacturing sector to absorb labour or vice versa.

Energy and materials also emerged as substitutes, however the elasticities for 1980s were lower as compared to 1970s. This again implies that the energy substitution with materials became relatively difficult in the 1980s, suggesting a partial cause for the rise in the output-energy ratio.

The other substitutes in the sector are, energy and materials, capital and labour, followed by labour and materials. Capital and materials display a complementary relation. The substitution between labour and capital suggests an explanation to the fall in labour demanded by the manufacturing sector in the 1980s (despite the rise in the level of output). As price of labour (wage rate) is rising relatively faster than the price of capital, the substitution possibility between them allows the manufacturing sector to substitute capital for labour. This decade also witnessed a hike in energy prices for the sector, further depressing the labour demand in the sector (as the nature of the relationship between energy and labour is one of complementarity). In order to understand the price responsiveness of factor inputs their own and cross price elasticities of demand have been estimated. The demand for labour and energy are own price responsive, while capital and materials are inelastic to own price changes. Demand for energy is more responsive to changes in the prices of other inputs than vice versa. It implies that even small changes in prices of other inputs can cause energy input to change in response.

In order to understand the nature of technical change in the energy sub-sector this study has estimated the inter-fuel substitution possibilities at the manufacturing level by using a cost function that allows for technical change to display a non-neutral fuel efficiency bias. The results imply that, the technical change in the Indian manufacturing sector during the period 1970-71 to 1990-91 has been biased towards the use of electricity, and towards the saving of oil. This period witnessed a faster rise in the oil prices vis-a-vis the other fuels, implying that, the technical change within the energy sub-sector has been in favour of expensive fuel-saving.

Some broad conclusions regarding the fuel substitution opportunities in the manufacturing sector have been drawn again using the three elasticity measures specified earlier. The estimated elasticities for the energy sub-model showed that, there exist substantial substitution possibilities between energy inputs in the Indian manufacturing sector. Substitution possibilities were found to be the strongest between coal and oil, followed by oil and electricity and coal and electricity. This suggests that, the manufacturing sector can adjust to a hike in oil prices with minimal effect on output. In the face of oil price rise it is imperative to ensure adequate supplies of coal to the manufacturing sector in order to avoid the adverse effects on the level of output. Moreover, these elasticities were greater in the 1980s in relation to those in the 1970s. Thus, the possibility of substituting the less expensive fuel for the more expensive ones rose in the 1980s.

The price elasticities of the energy sub-model showed that, among the fuel types electricity is least responsive to relative price changes and demand for oil appears to be the most responsive to price movements. The consumption efficiency rule or Ramsey's rule, for optimal pricing of public sector commodities requires that prices be inversely proportional to the price elasticity of demand. Accordingly, electricity must have the highest mark up cost followed by coal and then oil.

Overall in the final analysis it can be said that energy conservation measures must be given top priority in the more energy utilising industries of the sector - thus leading to an improvement in the output-energy ratio. Moreover high factor and fuel substitution elasticities reveal that there is sufficient scope to undertake appropriate factor and fuel substitution in order to bring down the nergy demand in the sector in real terms.

This study is not free from some limitations. A number of problems were encountered in the construction of price indices for capital services. Data problems were also faced while attempting to separate the individual fuel inputs in the manufacturing sector. For both the capital measure and the energy measure data from different sources had to be combined. Obviously there are problems of comparibility, though to a large extent the study has attempted to overcome them. This points out to the gaps in information available and calls for an improvement in the data base for the Indian economy.

As all studies on factor and fuel substitution suggest another major limitation is that estimated cost share equations in the model estimated assume instantaneous adjustment; it is really not tenable. This is especially so for the years of sharp hikes in fuel prices. A more dynamic model would perhaps suffice the requirement.

In conclusion it can be said that this macro level study and the issues it raises need to be supplemented and substantiated by more detailed industry and firm level studies.

APPENDICES

Appendix 4 A

The principal source of data for the present study has been the Annual Survey of Industries (ASI) published by the Central Statistical Organisation (Government of India). The ASI definitions for some of the concepts used in this study are presented here.

DEPRECIATION: Is consumption of fixed capital due to wear and tear and obsolescence during the accounting year and is taken as provided by the factory owner or is estimated on the basis of cost of installation and working life of the fixed assets.

FIXED CAPITAL: Represents the depreciated value of fixed assets owned by the factory as on the closing day of the accounting year. Fixed assets are those which have normal productive life span of more than one year. Fixed capital covers all types of assets, new or used or own constructed, deployed for production, transportation, living or recreational facilities, hospitals, schools, etc. for factory personnel. It includes the fixed assets of the head office allocable to the factory and also the full value of assets taken on hire purchase basis (whether fully paid or not) excluding interest element. It excludes intangible assets solely used for post manufacturing activities such as sale, storage, distribution etc.

FUELS CONSUMED: Represents total purchase value of all items of fuels, lubricants, electricity, water etc. consumed by the factory during the accounting year including gasoline and other fuels for vehicles except those that directly enter into products as materials consumed. It excludes that part of fuels which is produced and consumed by the factory in manufacture i.e., all intermediate products and also fuels consumed by employees as part of amenities. It includes quantities acquired and consumed from allied concerns, their book value being taken as their purchase value and also the quantities consumed in production of machinery or other capital items for factory's own use. It, however, excludes all intermediate products consumed during the accounting year. (Intermediate products in the above context mean all those products which are produced by the factory but are subject to further manufacturing).

GROSS OUTPUT: Is defined to include the ex-factory value (i.e., exclusive of taxes, duties etc. on sale and inclusive of subsidies etc. if any) of all products and by-products manufactured during the accounting year. It also includes the receipt for non-industrial services rendered to others, the receipt for work done for others on materials supplied by them, value of electricity sold and net balance of goods sold in the same condition as purchased. The terms gross output, value of output and total output have been used (in this study) interchangeably to mean the same thing.

TOTAL PERSONS ENGAGED: Relate to all persons engaged by the factory whether for wages or not, in work connected directly or indirectly with the manufacturing process and include all administrative, technical, clerical staff as also labour engaged in production of capital assets for factory's own use. This is inclusive of persons holding supervisory or managerial positions or engaged in administrative office, store keeping section and welfare section, sales department as also those engaged in the purchase of raw materials etc., and the production of fixed assets for the factory and watch and ward staff. It also includes all working proprietors and their family members who are actively engaged in the work of the factory even without any pay and the unpaid members of the cooperative societies who worked in or for the factory in any direct and productive capacity. (Note: For 1973-74 to 1979-80 total persons engaged was termed as employees). The number of workers or employees is an average number, obtained by dividing mandays (defined earlier) by the number of days the factory had worked during the reference year. In case of factories where only repair, maintenance or construction activity was carried on the average is calculated by dividing the mandays (defined elsewhere) worked by the number of days, repair and maintenance/construction work has been carried on.

TOTAL EMOLUMENTS: Are defined in the same way as wages (defined below) but, paid to all employees plus imputed values of benefits in kind i.e. the net cost to the employer on those goods and services provided to employees free of charge or at markedly reduced cost which are clearly and primarily of benefits to the employees as consumers.

Appendix 4 B

Table 4.1

MEASUREMENT OF CAPITAL INPUT

FINANCIAL YEAR	CAPITAL STOCK (AT 1960 PRICES)	WPI FOR MACHINE & MACH TOOL (60-61=100)	CAPITAL STOCK AT CURRENT PRICES
(1)	(2)	(3)	(4)
1970-71	854588	156.25	1335294
1971-72	885061	163.28	1445128
1972-73	926690	172.81	1601413
1973-74	972734	190.94	1857338
1974-75	1010507	244.06	2466243
1975-76	1064443	270.63	2880702
1976-77	1166529	266.88	3113233
1977-78	1235754	270	3336536
1978-79	1310401	285.78	3744864
1979-80	1402652	330.31	4633100
1980-81	1509028	361.88	5460871
1981-82	1592076	397.81	6333438
1982-83	1701279	418.13	7113558
1983-84	1817783	443.44	8060777
1984-85	1993024	463.91	9245838
1985-86	2119908	510.31	10818103
1986-87	2257336	538.28	12150788
1987-88	2518362	560	14102827
1988-89	2760492	605.91	16726097
1989-90	3001549	661.16	19845047
1990-91	3392763	716.85	24321145

SOURCE: Column 2,3 is taken from Balakrishnan and Pushpangadhan (1994).

For the last two years (1989-90 and 1990-91) the investment was computed and added on (see relevant section of chapter 3).

Column (4) was computed by converting the constant figures of column (1) into current prices using the WPI reported in column (3).

Table 4.2

ESTIMATES FOR RATE OF REPLACEMENT
AND RATE OF RETURN

FINANCIAL YEARS	RATE OF DEPRECIATION	GROSS YIELD ON PREFERENTIAL INDUSTRIAL SHARES
(1)	(2)	(3)
1970-71	0.098	0.095
1971-72	0.105	0.100
1972-73	0.107	0.102
1973-74	0.108	0.102
1974-75	0.102	0.107
1975-76	0.089	0.117
1976-77	0.090	0.120
1977-78	0.090	0.122
1978-79	0.094	0.121
1979-80	0.091	0.110 *
1980-81	0.097	0.110
1981-82	0.091	0.110
1982-83	0.088	0.110
1983-84	0.101	0.135
1984-85	0.109	0.150
1985-86	0.108	0.150
1986-87	0.101	0.150
1987-88	0.120	0.140
1988-89	0.115	0.140
1989-90	0.119	0.140
1990-91	0.107	0.140

Note: * From 1979-80 onwards the yield reported is for preferential shares cum convertible preferential shares.

Source: Column (2) is estimated using the ASI data for the Factory Sector on fixed capital and depreciation.

Column (3) is from the RBI Bulletin (various issues), from 1978 onwards the source is `Basic Statistics on the Indian Economy' (CMIE publication)

Table 4.3

ENERGY TYPES - INPUT ESTIMATES

YEARS	FOR MANUFACTURING SECTOR COAL	OIL	ELECTRICITY	TOTAL (2+3+4)	TOTAL (MINING + MANUFAC)
(1)	(2)	(3)	(4)	(5)	(6)
1970-71	24.02	10.90	29.56	64.48	76.27
1971-72	24.51	10.60	28.94	64.05	77.45
1972-73	24.79	9.00	32.25	66.04	85.59
1973-74	29.58	8.72	34.00	72.30	91.17
1974-75	38.89	8.62	32.68	80.19	99.32
1975-76	44.26	8.50	37.59	90.35	103.89
1976-77	44.01	8.55	41.63	94.19	102.55
1977-78	43.97	8.40	42.66	95.03	105.30
1978-79	43.93	8.50	47.77	100.20	111.50
1979-80	44.49	9.00	45.99	99.48	113.90
1980-81	46.35	10.19	48.10	104.64	115.59
1981-82	52.54	11.20	53.06	116.80	122.16
1982-83	60.03	11.23	52.96	124.22	129.64
1983-84	63.78	11.48	57.11	132.37	137.86
1984-85	62.31	12.27	62.97	137.55	142.34
1985-86	68.21	13.05	67.03	148.29	153.18
1986-87	69.74	13.54	70.29	153.57	163.36
1987-88	74.28	14.77	69.45	158.50	187.49
1988-89	74.97	15.60	75.45	166.02	196.95
1989-90	72.84	15.60	80.69	169.14	
1990-91	79.71	15.93	93.23	188.87	

Note: All quantities (column 2,3,4,5,6) are in Million Tons Coal Replacement (MTCR).

Source: Column 2,3 and 4 are computed using the `Productivity', Vol.31. No.4, Jan-March (1991). and CMIE (June, 1994) estimates:

Column (6) is taken from `Productivity'(op.cit).

Table 5.1

ESTIMATES OF ELASTICITIES OF SUBSTITUTION BETWEEN VARIOUS INPUTS IN THE MANUFACTURING SECTOR OF INDIA FOR THE SELECTED YEARS (MURTY, 1986)

YEAR	1960	1970	1977
h_{KK}	-37.95	-21.60	-21.96
h_{KL}	7.57	6.78	8.53
h_{KE}	14.75	10.48	8.24
h_{KM}	2.16	1.85	1.86
h_{LL}	-4.66	-4.85	-4.40
h_{LE}	-7.58	-8.98	-8.75
h_{LM}	0.28	0.11	0.13
h_{EE}	-17.47	-16.88	-12.92
h_{EM}	0.53	0.54	0.66
h_{MM}	-0.31	-0.34	-0.33

Table 5.2

ESTIMATES OF OWN AND CROSS PRICE ELASTICITIES OF DEMAND FOR VARIOUS INPUTS IN THE MANUFACTURING SECTOR OF INDIA FOR THE SELECTED YEARS (MURTY, 1986)

YEAR	1960	1970	1977
e_{KK}	-3.15	-2.49	-2.50
e_{KL}	0.79	0.58	0.57
e_{KE}	0.71	0.53	0.55
e_{KM}	1.65	1.39	1.40
e_{LL}	-0.49	-0.41	-0.29
e_{LK}	0.63	0.78	0.97
e_{LE}	-0.37	-0.45	-0.58
e_{LM}	0.22	0.08	0.10
e_{EE}	-0.84	-0.85	-0.86
e_{EK}	1.23	1.21	0.94
e_{EL}	-0.79	-0.77	-0.58
e_{EM}	0.41	0.41	0.49
e_{MM}	-0.24	-0.25	-0.25
e_{MK}	0.18	0.21	0.21
e_{ML}	0.03	0.01	0.01
e_{ME}	0.03	0.03	0.04

Table 5.3

ESTIMATES OF AES BETWEEN ENERGY INPUTS IN THE MANUFACTURING SECTOR OF INDIA FOR SELECTED YEARS (MURTY, 1986)

YEAR	1953	1960	1970	1977
$h_{CO} = h_{OC}$	1.0352	1.0343	1.0398	1.0683
$h_{CE} = h_{EC}$	2.6961	2.6371	2.5736	2.3587
$h_{OE} = h_{EO}$	4.3806	3.7925	3.5448	4.3493

Table 5.4

ESTIMATES OWN AND CROSS PRICE ELASTICITIES OF DERIVED DEMAND FOR ENERGY INPUTS IN THE MANUFACTURING SECTOR OF INDIA FOR SELECTED YEARS (MURTY, 1986)

YEAR	1953	1960	1970	1977
e_{CC}	-0.9308	-1.0265	-1.1025	-1.1548
e_{CO}	0.1487	0.1590	0.1567	0.1005
e_{CE}	0.7819	0.8668	0.9458	1.0543
e_{OC}	0.5861	0.5351	0.5009	0.4896
e_{OO}	-1.8577	-1.7825	-1.8042	-2.4334
e_{OE}	1.2704	1.2466	1.3027	1.9441
e_{EC}	1.5265	1.3644	1.2397	1.0819
e_{EO}	0.6295	0.5829	0.5349	0.4099
e_{EE}	-2.1566	-1.9475	-1.7740	-1.4915

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