134

ENERGY EFFICIENCY IN INDIAN MANUFACTURING SECTOR :
A CASE STUDY OF BASIC METALS AND ALLOYS

DISSERTATION SUBMITTED IN PARTIAL FULFILMENT
OF THE REQUIREMENTS FOR
THE AWARD OF THE DEGREE OF
MASTER OF PHILOSOPHY
IN APPLIED ECONOMICS OF THE
JAWAHARLAL NEHRU UNIVERSITY, NEW DELHI

PRIYA PAVITHRAN

CENTRE FOR DEVELOPMENT STUDIES
THIRUVANANTHAPURAM

1999

I hereby affirm that the research for this dissertation titled "*Energy Efficiency in Indian Manufacturing Sector - A Case Study of Basic Metals and Alloys*" being submitted to Jawaharlal Nehru University for the award of the Degree of Master of Philosophy in Applied Economics, was carried out entirely by me at the Centre for Development Studies, Thiruvananthapuram.

Thiruvananthapuram

Priya Pavithran

Certified that this dissertation is a bonafide work of Ms. *Priya Pavithran*, and has not been considered for the award of any other degree by any other university.

Dr.K Pushpangadan
Associate Fellow

Dr. K J Joseph
Associate Fellow

Supervisors

Chandan Mukherjee
Director
Centre for Development Studies
Thiruvananthapuram

ACKNOWLEDGEMENTS

With great respect and love I express my heartfelt obligations to Dr. K.Pushpangadan and Dr. K.J.Joseph, my supervisors who were a great source of inspiration for me. Their sincere guidance, fruitful discussions, friendly but sharp criticisms, ever willing help and constant encouragement enabled me to complete this work.

I thank Dr. K.Pushpangadan, who initiated this work and whose analytical rigor served to clarify several conceptual issues.

Words cannot express my obligations to Dr K.J Joseph who has contributed substantially to this work. I am grateful to him for the dedication and patience with which he guided me. I acknowledge him for the considerable time devoted to me for this piece of work.

I am greatly indebted to Professor K.K.Subrahmanian and Padma aunty who made me feel at home during my stay at CDS. I shared some cheerful moments with them. I express my sincere regards to them. Professor K.K.Subrahmanian encouraged me to take up this topic and I have greatly benefited from the discussions with him.

I express my sincere gratitude to Dr.P Mohanan Pillai and Dr. Achin Chakraborty, the M.Phil co-ordinators of our batch for their help and co-operation.

I would like to thank the staff of the CDS library, the administration and computer centre for the cooperation they extended during my stay at the centre. A special thanks to Shobha chechi, Gopakumar, Phil Roy, Anilkumar and Sujana Bai.

Coming to friends, I owe special thanks to Deepa, Beena, Meena and Veeramani who assisted me at the most crucial moment which helped me complete the editing and printing faster than I had anticipated.They helped me in more ways than I can fully acknowledge. My sincere thanks to all of them.

I thank my friend Margaret for the help she has extended to me, right from the day I decided my area of research. I also thank Darley for the warmth and affection she has showered on me.

I would like to thank my seniors for helping me at various stages of this thesis. I have benefited much from the discussions with them. Thanks are also due to my juniors and the project staff at CDS who have helped me in many ways.

I enjoyed the company of my classmates at CDS. I thank all of them wholeheartedly.

But for the love and care of my parents and the boundless Grace of the unseen Benevolence of the Universal Teacher it would not have been possible to attempt this work.

Priya Pavithran.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Energy is a key input in economic growth. Cross country studies on economic growth have since long identified the close correlation between the levels and the rate of economic growth and energy consumption[1]. In fact, energy consumption per capita has often been considered an appropriate proxy for not only the extent of industrialisation but also for the levels of welfare. Attempts of most developing countries towards augmenting their growth process have been constrained, *interalia*, by their access to adequate energy sources at affordable prices. Hence efforts have been made, both in the developed and developing economies, towards discovering and conserving energy sources along with efficient utilization of available sources.

In this worldwide trend, India has not been left behind. Attempts have been made from the early days of development planning towards exploring new energy (both conventional and unconventional) sources and bringing about technological innovations towards its conservation and efficient use. The importance attributed to the energy sector is evident from the fact that its share in total plan outlay has increased from 18.8 per cent in the sixth plan to 26.5 per cent in the ninth plan. These efforts seem to have yielded rich dividends. This is

---

[1] The key role of energy as an input in the production process is 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 with other factors of production.

evident from the structural shift in the composition of energy production. There has been a shift away from traditional sources of energy to modern commercial forms of energy (coal oil, gas and electricity). The share of commercial energy, which refers to all sources of energy that pass wholly or almost entirely through the market place (Sengupta; 1993), in total energy has almost doubled from 32 per cent to 64 per cent during 1970-94. Secondly, there has been an impressive growth in the production of energy. The production of commercial energy, [2], 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). The composition of commercial energy also has undergone major changes. The share of natural gas in total energy supply showed an impressive rise from two to eight per cent during the same period. Coal accounted for as much as 60 per cent of total energy, though its share declined marginally to reach 58 per cent in the 1990's. It, however, continues to remain the major fuel for the economy, registering a growth rate of 5.3 per cent between 1970-94. 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 energy increased from 54 to 71 per cent and that of nuclear energy declined marginally, from 2.9 to 2.6 per cent.

---

[2] The different forms of primary commercial energy sources in India are coal,oil,natural gas,hydro and nuclear power.

Along with the impressive performance in the production of energy the consumption of energy increased more than proportionately. As a result, India's demand for energy far exceeded the domestic production. This has been accompanied by a change in the structure of demand as well. Among major energy using sectors, the share of industry almost doubled during 1953-1990 to reach about 67 per cent and that of transport almost halved from about 46 per cent to 23 per cent during the period under consideration (see table 1). Thus, today industrial sector accounts for bulk of the energy consumed in India.

Table 1.1

Percentage share in final energy consumption by different sectors

Sector	1953-54	1960-61	1970-71	1980-81	1990-91
Industry	39.8	40.7	51.6	57.0	50.4
Transport	46.2	44.9	29.4	23.5	24.5
Household	9.9	10.6	14.3	12.3	13.8
Agriculture	1.7	1.8	3.8	6.1	9.0
Others	2.4	2.0	0.9	1.1	2.3

Source:GOI, Planning commission (1992)

The impressive performance on the production front, notwithstanding, India continues to be a net importer of oil which exerts severe strain on India's balance of payments. Being a net oil importer, India's balance of payments situation was severely affected by the unprecedented hikes in international oil prices during the 1970's. Between 1970 and 1980, the import value of petroleum , oil and lubricants (POL) increased from a mere 9 per cent to 78 per cent. Few years of respite was experienced in the mid 1970's 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 fluctuations in the global oil market. The Advisory Board on Energy (1986) estimated the total domestic investment required for meeting the demand for fuel at Rs 450,000 crores over the next 20 years. If the present demand and supply scenario is maintained, then by 2000 A D the oil import bill is expected to be of the order of Rs. 20,000 crores per annum. Therefore, meeting the future energy needs of the nation is going to be a major concern to the planners.

The excess demand for energy had its implication on the energy prices which in turn had a bearing on the general price level. 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) shows that, for the period of 1970-94, furnace oil showed 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, 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 the rise in crude oil prices (at a rate of 20.26 per cent) and equally sharp increase in the prices of furnace oil (19.9 per cent) and light diesel oil (17.05 per cent). Coal (the major fuel of the Indian economy) prices remained fairly low and steady in India before nationalisation of the coal industry. The period after nationalization in 1973 saw fast rise in coal prices at a rate of 17.20 per cent per annum between 1973-74 and 1985-86. Over the whole period, 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[3].

The discussion thus far has thrown up a number of issues that requires careful empirical analysis. The most important issue being, how best India could address her energy problem in the short run and in the long run? The problem has both supply and demand dimensions. While the interventions in the supply side have a long term perspective, the demand side of the problem could be addressed at least partly, in the short run. On the demand side, one of the major issues pertains to the energy use efficiency. Since there are evidences which suggests that energy efficiency in the Indian manufacturing industry (which accounts

---

[3] It may be noted 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 1990-91. In 1995-96, the average tariff (electricity prices) in India was lowest for agriculture (24.46 paise per unit) and highest for industrial and commercial sectors (218.36 paise per unit and 208.11 paise per unit respectively).

for nearly two-thirds of the total energy consumed) is very low[4], it may be appropriate to carry out a careful analysis of the energy use efficiency in the industrial sector. This forms the focus of the present study. To identify the specific issues and define the approach of the study we shall review the relevant studies in the area.

Review of literature

Industrial countries have shown a trend towards substantial reduction in the use of fuels, whereas India has been showing a reverse trend (due to rapid automation). There are a number of studies that point towards the scope for conserving energy and the existing possibilities of improving energy efficiency in Indian industries. For instance The United Nations Study (1984) claims that there is scope for the saving of significant amounts of energy at relatively low costs by simple changes in the production process. It also points out that a number of measures for improving efficiency are available 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 the face of serious energy shortages. It notes the attempts by certain developed countries like Japan, France and United Kingdom towards conservation. This has also been seen in a small sample of (ten) Indian industries which have proved exemplary in the field of conserving energy. Some of them are

---

[4] It has also been pointed out that 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 (almost doubled during the past two decades).

Arvind Mills, Ahmedabad, Bharat Petroleum Corporation, Bombay and so on. The scope for increasing energy efficiency in industry was also pointed out by Pachauri (1980) in his Indian Oil Study. He estimates a saving of Rs 24 crores per annum for the industry through improved efficiency.

The World Bank has also enquired into the question of energy efficiency in particular industries, with reference to the developing countries (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). These studies contain series of measures for improving energy efficiency on the lines of experience of the developed world. Andrew (1985) found that energy consumed per ton of paper produced declined by 10 per cent in the United States between 1972-1989 as a result of in-plant improvements. He estimated a return of 20-30 per cent in the form of energy savings. Similarly, for the steel industry, Meunier and Oscar quote the example of Japan and claim that a saving of 10-15 per cent on energy consumed can be achieved by the developing countries through the adoption of efficiency measures. Mogens and Kishore have also concluded that there exists substantial potential for reducing energy consumption in developing countries and have suggested various measures. Some of the measures suggested by these studies were improved utilization of waste residuals as fuels, introduction of energy audit, optimal plant size, improving design technology, operational environment, skills, appropriate pricing of energy inputs and so on.

On the other hand, one disturbing factor pointed out by these studies is that, Indian Industries are least energy efficient when compared to other industrial and developing countries. For instance, in the cement industry, India shows 0.163 tones of oil equivalent (toe) of fuel consumption per ton of output, whereas the same stands at 0.09 toe for Federal Republic of Germany and at 0.108 toe and 0.161 toe for Turkey and Pakistan respectively (Mogens and Kishore; 1983).

An important question addressed by a large number of studies refers to the possibilities of substituting energy with other inputs. Earlier studies on production structures assumed negligible substitution possibilities between energy and non-energy inputs (capital and labour). Since energy and materials cost constitutes a significant portion of the production cost, their omission as a separate variable in estimation may alter the estimates of substitution, scale economies, technical change and lead to sub-optimal estimates of output. Berndt and Wood (1975) tested a four input (KLEM) translog cost function with U.S manufacturing time series data for the period 1947-71. They found that energy and capital are complementary and that energy and labour are substitutable. Fuss (1977) in his study on the Canadian manufacturing sector using pooled time series (1961-71) cross section (5 regions) data concluded that energy and capital are complementary. Similar results have been reported by Magnus (1979) for Netherlands, while estimating a three input function (KLE) using annual time series data, 1950-1976. On the other hand, there are some studies that show substitutability between energy and capital. Griffin and Gregory (1976) found energy and capital as substitutes while estimating three input (KLE) translog cost function from pooled cross-section data for the manufacturing sector of nine industrialized organization for Economic Corporation and Development (OECD) countries, at five year intervals from 1955-1969. Pindyck (1979) applied a similar function to pooled cross-section time-series data for the industrial sectors of ten countries (seven European countries, Canada, Japan and the U.S) during the period 1963-73 and showed that energy and capital are substitutes.

The impact that energy shortages will have on the economy will depend crucially on the elasticities of substitution between energy and non-energy inputs. Likewise, if substantial substitution possibilities among energy and non-energy inputs are present, then a rise in energy prices can be absorbed by substituting other factors in place of energy, without affecting the output levels too adversely.

There are a number of Indian studies which investigate the price sensitivity of energy demand and substitution possibilities among energy components as well as between energy and non-energy inputs in the manufacturing sector. The focus on this sector could be because of the fact that it is the major fuel consuming sector in India. One such study is by Vashist (1984) which estimated the elasticity of substitution using a three input translog cost function for the total manufacturing sector for the period 1960-71. He found that labour is a substitute for capital and energy and also that energy and capital tend to be complements in the short run. William and Laumas (1981) estimated the substitution elasticities using a four input (KLEM) translog cost function using data for a cross-section of manufacturing industries for 1968. It was found that all factors are fairly good substitutes of energy, with the exception of labour. There was divided evidence with respect to the relationship between labour and energy; they emerge as complements for some product groups and substitutes for the others. They also found that the own price elasticity of energy is higher than that of other factors of production. Apte (1983) analysed the pattern of substitution between the energy and non-energy inputs, and within the energy inputs (broadly categorized as solid fuels, liquid fuels and electricity) for a set of five industries. He used a pooled time-series (1968-1971) and cross-section (across five industries) sample. His method involved a two-stage analysis using translog cost function. He found energy and capital to be complementary in four out of five industries. Jha, Murty and Paul (1991) measured the substitution elasticities between factors (capital, labour and a combined energy material [EM] input). They considered four manufacturing industries and estimated the translog cost function using aggregate time-series data covering the period 1960-61 to 1982-83. It was found that capital can be substituted by labour and/ or EM in all industries except cotton textiles.

Satyanarayana (1995) attempted to examine the nature of energy use, to investigate the type of technical change and quantify the inter-factor and inter-fuel substitution possibilities through a two-stage optimization technique using a four input (KLEM) translog form. The results showed that the output-energy ratio declined after 1982. The more energy utilising industries were responsible for this decline. The nature of technical change which was found to be in favour of energy using was partially responsible for this fall in ratio. Substitution elasticity between energy and capital and also between energy and materials declined in the eighties, thereby causing a fall in output-energy ratio. Energy and labour emerged to be complements. High factor and substitution elasticities reveal that there is sufficient scope for bringing down the energy demand in the sector in real terms.

From the studies reviewed above certain broad generalisations can be drawn, with specific reference to the Indian manufacturing sector. It was seen that as far as 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 comparison to developing nations. The evidence on the degree of factor and fuel substitution and demand elasticities is mixed. Regarding the substitution possibilities among inputs, the studies confirms that there exist substantial opportunities.

It is important to note that all these studies dealt with energy use at the industry level. It could be argued that the relevance of such studies is undermined by the fact that these studies are not preceded by any careful analysis of the behaviour of (firms) that constitute the industry. Hence a proper enquiry into the different dimensions of energy efficiency calls for firm level analysis. Indeed, there are a few micro-level studies. Such studies suffer from a major methodological problem because they looked into the technical inefficiency in the production process where energy is used as one of the inputs. Such aggregate or overall inefficiency measures are not capable of identifying inefficiency of individual input. In India, there is hardly any study at the industry level or at the firm level which has attempted to measure input-specific technical inefficiency. In general, we have identified two major gaps; (a). lack of analysis of the firm level behaviour and (b). absence of studies on input-specific technical inefficiency. The present study, therefore, is an attempt to fill these two gaps by analysing the input-specific inefficiency at the firm level.

Objectives of the study

The specific objectives of the study are as follows;

(1) to examine the trends and patterns of energy use in the Indian manufacturing sector,

(2) to estimate input-specific (energy) inefficiency at the firm level, and

(3) to analyse the factors responsible for inter-firm variations in energy efficiency.

Data source

The present study draws heavily on secondary sources for data. The data on value of output and energy for each industry for the years 1974 to 1994 have been obtained from the Annual Survey of Industries (ASI)- Summary Results for the Factory Sector published by the Central Statistical Organisation (CSO). The price indices for output and energy were taken as given by Chandhok (1990), and RBI Reports with the base year 1981-82. For the firm level study, data was taken from the database compiled by the Centre for Monitoring Indian Economy (CMIE) entitled 'PROWESS'.

Chapter Scheme

The present study comprises of six chapters including an introduction and conclusion. The second chapter examines the trends in energy use in the Indian manufacturing sector at disaggregate level. Here we also address issues regarding the substitution between energy, labour and capital. On the basis of the analysis of inter-industry variations in energy intensity we identified and selected the Basic Metals and Alloys industry for detailed analysis. The third chapter presents the methodology used in the study. The fourth chapter presents the estimated results of input-specific (energy) inefficiency at the firm level using Data Envelopment Analysis. An analysis of the determinants of inter-firm variations in energy inefficiency is the subject matter of chapter five. The last chapter provides the main findings and conclusions of the study.

CHAPTER 2

TRENDS AND PATTERNS OF ENERGY INTENSITY IN THE INDIAN MANUFACTURING SECTOR

Introduction

The focus of the present study, as identified in the previous chapter, is on the analysis of input-specific inefficiency at the firm level. From the operational side, a question which needs to be addressed is related to the selection of an industry for detailed firm level analysis. In the present chapter, an attempt is made to identify a specific industry on the basis of a disaggregate analysis of the trends and patterns in energy intensity in the Indian manufacturing sector. The chapter is organised as follows - The trend in energy intensity in the manufacturing sector is examined in the first section. The second section deals with inter-industry variations in energy use in the manufacturing sector. The third section brings out the case for studying the firms under Basic Metals and Alloys industry and this is followed by the conclusion to this chapter.

Trends in energy intensity in the Indian manufacturing sector:

The trend in energy use in the Indian manufacturing sector has been examined using the energy-output (E/O) ratio which measures the energy intensity (amount of energy consumed per unit of output) in a unit. Industries at two digit level classification provided by National Industrial Classification (NIC) has been used in the analysis [1]. In this study, the manufacturing sector

---

[1] The relevant classification can be found in annexure II (supplement to) ASI, Summary results for the Factory Sector.

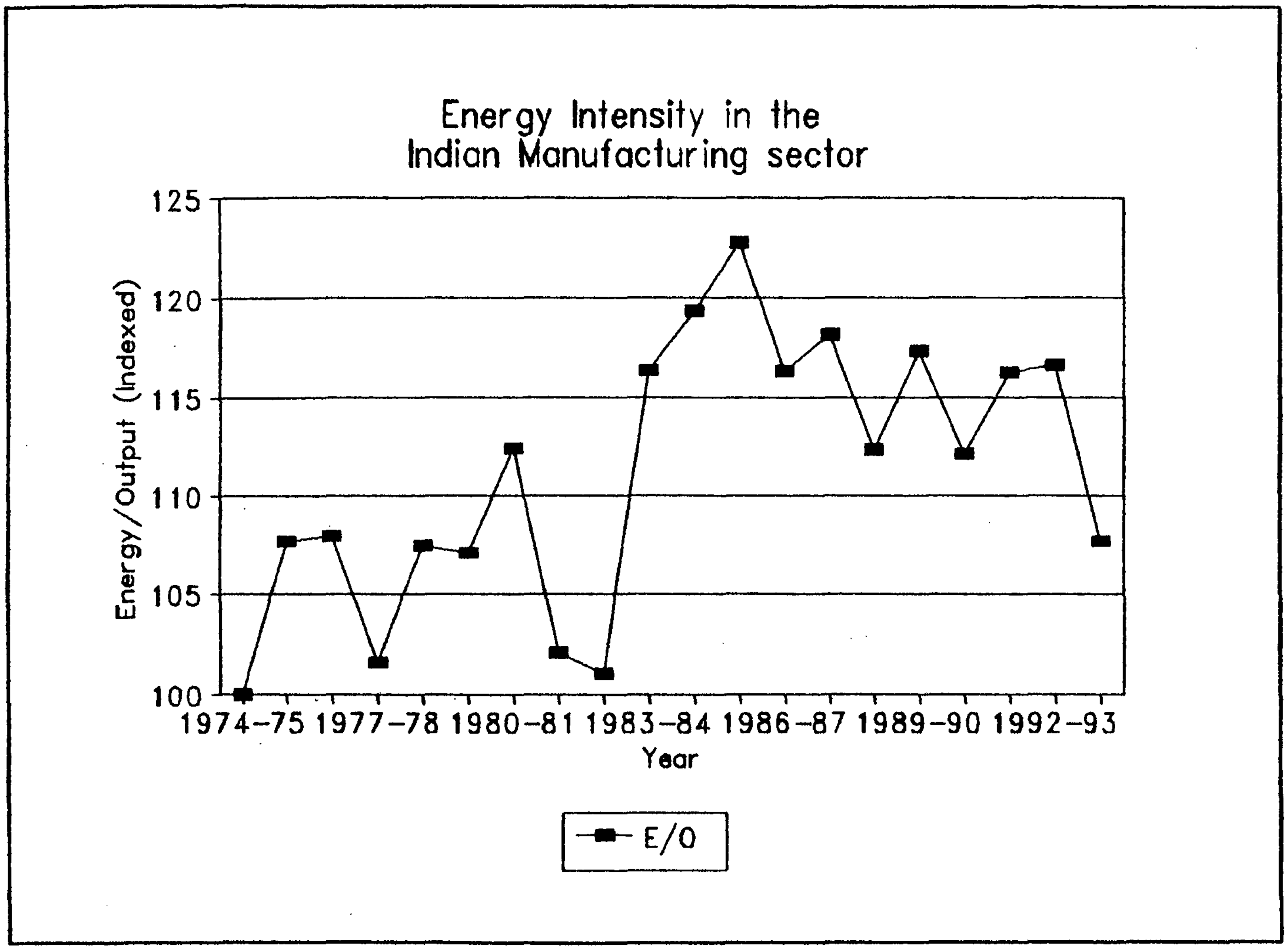
has been defined as all industries excluding `electricity,´ `water works and supply´, `gas and steam´ and `repair works´. The time period covered by this study is 1974-94. This period of analysis is significant as this was a time of intense turmoil in the international oil market with implications for the net energy importing nations like India. The oil crisis in 1973 marked the end of the cheap oil era and the beginning of a subsequent and all time increase in the prices of all fuel types.

To understand the energy intensity in the manufacturing sector during the 1974-75 to 1993-94 period, see Graph 2.1 (page no.16) which illustrates the energy-output ratio of the manufacturing sector. The value of output in the manufacturing sector and the value of energy used in production have been taken at constant prices. The deflator used for output is the Wholesale Price Index(WPI) for `manufacturing sector´, and the WPI for `fuel, oil and lubricants´(base 1981-82=100) for energy[2]. Until the eighties, no particular trend was observed in the E/O ratio, however after 1983 a sharp increase can be seen till 1986. Then onwards the ratio shows a declining trend with year to year fluctuations. Notwithstanding the declining trend, we can see a sizable rise in the level of energy intensity. The E/O ratio touches its peak in 1985-86 as it started rising after 1983. This indicates that after 1983 the amount of energy used to

---

[2] The WPIs are taken from Chandhok (1990) and Index Number of Wholesale Price in India.

GRAPH 2.1

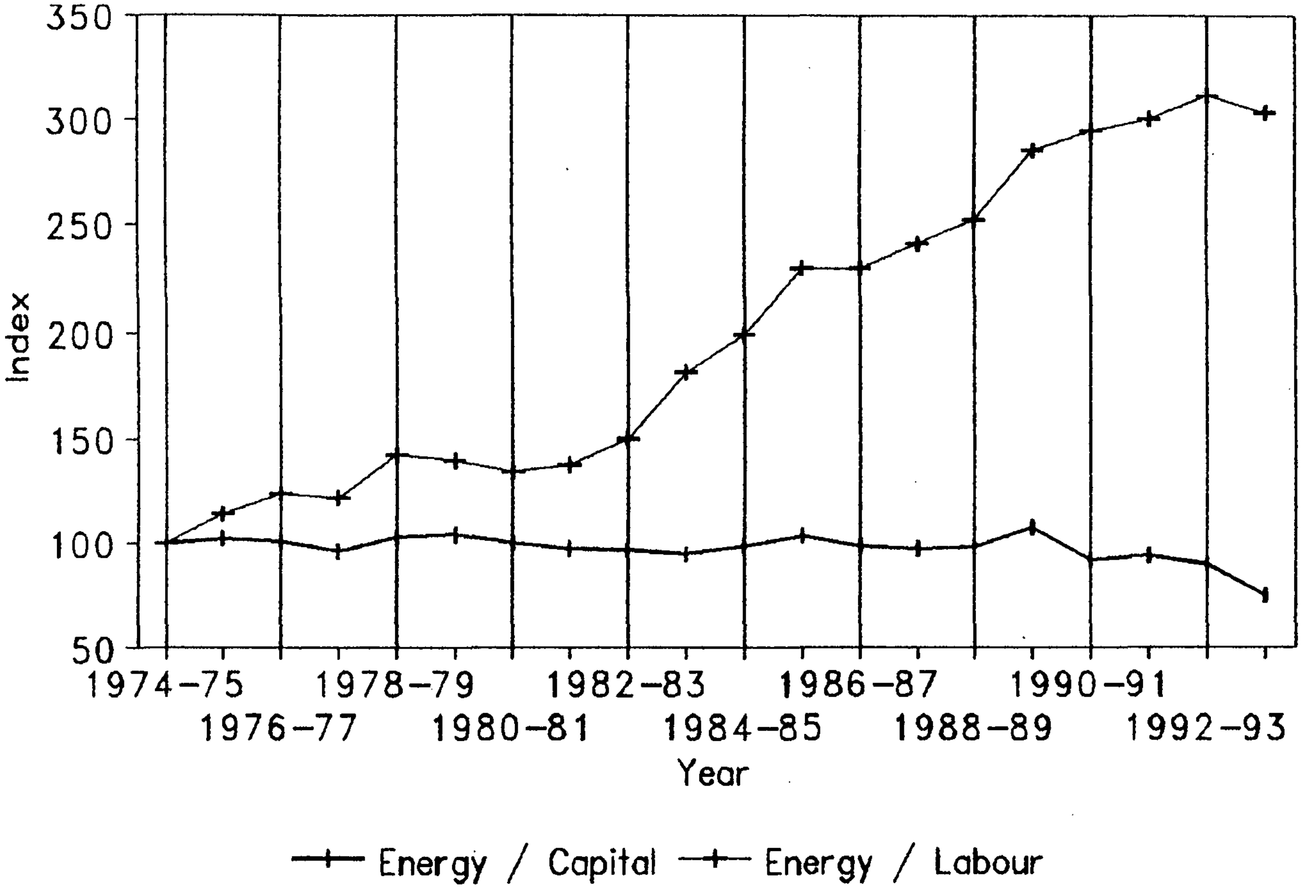

Energy Intensity in the
Indian Manufacturing sector
Energy/Output (Indexed)
125
120
115
110
105
100
1974-75
1977-78
1980-81
1983-84
1986-87
1989-90
1992-93
Year
E/O

produce one unit of output was higher than that required prior to 1983. This implies that the energy use in the manufacturing sector has increased after 1982-83. In a scenario of rising fuel cost, the industries are expected to increase their fuel productivity (manage energy efficiently), conserve fuel and also examine the possibility for substitution of energy with less expensive inputs and thus reduce cost of production. Trends in input substitution is examined in Graph 2.2. (See Graph 2.2, p.18). The figure shows a sharp increase in the energy-labour ratio in the Indian manufacturing sector especially after 1983. *This would mean that substitution of labour by energy has been taking place over the years. However the energy-capital ratio remained more or less constant. Thus it may be inferred that the energy use in the Indian manufacturing sector has increased especially after 1983 partly due to the increased substitution.* This increase in energy use may indicate inefficiency in energy use in the manufacturing sector. Let us examine this in more detail taking the inter-industry variations in energy intensity. *The finding becomes meaningful only if there is no substitution between energy and other inputs such as labour, capital and materials.*

Inter-industry variations in Energy Intensity:

It was seen that the pattern of energy intensity in the manufacturing sector increased after 1983. The trend growth rate of energy intensity variation at industry level will provide further insights regarding energy utilisation in the manufacturing sector. The trend growth rate of E/O ratio was

Energy–Labour and Energy–Capital Ratios
In the Indian Manufacturing Sector



computed for a twenty year period (1974-94) and for two sub-periods - before and after the oil crisis (1974-83 and 1983-94 respectively) across industries in the manufacturing sector have been taken for the study. The year 1983 has been taken as the year of break (kink) since this captures the period before and after the oil crisis and this break has been confirmed based on a structural break test. Moreover the dummy variable test for the manufacturing industry as a whole has shown that the trend break or kink at 1983 is significant (the growth rate in the second period is significantly different from the first period). The growth rates of E/O shows that there are inter-industry variations. (See Table 2.1). Of the 18 industries, industries 22, 32 and 34 (Beverages and Tobacco, Non-metallic mineral products and Metal products) registered an increase in growth rate of E/O in the second sub-period compared to the first sub-period. This implies that energy consumption by these industries is growing at a higher rate in the 80's compared with the 70's. Industries 21, 30 and 35 also showed an increase in growth rate after 1983 but the R-squared was very low for these industries (0.26, 0.23 and 0.11 respectively). Industries 36 and 38 showed negative growth rate in the second sub-period. The negative growth rate indicates that the E/O ratio has been declining over the years. However it was observed that the rate of decline is lower in the second sub-period compared to the first sub-period.

Table 2.1
TREND GROWTH RATES OF ENERGY-OUTPUT RATIO :

Industry	1974-83	1983-84	1974-94
20-21	7.89 (0.775)	1.012 (1.431)	9.01
22	2.451 (2.52)**	2.87 (4.26)**	2.661
23	2.057 (1.75)***	0.599 (0.733)	1.328
24	-1.747 (-2.26)**	-0.523 (0.025)	-1.135
25	2.913 (2.336)**	2.482 (2.86)**	2.698
26	1.381 (1.312)	-0.328 (-0.448)	0.527
27	2.448 (1.349)	1.287 (1.021)	1.868
28	3.149 (4.89)*	2.492 (5.57)**	2.821
29	6.719 (7.01)*	-0.838 (-1.259)	2.941
30	-0.179 (-0.088)	2.671 (1.900)***	1.246
31	2.018 (3.153)*	-1.886 (-4.241)*	0.066
32	1.238 (2.146)**	1.472 (3.67)*	1.355
33	1.412 (1.380)	-0.288 (-0.405)	0.562
34	-1.006 (-1.287)	4.781 (8.79)*	1.888
35	-1.959 (-3.47)*	0.044 (0.113)	-0.958
36	-3.026 (-3.47)*	-1.47 (-2.426)**	-2.248
37	0.34 (0.494)	-1.391 (-2.907)**	-0.526
38	-6.638 (-4.830)*	-3.331 (-3.487)*	-4.985
MFG	1.157 (2.178)**	0.272 (0.736)	0.715

Source: ASI

Note: Figures in parentheses are t-ratios. * Significant at one per cent level ** Significant at five per cent level
*** Significant at ten per cent level

Satyanarayana(1995) observed that in Indian manufacturing sector the more energy utilising and less energy utilising industries did not experience a change in their energy utilisation status after 1983. This suggests that there has been no shift in favour of more energy utilising industries (new industries have not joined the group) after 1983. The shares of the more energy utilising and less energy utilising factories in the total number of factories reveals 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 seventies, this share came down to 45.50 per cent after 1983. 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 again implies that there has been no structural shift in the manufacturing sector towards more energy utilising industries. In fact her results showed that the less energy utilising factories had increased their share in the manufacturing sector. Besides this, the average output-energy (O/E) ratio for the more energy utilising industries showed a decline from 18.76 in the seventies to 16.84 after 1983 whereas for less energy utilising industries, this ratio remained more or less stable at 43.58 in the seventies and 43.62 after 1983[3]. Thus, though there was no shift towards more energy utilising industries in the sector, the fall in the output-energy ratio of the industries in this category were mainly responsible for this trend in the manufacturing sector.

---

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

The Case for selecting Basic Metals and Alloys industry:

Having established that the energy intensity and inefficiency has increased in Indian manufacturing, we need to study the factors responsible for the increase in the energy used per unit of output in the manufacturing sector after 1983. This can be meaningfully done by carrying out a firm level study taking the firms belonging to an industry which is more energy utilising and also comparatively large in size. The industry for the indepth study is chosen in the following manner. The industries in the manufacturing sector have been divided into three categories, High, Medium and Low energy intensive industries, based on a cut off average E/O ratio computed for the manufacturing sector as a whole. The average E/O ratio for the manufacturing sector has been computed by averaging the average E/O ratio of each industry. The average E/O ratio for each industry for both the twenty year period (1974-94) and for the last five years (1989-94) were taken. To categorise the various industries into the three groups the computed E/O ratios of the industries were arranged in descending order. Using the cut off ratio computed from the manufacturing sector the industries lying above the cut off point were categorised as Highly Energy Intensive Industries (HEI). Altogether six industries belonged to this category. The next six industries where categorised as Medium Energy Intensive Industries (MEI) and the remaining six industries as Low Energy Intensive Industries (LEI). It may be noted that the industries classified as High, Medium and Low energy intensive in the time period 1989-94 were the same as those that occurred in the time period 1974-94. Table 2.2 illustrates the three categories of industries along with their E/O ratio and output share.

Table 2.2

Mean Energy Intensity and Mean Share of output in total manufacturing; 1974-94.

Category 1: Highly Energy Intensive Industries (HEI)

NIC code	Industry	E/O	Rank of E/O	Output Share	Rank
32	Non-metallic mineral products	0.253	1	0.038	10
28	Paper and paper products	0.138	2	0.138	11
33	Basic metals and alloys	0.132	3	0.123	3
25	Jute, hemp, mesta and other vegetable fibre	0.103	4	0.005	17
23	Cotton and cotton textiles	0.083	5	0.061	7
31	Chemicals & chemical products	0.082	6	0.174	1

Category 2: Medium Energy Intensive Industries (MEI)

NIC code	Industry	E/O	Rank of E/O	Output Share	Rank
24	Wool, silk and synthetic fibre	0.059	7	0.059	9
34	Metal products	0.054	8	0.019	13
27	Wood and wood products	0.041	9	0.003	18
22	Beverages and tobacco	0.036	10	0.017	15
20-21	Food and food products	0.031	11	0.155	2
37	Transport equipment	0.03	12	0.065	6

Category 3: Low Energy Intensive Industries (LEI)

NIC code	Industry	E/O	Rank of E/O	Output Share	Rank
35	Non-electrical machinery	0.0253	13	0.0253	8
30	Rubber, plastic, petroleum and coal products	0.025	14	0.122	4
36	Electrical machinery	0.018	15	0.072	5
29	Leather and fur products	0.012	16	0.011	16
26	Textile products	0.015	17	0.021	12
38	Miscellaneous	0.013	18	0.018	14

Source: Same as in Table 2.1.

The industry for indepth study has to be taken from the highly energy intensive ones. Since there are six industries in this category, we have to choose an industry from among this group. The choice will be based on the energy intensity and output share of the industry in the total manufacturing sector. Among the six industries falling under the highly energy intensive industries (see Table 2.2), it is clear that non-metallic mineral products ranks first in energy intensity but it is only tenth in output share; paper and paper products ranks second in energy intensity but eleventh in output share; basic metals and alloys ranks third in energy intensity and third in output share; and chemicals and chemical products ranks sixth in energy intensity and first in output share. Chemicals and chemical products being a heterogenous group is rejected. Basic metals and alloys industry appears to be the best choice as it ranks third in terms of energy intensity and it is an important producer in terms of output share.

Summary

This chapter examined the trend in energy intensity of the manufacturing sector using the growth rate of energy-output ratio for a period 1974 to 1994. It was seen that the manufacturing sector recorded an increase in the energy intensity. This may be attributed partly to increased substitution of labour with energy inputs. Based on the analysis of trends and patterns in energy intensity across different industries we have identified the basic metals and alloys industry for the firm level analysis.

Having selected the industry for detailed study, let us now proceed with the method of analysis which is taken up in the next chapter.

Chapter 3

THEORETICAL MODELS BASED ON NON-PARAMETRIC METHODS

Introduction

In this chapter a description of the methodology based on non-parametric methods employed in this study is presented. The plan of the chapter is as follows: The first section gives a brief overview of the production and cost frontiers. The concept of x-efficiency is explained in the second section. A brief discussion of the various measures of efficiency is contained in the next section. It examines the concept of frontier estimation of efficiency and explains the three frequently used frontier based measures of efficiency, namely, parametric stochastic frontier production function, Non-parametric programming and parametric programming. The methodology employed in estimating input specific inefficiency in this study (DEA) , is explained in fourth section. The merits of this non-parametric method is also discussed. Two nonparametric measures of association- Spearman's rank correlation coefficient and Kendall's test of concordance are presented in the fifth section.

Production and Cost Frontiers

Theoretically, the concept of a production frontier is none other than the production function which defines the maximum possible output for any given inputs. A firm is inefficient if it lies below the production frontier or above the cost frontier. In terms of the production function a firm is inefficient if

$$y_i < f(x_i;\beta)$$

where small y_i is the actual output and $f(.) = y_{max}$ as given in equation (1). Now the residual ϵ_i defined as $(y_i - y_{max})$ gives the efficiency ratio in a firm as

$$\epsilon_i = y_i \; / \; f(x_i;\; \beta)$$

Similarly, Hamond (1986) gives the efficiency ratio in terms of a cost function. The function is specified as:

$$c_i > g(z_i;\; \alpha)$$

where c_i is the average cost of the firm and $g(.) = c_{min}$ is defined as the frontier (minimum) cost. Now, the residual, θ_i defines the efficiency ratio of the firm as:

$$\theta_i = g(z_i;\alpha)/c_i$$

The first empirical treatment of the production function as a frontier is in Farrell (1957) and Farrell and Fieldhouse (1962). The Farrell methodology remains the foundation of the modern frontier analysis. He began by dichotomising Overall or Pareto efficiency into two multiplicative components: OE = TE . AE where TE is technical efficiency and AE is allocative efficiency.

Technical efficiency is defined as the capacity and willingness of a firm to produce the maximum possible output from a given bundle of inputs and technology. It deals with the management of technology. Allocative efficiency, on the other hand refers to the ability and willingness of a firm to equate its specific marginal value product with its marginal cost. It is concerned with the acheivement of maximum profits from varying factor proportions. Thus while technical inefficiency arises from excessive input usage, allocative inefficiency results from employing inputs in the wrong proportions. Each of these inefficiencies can be defined in terms of a production frontier as the ratio of potential and actual performance.

Consider a firm employing two inputs x_1 and x_2, producing a single output y. The production is specified as $y=f(x_1, x_2)$ and it is assumed (by Farrell) that the returns to scale is constant, ie, linearly homogeneous. Then the production function can be specified as $1 = f(x_1/y, x_2/y)$. This enables us to draw an isoquant II.

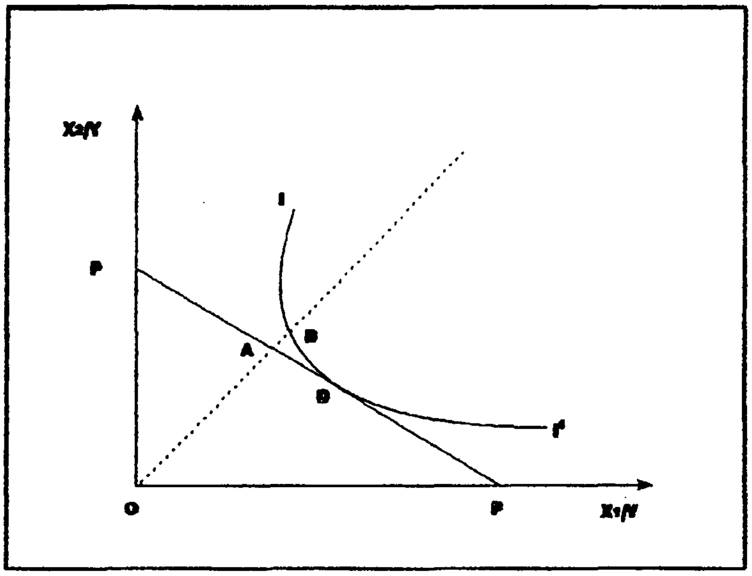
Here the firm is producing unit-output at the point C. Technical efficiency, which is defined as the ratio of the actual to the potential, can now be stated as OB/OC. It is clear that $0 \leq TE \leq 1$. Now, the allocative efficiency can be specified given the isocost line PP′which is defined by the ratio of factor prices. The allocative efficiency ratio can be given by OA/OB, whereby the firm is producing output in the most price efficient way. It can now be seen that the overall efficiency or economic efficiency is the product of technical and allocative efficiencies.

$$OE = TE \,.\, AE$$

$$OA/OC = OB/OC \,.\, OA/OB$$

Figure 3.1

Farrell Efficiency Measurement



The concept of X-Efficiency

A central notion is that firms do not produce on the outer bounds of their production possibility surface but well within it. Thus firms frequently produce less than maximum output with given inputs, and at various times they increase output without increasing inputs. Formally, X-inefficiency is defined as a situation in which a firm's total costs are not minimised because the actual output from given inputs is less than the maximum feasible level (Pearce, 1992). The degree to which actual output is less than the maximum output (for given inputs) is the degree of X-inefficiency, and the increase in the output with the same inputs increases X-efficiency (Leibenstein, 1976). Blois (1974) suggested that it would seem that the degree of X-inefficiency present in a firm could be defined in terms of the ratio of the actual cost per unit of output to the theoretical minimum cost per unit of attaining that output.' Accepting this suggetion, Leibenstein (1976) stated that the concept of X-efficiency is best expressed in value terms of both inputs and outputs. Suppose a firm maximises output in physical quantity terms, from given inputs but chooses to prpduce the wrong quantity. Inthat case also X-inefficiency exists and is better to express it in value terms.

Farrell (1957) and Leibenstein (1966) tried to explain why firms are not minimising their costs. Farrell found the reason in total inefficiency which is the product of allocative and technical Inefficiencies. Leibenstein, attributed the reason not only to the allocative and technical inefficiencies. Leibenstein, attributed the reason not only to the allocative and technical factors but to all the 'X' factors like historical factors, motivational factors, organisational structure, inadequate "pressure"components or a combination of all these factors generating an "inert area" of production in the firm. Leibenstein (1966) pointed out that non-allocative inefficiencies also exist in the firms, which he called X-Inefficiency. According to Leibenstein,

\> the concept of technical efficiency suggests that the problem is a technical one and has to do with the techniques of an input called management. Under X-efficiency, the basic problem is viewed as one that is intrinsnic to the nature of human organisation, booth organisation within the firm and organisation outside the firm (Leibenstein, 1977, p.312).

> X-efficiency is not the same as technical efficiency, since X-efficiency may arise for reasons outside the knowledge or capability of management attempting to do the managing. In other words, it is not only a matter of techniques of management, or anything else "technical" in carrying out decisions, that is involved in X-efficiency (Leibenstein, 1980, p.27).

The only limitation which the X-efficiency paradigm had been facing was its empirical estimation. According to Button (1985) "the problem of X-efficiency is that it focuses on relationships that are essentially unobservable. The factors which X-efficiency paradigm identifies for the analysis wewr not able to be quantified; and there was no adequate tool to capture the degree of X-efficiency. But the development of the frontier measurement using econometric method of stochastic Frontier Production Function and later the development of Data Envelopment Analysis (DEA) have helped to overcome this limitation.

Different approaches to the measurement of efficiency

Several measures of efficiency have been introduced in economic literature ranging from simple ratios to econometric modelling. The partial productivity measure of efficiency was criticised, since it ignores the effect of other inputs on efficiency. This led to the alternative measure of efficiency based on all inputs, that is, the Total Factor Productivity (TFP) index. Asthe TFP index is constructed using weights the measure suffers from the different inputs (Farrell, 1957).

These formulations of efficiency are termed as the classical approach, the constraints of which led to the development of the frontier based measures of efficiency. The conventional production and cost functions have been statistically estimated using the OLS regression technique and hence are average functions. The average functions are naturally associated with mean output, for given input levels as different from the frontier functions which are associated with maximum possible output.

There are two competing paradigms on how to estimate production frontiers. One uses mathematical programming techniques (deterministic) while the other employs statistical methods (stochastic).

Parametric Stochastic Frontier Model

This statistical methodology involves the explicit identification of the underlying functional form and the distribution of technical efficiency (Baurer; 1990, p.4). This model makes a parametric representation of technology along with a two part composed error term. One part is the statistical noise , generally assumed to follow a normal distribution. The other part represents inefficiency and is assumed to follow a particular one sided distribution. These can be half normal, exponential, truncated normal or two-parameter gamma.

The parameters of the production function are estimated using regression techniques. The residuals are decomposed into, an unobservable random component and an inefficiency component, i.e, the non-noise component of the error term gives the measure of X-efficiency.

However it is argued that the estimation of an explicit functional form imposes unwarranted structure on the technology. Similarly the choice of the distribution for the efficiency residuals is usually arbitrary, guided mainly by its computaional tractability.

The Deterministic Production Frontier

This approach envisages a deterministic optimal relationship between inputs and output in the sense that all variations in the firms performance is attributed to variations in firm efficiency alone. The deterministic approach consists of parametric and non-parametric programming techniques.

Non-Parametric programming(Data Envelopment Analysis)

Under this approach developed by Farrell (1957), the frontier is constructed as a free disposal convex hull of the observed input-output ratios by linear programming techniques; for a given set of firms, under different assumptions about free disposability and returns to scale. It is non-parametric in the sense that it does not assume that the underlying technology "belongs to a certain class of functions of a specific functional form which depend on a finite number of parameters, such as the well known

Cobb-Douglas functional form" (Diewert and Parkan, 1983, p.131). It is "non-statistical" in the sense that it makes no explicit assumption on the probability distribution of errors in the production function (Sengupta, 1987 a).

Parametric programming

This approach uses a deterministic linear program to estimate a frontier technology. Its main difference from the non-parametric programming technique is that the paramatric technology is smooth, while its non-parametric counterpart is piecewise linear. But this method is constrained by many limitations which make it of limited applicability.

Data Envelopment Analysis[1]:

Built on the earlier work of Farrell (1957), DEA is based on an engineering like approach, comparing a set of inputs, common to all firms. The literature on DEA is a collection of programmes - both "fractional " and "linear". The fractional program can be thought of as the conceptual DEA model, while the linear program is that used in actual computation of the efficiency ratio. The fractional program determines for each firm a set of factor weights, such that the ratio of weighted output to weighted inputs for that firm is maximised.

DEA employs a linear program to arrive at this efficiency ratio which is consistent with a frontier interpretation of

---

[1] **The discussion in this part is based on Ganley and Cubin (1992).**

performance. DEA floats a piecewise linear surface to the rest on the top of the observations. The facets of the hyperplane define the efficiency frontier, and the degree of inefficiency is quantified and partitioned by a series of matrices that measure various distances from the hyperplane and its facets (Seiford and Thrall, 1990).

For a cross section of Z firms, DEA generates Z sets of weights such that the ratio of output to input collapses to a summary, scalar measure of productive efficiency for each firm. The constraints in the programme ensure that the efficiency index has an intutive interpretation in the closed interval (0,1). If the index is unity, a firm is relatively efficient or best-practice. A value less than unity indicates a firm is inefficient relative to peer organisations.

DEA gives a measure of efficiency for each firm which allows for intrafirm performance evaluation. This advantage of DEA makes it preferable to the regression techniques, in which a single set of parameters is generated for the entire data set. Moreover DEA imposes no functional form on production technology. It handles multiple outputs; and qualitative as well as quantitative data can be used as inputs. Again, real and physical values can be used at the same time as outputs and inputs, since the objective is not to estimate the functional parameters, but a relative measure of performance.

The Fractional DEA program

Based on the Farrell's measure of efficiency, Charnes, Cooper and Rhodes (1979, 1978) formulated the fractional form of DEA. Suppose there are Z firms producing outputs Y_i, $i=1,\ldots.,t$ from inputs X_k, $k=1,\ldots.,m$; then the fractional program can be written as:

$$\underset{V_i W_k}{MAX} \sum_{i=1}^{t} V_i Y_{ip}$$

Subject to Z "less than unity" constraints

$$0 \leq \frac{\sum_{i=1}^{T} V_i Y_{ic}}{\sum_{k=1}^{m} W_k X_{kc}} \leq 1$$

C= 1,......,p....,z

And V_i, $W_k > 0$ $\forall$ i and k

Where V_i and W_k are the respective output and input weights.

The Linear DEA program

The fractional program is not used for actual computation of the efficiency scores because it has intractable non-linear and non-convex properties(Charnes, Cooper and Rhodes (1978)). Rather, Charnes and Cooper transformed it to a linear program which has two orientations: the output orientation, which computes the input efficiency of the firms and the input orientation, which computes the input efficiency . Like all linear programs, each has two components: a primal and a dual.

The Primal:

The linear program of output orientation for the p th branch is obtained by setting the denominator in the objective function of the fractional program equal to unity and hence:

$$\underset{V_i W_k}{MAX} \sum_{i=1}^{t} V_i Y_{ip}$$

Subject to

$$0 \leq \sum_{i=1}^{t} V_i Y_{ic} \leq \sum_{k=1}^{m} W_k X_{kc}, \; c=1 \ldots . p, \ldots z$$

$$\sum_{k=1}^{m} W_k X_{kc} = 1$$

And V_I, $W_k > 0 \quad \forall \quad i$ and k

This program is linear. It constraints the weighted sum of inputs to be unity and maximises the weighted sum of outputs at the p^th branch choosing appropriate values of V_i and W_k. The less-than-unity constraints of the fractional program are embodied in the constraints of the primal linear program such thatthe efficiency score cannot exceed unity.

The strict positivity assumption on weights was introduced by Charnes, Cooper and Rhodes(1979) such that

$W_k > \in, \; k=1, \ldots , m$

$v_i > \in, \; i=1, \ldots , t$

Where ϵ is an infinitesimal or non-Archimedean constant usually of the order 10^{-5} or 10^{-6}. They were introduced into the primal because under certain circumstances 1978 model implies unity-efficiency ratings in the fractional program for firms with non-zero slack variables such thst further improvements in performance remained feasible.

The Dual formulation:

The dual of the output oriented program is expressed as the minimisation of quantities of the m inputs required to meet stated levels of the t outputs. ie,

$$\underset{\lambda^c}{MIN} h_p - \epsilon \left(\sum_{k=1}^{m} S_k + \sum_{i=1}^{t} S_i \right)$$

$$X_{kp} \cdot h_p - S_k = \sum_{c=1}^{z} X_{kc} \lambda_c, k=1, \ldots, m$$

$$Y_{ip} + S_i = \sum_{c=1}^{z} Y_{ic} \lambda_c i=1, \ldots, t$$

$$\lambda_c \geq 0, c=1, \ldots, p, \ldots z$$

$$S_k \geq 0, k=1, \ldots, m$$

$$S_i \geq 0, i=1, \ldots, t$$

with h_p unconstrained; and ϵ is an infinitesimal (or non-Archimedean) constant analogous to that used in the primal (Charnes and Cooper (1984)). The p^{th} firm is relatively efficient if and only if the efficiency ratio h_p^* equals unity and the slack variables are all zero. That is , if and only if: $h_p^*=1$ and $S_k^*=S_{i*}=0$ $\forall$ k and i.
where * indicates the optimal values of the variables in the dual program.

In computation, the dual program is more tractable than the primal. In the primal the constraints are indexed on all Z firms. By contrast, in the dual the constraints are indexed on inputs and outputs and sum over firms. The number of inputs and outputs is never likely to exceed the number of firms. Philips, Ravindran and Solberg (1976) have shown that the computational efficiency of the simplex method falls with increases in the size of the constraint set. Hence the dual program with only (m+t) constraints on inputs and outputs is computed in preference to its primal with Z constraints.

Diagrammatic interpretation of the dual

Figure 3.2 gives a diagrammatic presentation of the dual. A branch is technically efficient in its use of inputs if no other branch or linear combination of branchs, is producing equal amounts of outputs for less of atleast one input. This definition is equivalent to the formal efficiency conditions from the dual as given above.

Figure 3.2

Diagramatic Intrepretation of the Dual

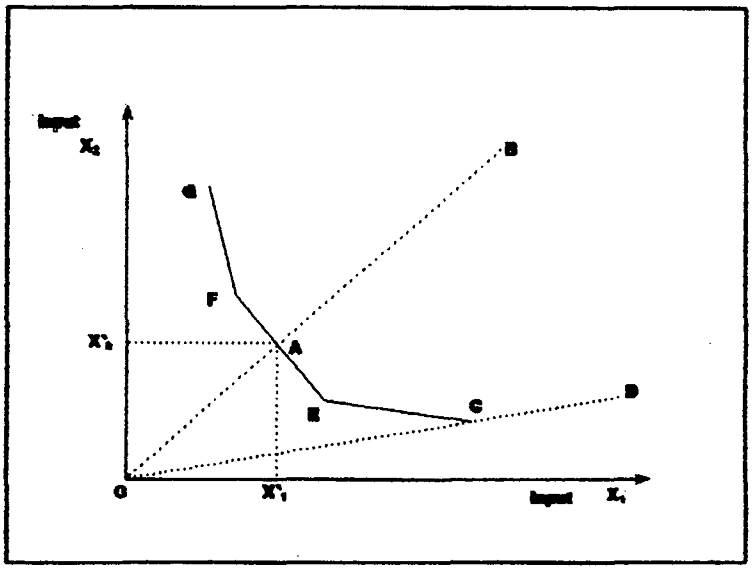


Figure (3.2) illustrates a hypothetical frontier technology based on 5 firms (G, F, B, E, and D) producing a single output Y from two inputs X1 and X2. Firms G, F and E, lying on the frontier, are best practice. This implies that no other branch or linear combination of branches can be identified producing the same level of output for less of either of both inputs. These branches have unity efficiency ratios and zero slacks in the solution to the dual. Branches B and D are inefficient relative to frontier performance. That is, for the same level of output it is possible to find a firm, or a linear combination of firms, which are using less of atleast one of the inputs. For the firm B, a linear combination of firms E and F is producing at least as much output as B with less of X1 and X2. The firms E and F can be called peer groups for the firm B since they provide the blueprints to improve performance for the firm B. It is because other things being equal, they are likely to be implementing superior managerial procedures.

From the above model (dual input oriented model) it is clear that there are constraints on inputs and outputs in the dual. The input constraints define a radial contraction in inputs given by the ratio h_{p*} , with the additional reductions given by the non-zero input slack variables, S_{k*}, $k=1,\ldots\ldots,m$. The output constraints do not include a radial adjustment and are only of importance in so far as any of the optimal output slacks S_{i*}, $i=1,\ldots\ldots,t$ are non-zero.

In figure 3.2 the solution for firm B has all input and output slacks equal to zero. However, firm D has a non-zero slack on the input X_1. The efficiency ratio for D is OC/OD which defines an initial radial contraction in both inputs. However, at the point C, firm E is producing the same output for less of X_1 and the same amount of X_2. Hence D is not fully efficient until it reduces its consumption of X_1 by the horrizontal distance C to E. This distance is given by a non-zero slack S1 in the final solution of the dual for firm D.

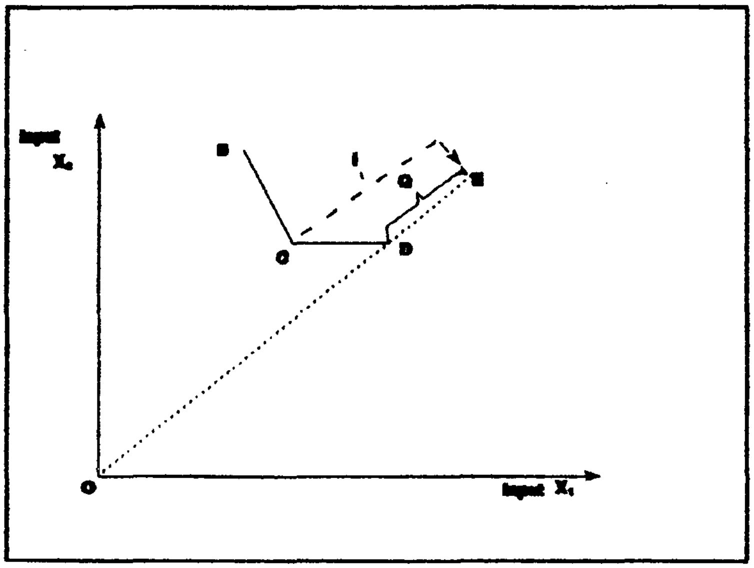
For a cross section of Z firms, DEA generates Z efficiency indices in the closed interval (0,1). If the index is unity, a firm is relatively efficient or best-practice. A value less than unity indicates that a firm is inefficient relative to peer organisations. Again, the efficiency index can be split into two:

Theta (θ) : It gives the radial reduction in inputs possible in order to obtain the projected input values.

Iota (i) : It measures the radial contraction possible plus the additional reduction in the use of input(s), if there is a slack on that input. Both these measure will be value one 1 for efficient firms. These measures can be explained with the following figure.

Figure 3.3

Radial Contraction Path and Slack

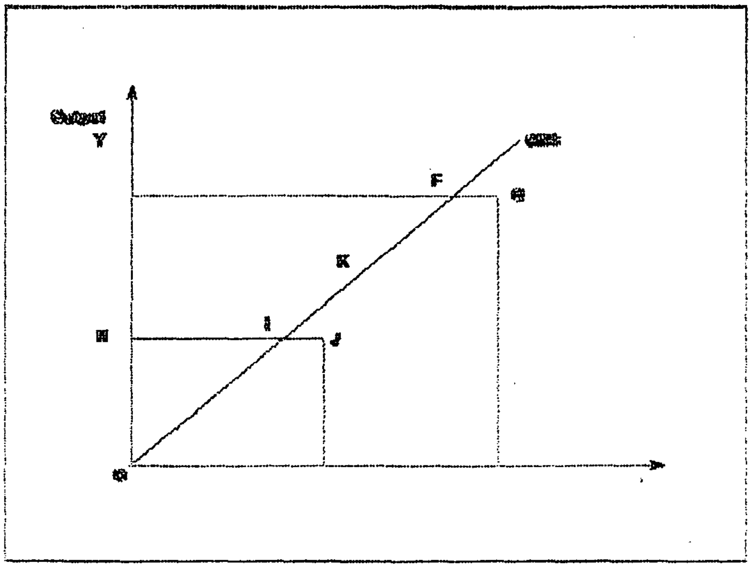


In the figure 3.3, for the inefficient firm E to be rated efficient, it should make a radial contraction of inputs X_1 and X_2 to D; plus a reduction in the use of input X_1 to reach C. The radial contraction is measured by theta (θ) and this radial contraction plus additional reduction in inputs is given by iota (i).

Returns to scale[2]:

The original DEA program of Charnes, Cooper and Rhodes (1979, 1978) were based on a linear program which embodied constant returns to scale. The program constructs a constant returns frontier by identifying that branch which maximises the ratio of output to input. This ratio can be interpreted as the maximum average productivity and denotes the scale efficient branch since it is consistent with a position of constant returns to scale (CRS).

Figure 3.4
Average Productivity and Returns to Scale



In figure (3.4), firm K (on the frontier) maximises average productivity. A ray drawn from the origin to any of the remainning firms (J or G) would have a lower slope and would not maximise average productivity, ie $(Y_{K/XK}) > (Y_{C/XC})$, C .

---

[2] The discussion on returns to scale is followed from Banker (1984).

constant returns to scale frontier is therefore an unbounded ray beggining at the origin and passing through a point of maximum average productivity such as at firm K. Since firm K maximises average productivity it is scale efficient and has a unit weight in the constraints, ie. $*_k = 1$. The remaining firms J and G have lower average productivity ratios.

Banker (1984) pointed out that the weight on best-practice firm describes the returns to scale. That is,
$\lambda^*_{bp} < 1 \rightarrow$ IRS
$\lambda^*_{bp} = 1 \rightarrow$ CRS
$\lambda^*_{bp} > 1 \rightarrow$ DRS
For multiple inputs and outputs several firms may be scale efficient on atleast one variable such that the Banker scale indicater would be the sum of the optimal weights on each of those firms:

$$\sum_{c=1}^{z} *\lambda_c < 1 => IRS$$

$$\sum_{c=1}^{z} \lambda_c * C = 1 => CRS$$

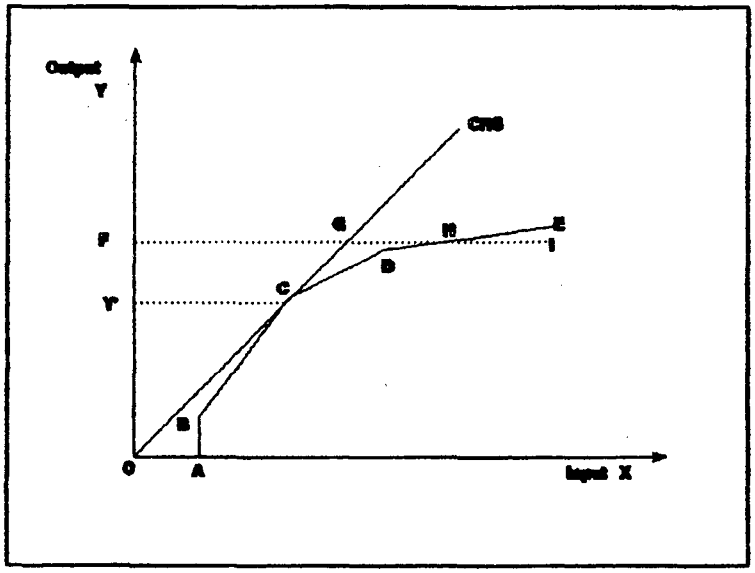
$$\sum_{c=1}^{z} \lambda_c * > 1 => DRS$$

Where some of the $\lambda^*_c = 0$ for inefficient firms.

However, the assumption of constant returns to scale is overrestrictive and this compelled the economists to continue with the statistical procedures.

Figure 3.5

The Varying Returns to Scale



The returns to scale vary from facet to facet, each of which represents the solution to a constraint in the dual. For combinations of input and output lower than the scale efficient branch, eg. along the facet BC, there are IR's; facets reflecting higher levels of production have DRS. The scale efficient branch (C) is included in both the VRS and the CRS frontiers.

So, the full revised program of Banker (1984) is presented as follows:

$$\underset{\lambda_c}{MIN} h_p - \epsilon \left(\sum_{k=1}^{m} S_k + \sum_{i=1}^{t} S_i \right)$$

$$X_{kp} \cdot h_p - S_k = \sum_{c=1}^{z} X_{kc} \lambda_c, \; k=1, \ldots, m$$

$$\lambda_c \geq 0, \; c=1, \ldots, p, \ldots z$$

$$Y_{ip}+S_i=\sum_{c=1}^{z} Y_{ic}\lambda_c,\ i=1,\ldots,t$$

$$\sum_{c=1}^{z} \lambda_c=1$$

$$S_k\geq 0,\ k=1,\ldots,m$$

$$S_i\geq 0,\ i=1,\ldots,t$$

In general, the CRS efficiency comparison gives a poorer picture of performance since a firm has to be both technically and scale efficient to qualify for a unity efficiency ratio. Under a VRS technology dominance is weaker in the sense that scale inefficient production may qualify as best-practice if it is technically efficient, ie

$$TE_{i,\ crs} \leq TE_{i,\ vrs}$$

With CRS and VRS results before them Grosskopf and Valdmanis (1987) argue that the CRS technology should be interpreted as reflecting longrun performance possibilities. Analogously, the VRS assumption indicates feasible attainment in the short run. On this basis the long run CRS adjustment costs will be greater than those suggested by the VRS technology. The CRS targets are effective adjustments towards longrun equilibria, ie., the minimum point of a U shaped average cost curve. In the short run even the best practice costs will be greater than those attainable in the long run and so VRS costs adjustments will be smaller than their CRS counterparts.

Apart from the efficiency scores, DEA reports the magnitude of inefficiency of each input. It is obtained by the difference in the actual input usage and the required input usage for the firm to be rated efficient. Again, DEA helps us to understand the magnitude of excess in each input even after the radial reduction is made possible in their usage. This will indicate the extra reduction required in the usage of those specified inputs.

Non-parametric Measures of Association[3]

Two important non-parametric measures of association have been explored: Spearman's rank correlation coefficient (Rho), and Kendall's coefficient of concordance W. Spearman's is a bivariate technique for correlating X and Y and Kendall's is multivariate, applicable when more than two variables are involved. In both techniques the matched observations are reduced to matched ranks. The techniques are "distribution-free" and possess no equivalent parameters in the universe.

Spearman's rank correlation coefficient is computed by the formula:

$$p=1-\frac{6\Sigma d^2}{N^3-N}$$

A correlation coefficient Rho is yielded, which has values 0 to ±1, values approaching ±1 having high correlation, values approaching zero having low correlation. A test of significance

---

[3] See Belsley H L (1978).

for Rho for small paired samples(N<10) is given by comparing the computed Rho to the table values of Rho. A computed Rho greater than the table value requires rejection; the opposite indicates acceptance of the null hypothesis, H0: the correlation coefficient is zero. With large paired samples (N>10), student's t-test is used as follows:

$$t=P\sqrt{\frac{N-2}{1-P^2}}$$

with t as a one-tailed test. Where the computed t exceeds the standard deviate t, rejection occurs, and vice versa.

Kendall's coefficient of concordance is computed from the formula

$$W=\frac{12S}{K^2(N^3-N)}$$

where 12 = a constant

s = sum of squared deviations of rank sums from the mean of the rank sums

k = number of rows, that is, observations

N = number of columns, that is, variables to be ranked

It is interpreted as a correlation coefficient, except that all values are positive. W can range only between zero and one. However, the closer to one that W occurs, the higher is the association or concordance among the multivariate series of observations. The closer W approaches zero, the less there is concordance or agreement. It may be tested for significance where small matched samples occur (k from 3 to 20; N from 3 to 7), by comparing s to the table value for the W-test. Where s is greater, reject; where it is less, accept. The null hypothesis is H0: the coefficient of concordance is zero. Where matched samples are large (N>7), W is distributed as chi-square, and chi-square is used as the test, with the following formula:

$$\chi^2 = k(N-1)W.$$

Where the χ^2 statistic exceeds the chi-square distribution value, reject; where it is less, accept.

CHAPTER 4

ENERGY INEFFICIENCY AT THE FIRM LEVEL: THE ESTIMATES

Introduction

Having dealt with the method of analysing input specific inefficiency using Data Envelopment Analysis (DEA), let us now proceed with the empirical estimation and present the results of the model. As we have already stated, the analysis is confined to the basic metals and alloys industry. The chapter is organised into two sections. The data source and variables used for the firm level analysis have been introduced in the first section. As a prelude to this analysis, we have also examined the share of energy in total inputs in different products groups. Against this background, the second section presents the results of DEA in terms of the levels of energy use and inefficiency across different firms. We also carry out an analysis of the association between the energy use inefficiency and the in efficiency in the use of other factors. This is carried out through two non-parametric tests, namely-Spearman's rank correlation coefficient and Kendall's coefficient of concordance. Finally, we have also attempted to examine the association between inefficiency levels in the use of energy and the firm characteristics.

Data Source and Variables

The firm level data for the year 1995-96 has been obtained from CMIE's computerised database known as PROWESS, which gives data for about six thousand companies listed in BSE. The advantage of-this data set is that it is computerised and timely. This data set is useful for cross section analysis, though its utility for time series analysis is limited since it is available only from 1989-80 onwards.

The companies under Basic Metals and Alloys industry have been classified under four product groups as given below. The figures in parenthesis give the number of companies in each product group.

a) Castings & Forgings (64)
b) Pig Iron & Sponge Iron (15)
c) Steel (164)
d) Non-Ferrous Metals (69)

The estimation of energy inefficiency using DEA requires data on value of output and data on various inputs (energy, wages and salaries, Gross Fixed Assets and total raw materials). The definition and the method followed in the construction of variables are given below for this purpose.

Value of output: It is the sum of net sales and change in stock. (Value of Output = Sales - Indirect Taxes + Change in Stocks).

Energy *(Cost)*: This is the total cost of commercial energy like power, fuel and coal used in the firms under study. Energy costs are to a certain extent, industry specific. Thus coal consumption is a source of energy for cement and steel companies, and is hence classified as part of their energy cost. On the other hand, coal consumption for power generation companies is treated as a raw material expense and not energy cost.

Wages and salaries: This includes total expenses incurred by an enterprise on all employees, including the management. Besides salaries and wages, items such as payment of bonus, contribution to employees provident fund and staff welfare expenses are also included under wages.

Gross Fixed Assets (GFA): These are the fixed assets that are used for producing goods and services and are shown as gross of depreciated value. These include movable and immovable assets as well as capital work-in-progress, ie., assets which are in the process of being installed.

Total Raw materials expense: This is the total cost of raw materials and stores consumed during the accounting period. It includes raw material expense, consumption of stores and spares and packaging material, purchase of finished goods for resale, etc.

All costs incidental to the purchase of raw materials are also included under this head. Some of the incidental expenses like transportation of raw material (which is known as freight inward), handling expenses, octroi, purchase tax, coolie and cartage form part of the raw material cost. Though freight inward form part of the raw material expenses, the freight outward is treated as distribution expenses.

These are various inputs used in DEA analysis for estimating levels of energy inefficiency. To have an understanding of the need for ensuring energy efficiency comes from the assumption that energy could be a major input in the total inputs.

FIRM LEVEL ENERGY INEFFICIENCY: RESULTS OF DEA

To appreciate the empirical results, it is important to have some understandimng of the the extent of energy used by the product groups under study. We have used here the share of energy in the total inputs (all in terms of cost figures) for this purpose. Within each product group, the share of energy used as input might vary. However, for the convenience of analysis here, we have used the average share of excess energy used by firms under each product group. The classification of the firms is made on the basis of the share of energy used in total inputs in the product groups; i.e, above and below the average shares. Table 4.1 shows this.

Table 4.1:
Classification of companies on the basis of average share of energy used in total inputs

Product groups	Average share of energy	No: of companies		Total
		> avg	< avg	
Pig & sponge iron	2.203	5	10	15
Steel	8.467	56	108	164
Castings & Forgings	6.127	27	37	64
Non-ferrous metals	2.823	26	33	59

Source : CMIE; 1996

The average share of energy used in the total inputs of firms differ across product groups. For example, while the average share of energy in the total inputs were above eight per cent for steel, it was only around two per cent in the case of iron products. The table reveals that in all the four product groups, majority of the firms fall under the category wherein the share of energy in the total inputs were below the average. In fact this shows that in many firms, the share of energy used in their total inputs were very low (high), but variations are visible across firms even among same product groups.

Results of DEA

As stated in the methodology chapter, DEA provides one of the better ways of estimating efficiency. The features of DEA in this estimation procedure are the following. Ganley and Cubbin (1992) identifies the DEA efficiency score as a quantitative guide to the inertia of its production process in the firms. DEA also identifies the exact magnitude of the excess of each input in different companies. It is found by taking the deviation between the required and the actual use of each input. Even after the radial reduction of these excess inputs, what remains is identified as slack.

In the empirical estimation, the value of output is taken as the output variable and variables such as energy, raw material, wage and GFA as input variables. This estimation provided us with the existing levels of X-inefficiency in the companies. The excess energy used (that is, inefficiency in energy use) has been estimated in this manner under both the CRS and VRS assumptions. The estimation of energy inefficiency under the VRS assumption was anticipated to indicate that in the short run, the firms could be made more efficient with less reduction of energy inputs. The estimation was also to indicate that under the assumption of CRS, the adjustment costs for making the firm efficient became greater than those suggested by the VRS technology since CRS reflects long run performance possibilities. Therefore the efficiency scores of companies turned to be smaller (which means larger reductions is needed in the input usage).

To begin with, the firms were classified on the basis of the DEA scores of firms (in terms of their excess energy use). On the basis of the estimation of energy efficiency/ inefficiency levels and the consequent classification of firms, we have tried to analyse the product groups as well as the financial performance of the firms across product groups.

Energy inefficiency across product groups

Firms using energy for their production might find that energy inefficiency need not follow the same pattern in the case of both the long run and the short run. Similarly, firms producing different products might show differences in their levels of energy use. Keeping these factors in mind, the analysis in this section look at the trends in the energy (in)efficiency levels across product groups both for the short run as well as the long run. The broad trends are given in table 4.2 & 4.3.

Table 4.2
Number of firms in different energy inefficiency levels across product groups (both for VRS and CRS).

CRS	1-20	20-40	40-60	60-80	80-100	IE TOT	zero IE	TOT
Castings & forgings	27	16	5	3	2	53	11	64
Pig & Sponge Iron	3	2	2	0	0	7	8	15
Steel	71	53	11	0	1	136	28	164
Non-Ferrous Metals	17	13	10	2	0	42	17	59
Basic metals & alloys	118	84	28	5	3	238	64	302
VRS								
Castings & forgings	24	7	4	3	1	39	25	64
Pig & sponge	2	1	1	0	0	4	11	15
Steel	62	45	8	2	0	117	47	164
Non-Ferrous Metals	14	8	6	1	1	29	30	59
Basic metals & alloys	102	61	19	6	0	189	113	302

Source: Computed from data for the year 1996 provided by the computerised data base (PROWESS); CMIE.

Table 4.3
Distribution of firms (Percentage share of firms) of different product groups in different energy inefficiency levels (both for VRS and CRS).

CRS	1-20	20-40	40-60	60-80	80-100	IE TOT	zero IE	TOT
Castings & forgings	42.1	25.0	7.8	4.7	3.1	82.8	17.2	100
Pig & Sponge Iron	20.0	13.3	13.3	0.0	0.0	46.7	53.3	100
Steel	43.2	32.3	6.7	0.0	0.6	82.9	17.1	100
Non-Ferrous Metals	28.8	22.0	17.0	3.4	0.0	71.2	28.8	100
Basic metals & alloys	39.1	27.8	9.3	1.7	1.0	78.8	21.2	100
VRS								
Castings & forgings	37.5	10.9	6.2	4.7	1.6	61.0	39.0	100
Pig & sponge	20.0	13.3	13.3	0.0	0.0	46.7	73.3	100
Steel	37.8	27.4	4.9	0.0	0.0	71.3	28.7	100
Non-Ferrous Metals	23.7	13.6	10.2	0.3	0.3	49.2	50.1	100
Basic metals & alloys	33.8	60.2	6.3	0.0	0.0	62.6	37.4	100

Source: Same as of table 4.2

Table 4.2 shows the number of firms in the VRS and CRS category at different energy inefficiency levels for the product groups. Table 4.3 shows the distribution of firms in the different product groups across different levels of energy use in excess. While the former explains the actual number of firms at different energy efficiency levels, the latter describes the actual performance product groups in terms of energy efficiency of firms.

First of all, an analysis of the levels of efficiency and inefficiency for the long run is made. The table shows that in the long run, the iron products group had the maximum percentage of efficient firms, with more than half of the firms in this group did not use any excess energy. While in the case of non-ferrous metals, the efficient firms accounted for one-fourth of the total in the long run, the steel products, casting and forging products and basic metals and alloy firms had only around one-fifth of their firms using energy in the long run efficiently. However, a more dis-aggregated analysis of the firms using energy inefficiently in the long run showed that in majority of the firms, especially in casting and forging group as well as in steel product groups, more than 40 per cent of the firms had inefficiency in energy use at excess level to a narrow range. This means that with a little more effort in the energy management, these firms could be brought under the category of energy efficient firms.

Coming to the short run analysis of the firms and their product groups, it is clear from the table that in all the four product groups more firms were found to be inefficient in the long run than in the short run. In fact the figures points to the fact that some firms in all the product groups which were efficient in the short run had become inefficient in the long run. The long run energy use scenario of firms in these product groups showed that the concentration of inefficient firms (in terms of energy use) were in the lower stratum of 1-20 per cent of excess energy use. Both in the long run as well as in the short run, the number of firms with substantial excess energy (say 50 per cent) and consequently fell beyond the scope of any energy management programme were fortunately very less in number in these product groups. Product group wise, the steel products had the maximum inefficient firms followed by castings and forging and basic metals and alloys products.

On the whole, it can be inferred that both under CRS and VRS assumption, in all the four product groups, the number of companies decreased as the range of excess energy use increased. Further, in majority of the companies the extent of excess energy used found to be less than 40 per cent. Also, both under CRS and VRS assumption the product group representing steel had the maximum number of inefficient firms, followed by castings and forgings, non-ferrous metals and iron.

Nonparametric test

The rank correlation coefficients (r) matrix between excess of raw material, energy, wages and GFA were calculated for all the four product groups, both under CRS and VRS assumptions. The rank correlation coefficient (r) between the excess of each pair of inputs were positive, very high and statistically significant. On the whole, one could tentatively conclude that the structural interrelationship between different inputs, in each sub-industry is such that, there is high linkage or interdependence between the various inputs. However, Spearman's rank correlation coefficient is a bivariate analysis which gives the association between two variables. So in addition to this, a multivariate analysis called Kendall's coefficient of concordance (W) which gives the association between the excess of all the four inputs was estimated and the statistical test of concordance was carried out. In three of the product groups (Steel, Castings and Forgings and Non-ferrous metals), coefficient of concordance (W) is significant. In the case of steel the coefficient of concordance (W) under the CRS and VRS assumptions were 0.03869 and 0.07372 respectively, for castings and forgings this coefficient was 0.00573 and 0.07218 and for non-ferrous metals it was 0.139 and 0.3409. In the product group producing Pig iron & sponge iron, the coefficient of concordance is zero and hence insignificant, under both CRS and VRS assumption. Thus, both the nonparametric tests indicate that there is no association between the excess inputs consumed in the product group producing pig iron and sponge iron. However for the product groups namely, Castings and forgings, Steel and Non-ferrous metals there is significant association between the excess of various inputs.

Energy inefficiency and Firm Characteristics

At this stage, it may be instructive to examine the association between energy inefficiency levels and certain important firm specific characteristics like profitability, firm size, age structure, export intensity, capital intensity (GFA), and technology behavior. The method followed here uses descriptive statistics and these figures are expected to give a background for the econometric analysis that we are planning to carry out in the next chapter.

a. Financial Performance (profit)

It may be argued that the energy use efficiency *interalia* is expected to have a bearing on the financial performance of any firm, particularly in industries where energy is a major component of cost item and the firms are price takers. Nevertheless it is possible that even with high energy use, inefficient firms record a better financial (profit) performance if the firms are price makers. Hence it may be argued that the influence of energy used efficiently on the profits levels depend, among other things, on the competitive environment in which it operates.

Table 4.4 and 4.5 give the financial performance of the firms in terms of the profitability and loss. To have a comparison of the financial performance of the energy efficient as well as energy inefficient firms (both in the short run and in the long run), the analysis had taken care of the VRS and the CRS assumptions.

Both in the long run as well as in the short run, majority firms are profit making ones. However, it cannot be assumed that profit making firms are energy efficient ones or the loss making firms are the energy inefficient ones.

Table 4.4
Number of Energy Efficient and Inefficient firms according to Financial Performance.

CRS

Product Group	Total No of firms	Profit Making		Loss Making	
		Efficient	Inefficient	Efficient	Inefficient
Casting & Forging	64 (100)	9 (14.1)	43 (67.2)	2 (3.1)	10 (15.6)
Iron	15 (100)	7 (46.7)	4 (26.7)	1 (6.7)	3 (20)
Steel	164 (100)	24 (14.6)	97 (2.4)	4 (2.4)	39 (23.8)
NFM	59 (100)	16 (27.1)	28 (47.5)	1 (1.7)	14 (23.7)
BMA´s	302 (100)	56 (18.5)	172 (56.9)	8 (2.7)	66 (21.85)

VRS

Product Group	Total No of firms	Profit Making		Loss Making	
		Efficient	Inefficient	Efficient	Inefficient
Casting & Forging	64 (100)	20 (31.3)	32 (50.0)	5 (7.8)	7 (10.9)
Iron	15 (100)	8 (53.3)	3 (20.0)	3 (20)	1 (6.7)
Steel	164 (100)	41 (25.0)	80 (48.8)	6 (3.7)	8 (13.6)
NFM	59 (100)	22 (37.3)	22 (37.3)	8 (13.6)	7 (11.9)
BMA´s	302 (100)	91 (29.9)	137 (45.4)	22 (7.9)	52 (17.2)

Figures in parentheses are percentages to the total number of firms

However, as shown in the table (table 4.4) the concentration of firms in all the product groups, except the iron (in iron, majority of firms comes under the category of energy efficient and profit making, especially in the short run[1]), are in the category of profit making, but inefficient ones. However, the relationship between inefficient use of inputs and consequent result of loss are evident from the fact that majority of the loss making firms are using energy inefficiently.

Further investigations into the analysis points to the fact that under CRS conditions (long run period), the chances of profitability are larger in the case of efficient firms than in the case of inefficient firms. For example, the share of profit making firms in the total energy efficient firms were 81.1 percent in the case of casting and forging products, 87.5 percent in the case of iron products, 85.7 per cent in steel industries and 94 per cent in NFM products. Contrast to this, the share of profit making firms in the energy inefficient group shows a lesser figure, say, 66 per cent in casting and forging, 57 per cent in iron, 71 per cent in steel and 67 per cent in NFM products. This is a hint to the fact that energy efficient firms have a better chance of becoming profitable.

---

[1] It is interesting to note here that the iron product groups showed maximum share of energy efficient firms in our analysis in the previous section. Here, the analysis have shown that most of these energy efficient firms are profit making also. May be this is a pointer to the fact that firms using any input efficiently have better chances of making profits.

Under the VRS assumption (short run), the same do not hold good. Here, the share of profit making firms in the group of efficient firms as well as in the group inefficient firms do not show much difference. This may be due to the fact that short run is too short a period to alter the efficiency of firms in energy use.

Overall, it could be said that in the long run, the energy efficient firms seems to be more profitable than loss making while the inefficient firms (in terms of energy use) have a larger share of loss making firms.

It is expected that most of the loss making firms would be inefficient. However, it is a paradox that some of the profit making firms are inefficient, or some of the inefficient firms are profitable. The factors that leads to this ambiguity is beyond the scope of our analysis. However, a disaggregated analysis of the profit making firms in terms of the levels of energy inefficiency is worth for our study which is attempted here.

Table 4.5
Number and percentage of Profit making Firms according to their levels of energy inefficiency.

CRS	1-20	20-40	40-60	60-80	80-100	IE TOT	zero IE	TOT
Castings & forgings	25	11	4	1	2	43	9	52
percentage to total	*48.1*	*21.2*	*7.7*	*1.9*	*3.9*	*82.7*	*17.3*	*100*
Pig & Sponge Iron	3	0	1	0	0	4	7	11
percentage to total	*27.3*	*0.0*	*9.1*	*0.0*	*0.0*	*36.4*	*63.3*	*100*
Steel	61	32	4	0	0	97	24	121
percentage to total	*50.4*	*26.5*	*3.3*	*0.0*	*0.0*	*80.2*	*19.8*	*100*
Non-Ferrous Metals	14	7	6	1	0	28	16	44
percentage to total	*31.8*	*15.9*	*13.6*	*2.3*	*0.0*	*63.6*	*36.4*	*100*
Basic metals & alloys	108	50	15	2	2	172	56	228
percentage to total	*45.2*	*21.9*	*21.9*	*0.9*	*0.9*	*75.4*	*24.6*	*100*
VRS								
Castings & forgings	21	6	3	1	1	32	20	52
percentage to total	*40.4*	*11.5*	*5.8*	*1.9*	*1.9*	*61.5*	*38.5*	*100*
Pig & sponge	2	0	1	0	0	3	8	11
percentage to total	*18.2*	*0.0*	*9.1*	*0.0*	*0.0*	*27.3*	*73.3*	*100*
Steel	52	25	2	1	0	80	41	121
percentage to total	*43.0*	*20.7*	*1.7*	*0.8*	*0.0*	*66.1*	*33.9*	*100*
Non-Ferrous Metals	12	5	4	1	0	22	22	44
percentage to total	*27.3*	*11.4*	*9.1*	*2.3*	*0.0*	*49.2*	*50.0*	*100*
Basic metals & alloys	87	36	10	3	1	137	91	228
percentage to total	*38.2*	*15.8*	*4.4*	*1.3*	*0.4*	*60.1*	*39.9*	*100*

Both under CRS and VRS assumptions, it could be seen that the profit making firms of different product groups differ in their energy use. Among the firms under energy inefficient category, majority fall under the category where the levels of energy inefficiency is less than 20 per cent. This shows that less the inefficiency in energy use, more the chances for the firms to become profitable. Maximum number of profitable firms using excess energy (more than 40 per cent) were found in the non-ferrous metal products group. However, these figures account for less than 15 per cent. A definite conclusion is not warrented at this stage due to the absence of more rigorous analysis (which will be taken up in the next chapter).

The forgoing observations were found true irrespective of the nature of the product, under both CRS and VRS assumptions.

b) Firm size

The analysis of energy inefficiency and output levels has been taken here in two dimensions. First dimension is from the point of view of firm size (here taken as output) ranges and second, from the side of energy efficiency levels.

Table 4.6
Distribution of Output range across Energy inefficiency levels.

output range	No of firm Efficient	IE 01-20	IE 20-30	IE 30-40	IE 40-60	IE 60-80
0-50	36 (55.4)	63 (52.9)	53 (63.1)	23 (82.1)	4 (80.0)	2 (66.7)
50-100	15 (23.1)	22 (18.5)	15 (17.9)	3 (10.7)	1 (20.0)	1 (33.3)
100-150	5 (7.7)	8 (6.7)	8 (9.5)	1 (3.6)	0 (0.0)	0 (0.0)
150-200	3 (4.6)	7 (5.9)	2 (2.4)	1 (3.6)	0 (0.0)	0 (0.0)
200-500	1 (1.5)	14 (11.8)	3 (3.8)	0 (0.0)	0 (0.0)	0 (0.0)
500 <	5 (7.7)	5 (3.6)	3 (3.8)	0 (0.0)	0 (0.0)	0 (0.0)
TOTAL	65 (100)	119 (100)	84 (100)	28 (100)	5 (100)	3 (100)

Six ranges of value outputs (in crore Rupees) are taken here. More than half of the firms in both efficient as well as inefficient category had a small output range of less than 100 crores. The energy efficient firms had a better range of output values while the inefficient ones had a narrow range. As the level of inefficiency of the firms increased, the output range became smaller as could be seen from table 4.6 (see table 4.6 for the details on energy inefficiency levels and value of output ranges).

The dimensions from the output value range side show that as output range increased, the share of firms in the efficient category also increased. This is an indication to the fact that if energy efficiency is ensured, the probability of having higher values of output also increases. As the value of output becomes larger, the firms have a propensity to become more efficient. See Table 4.7.

Table 4.7
Distribution of firms in the energy inefficiency levels across output values.

Output ranges	Energy inefficiency levels						
	0	1-20	20-30	30-40	40-60	60-80	total
0-50	19.89	34.81	29.28	12.71	2.21	1.10	100
50-100	26.32	38.60	26.32	5.26	1.75	1.75	100
100-150	22.73	36.36	36.36	4.55	0.00	0.00	100
150-200	25.00	58.33	16.67	0.00	0.00	0.00	100
200-500	5.56	77.78	16.67	0.00	0.00	0.00	100
500<	38.46	38.46	23.08	0.00	0.00	0.00	100
TOTAL	21.45	39.27	27.72	8.91	1.65	0.99	100

c) Age structure

The age structure of the firms and the efficiency in the energy use of the firms can have some relationship. The firms of very young age might not use the energy potential to the full extent, but need not be inefficient. However, the older the firm gets, the possibility of them becoming less efficient in energy management cannot be ruled out. This is due to the fact that after a point of time, the depreciation factor of inputs used could cause excess energy use. So the assumption in this part of the analysis is that older the firms, less efficient is their energy use. Table 4.8 gives the age structure of the firms in different energy inefficiency levels.

Table 4.8
Distribution of firms under different ranges of age across Energy inefficiency levels.

Age range	0	1-20	20-40	40-60	60-80	80-100
0-5	9 (13.85)	11 (9.40)	7 (8.33)	3 (10.71)	1 (20)	0 (0)
6-10	21 (32.31)	24 (20.51)	13 (15.48)	8 (28.57)	3 (60)	2 (66.6)
11-25	25 (38.46)	56 (47.86)	37 (44.05)	9 (32.14)	1 (20)	1 (33.3)
25-50	10 (15.38)	21 (17.95)	22 (26.19)	7 (25.00)	0 (0)	0 (0)
50-75	0 (0)	3 (2.56)	2 (2.38)	1 (3.57)	0 (0)	0 (0)
75-100	0 (0)	2 (1.71)	2 (2.38)	0 (0)	0 (0)	0 (0)
100&<	0 (0)	0 (0)	1 (1.19)	0 (0)	0 (0)	0 (0)
Total	65 (100)	0 (0)	84 (100)	28 (100)	5 (100)	3 (100)

It could be seen from the table that the efficient firms (65), are relatively younger and in this category, there is not a single firm which is older than 50 years old. The maximum number of efficient firms are found in the age structure of six to 25 (46 in number, i.e, more than 70 per cent). However, the table also shows that among inefficient firms also, the maximum firms come under the same age group. Correspondingly, as the age increases, the share of inefficient firms in the category increased. This analysis shown in the following table (see Table 4.9). An interesting point has been noted in the table in the column of firms in the energy inefficiency levels of 1-40 per cent. Here, of the 201 firms, around 25 per cent were older than 25 years. These firms would have been efficient in their energy use at an earlier point of time, but now have become inefficient as their age increased and some worn out occurred. It shows that as age increases, the inefficiency of energy use increases.

Table 4.9
Distribution of firms at different Energy inefficiency levels across age structrure

Energy inefficiency levels							
Age	0	1-20	20-40	40-60	60-80	80-100	tot
0-5	29.03	35.48	22.58	9.68	3.23	0.00	100
6-10	29.58	33.80	18.31	11.27	4.23	2.82	100
11-25	19.38	43.41	28.68	6.98	0.78	0.78	100
26-50	16.67	35.00	36.67	11.67	0.00	0.00	100
50-75	0.00	50.00	33.33	16.67	0.00	0.00	100
75-100	0.00	50.00	50.00	0.00	0.00	0.00	100
100&<	0.00	0.00	00.00	0.00	0.00	0.00	100
Total	21.52	38.74	27.81	9.27	1.66	0.99	100

d). Exports

It is assumed here that the firms who export their products might be using energy in an efficient way. On the other hand it is expected that the efficient firms might be able to export their products. The table 4.10 shows the total exports of the firms and the levels of energy inefficiency.

Table 4.10
Distribution of firms of different levels of export earnings across energy inefficiency levels.

Exports	0	1-20	20-40	40-60	60-80	80-100
0	42 (63.64)	54 (46.55)	67 (78.82)	24 (85.71)	5 (1)	3 (1)
0-50	19 (28.79)	52 (44.83)	16 (18.82)	4 (14.29)	0 (0)	0 (0)
50-100	1 (1.52)	5 (4.31)	1 (1.17)	0 (0)	0 (0)	0 (0)
Above 100	4 (6.06)	5 (4.31)	0 (0)	0 (0)	0 (0)	0 (0)
Total	66 (100)	116 (100)	85 (100)	28 (100)	5 (100)	3 (100)

The table shows that most of the firms do not have any exports worth mentioning (the firms with export earnings is less than half of the total firms under study). However, among the firms with export earnings, one-fourth were energy efficient and half were on a level of low energy inefficiency- of 1-20 per cent. This shows that only firms with energy efficiency or less inefficiency are able to export their products compared to least efficient firms. See table 4.11 for share of firms in each inefficiency levels of the different ranges of export earnings.

Table 4.11
Distribution of Firms of different energy inefficiency levels according to their export earnings

Value of Exports	Energy inefficiency levels						
	0	1-20	20-40	40-60	60-80	80-90	total
0	21.54	27.69	34.36	12.31	2.56	1.54	100
0-50	20.88	57.14	17.58	4.40	0.00	0.00	100
50-100	14.29	71.43	14.29	0.00	0.00	0.00	100
100<	44.44	55.56	0.00	0.00	0.00	0.00	100

The table shows that as export value increases, the efficiency level of firms also increases. This means that increase in export earnings could be related to energy efficiency of the firms, or the export intensity of firms lead them for a better energy use.

e). Capital intensity

The theoretical assumption regarding capital is that higher energy inefficiency is associated with higher investments in machinery as they were supposed to consume more energy. Table 4.12 below shows the levels of energy inefficiency and the gross fixed assets of the firms.

It is important to understand at this juncture that mere investment do not lead to efficient use of inputs. What matters most is the efficiency with which the available capital is used. Smaller investment does not mean that the firms would not operate in efficient conditions. Some times, the small amount of capital helps the firms to manage them efficiently.

The table shows that majority of the energy efficient and less energy inefficient firms had lesser capital intensity. This could be due to the fact that higher capital investment involves high use of energy consumption.

Table 4.12
Distribution of firms with different ranges of GFA across Energy inefficiency levels.

GFA	0	1-20	20-40	40-60	60-80	80-100
0	3 (4.55)	3 (2.54)	5 (5.88)	2 (7.14)	0 (0)	0 (0)
1-50	48 (72.73)	83 (70.34)	59 (69.4)	21 (75)	5 (1)	3 (1)
50-100	6 (9.09)	11 (9.32)	3 (3.53)	0 (0)	0 (0)	0 (0)
100-200	1 (1.52)	7 (5.93)	13 (15.29)	3 (10.7)	0 (0)	0 (0)
200-300	2 (3.03)	7 (5.93)	1 (1.18)	2 (7.14)	0 (0)	0 (0)
300-1000	2 (3.03)	5 (4.24)	3 (3.53)	0 (0)	0 (0)	0 (0)
Above 1000	4 (6.06)	2 (1.70)	1 (1.18)	0 (0)	0 (0)	0 (0)
Total	66 (100)	118 (100)	85 (100)	28 (100)	5 (100)	3 (100)

However, if we take the capital intensity as the basis of analysis, it shows that at higher investment levels, more firms are found in the energy efficient levels or least energy inefficiency. This points to the fact that higher the level of investment, the larger the possibility of the firm becoming energy efficient or with increase in GFA, more firms become efficient as shown by figures in table 4.13.

Table 4. 13
Distribution of firms with different ranges of GFA across Energy inefficiency levels.

	Energy inefficiency levels						
GFA	0	1-20	20-40	40-60	60-80	80-100	total
0	23.08	23.08	38.46	15.38	0.00	0.00	100
1-50	21.92	37.90	26.94	9.59	2.28	1.37	100
50-100	30.00	55.00	15.00	0.00	0.00	0.00	100
100-200	4.17	29.17	54.17	12.50	0.00	0.00	100
200-300	16.67	58.33	8.33	16.67	0.00	0.00	100
300-1000	20.00	50.00	30.00	0.00	0.00	0.00	100
1000<	57.14	28.57	14.29	0.00	0.00	0.00	100
Total	21.64	38.69	27.87	9.18	1.64	0.98	100

e). Technology behaviour

Firms spending more on R&D as well as firms which import foreign technology are expected to use energy more efficiently, especially if their R&D is oriented towards developing energy saving technologies. From the table 4.14, it appears that 86 per cent of the efficient firms do not spend any amount on technology improvements.

Table 4.14
Distribution of firms of different ranges of technological levels across Energy inefficiency levels.

Techno-logy	0	1-20	20-40	40-60	60-80	80-100
0	56 (86.15)	93 (79.49)	64 (76.19)	20 (71.43)	5 (1)	2 (66.67)
0.1-1	4 (6.15)	19 (16.24)	16 (19.05)	8 (28.57)	0 (0)	0 (0)
1-10	5 (7.69)	3 (2.56)	3 (3.57)	0 (0)	0 (0)	1 (33.33)
Above 10	0 (0.00)	2 (1.71)	1 (1.19)	0 (0)	0 (0)	0 (0)
Total	65 (100)	117 (100)	84 (100)	28 (100)	5 (100)	3 (100)

The analysis of the share of firms of each energy inefficiency levels in different technology levels show that the more the technology intensity, better the efficiency of energy use.

Table 4.15
Distribution of firms of different Energy inefficiency levels across the Technology value ranges.

	Energy inefficiency levels						
technology	0	1-20	20-40	40-60	60-80	80-100	tot
0	23.33	38.75	26.67	8.33	2.08	0.83	100
0.1-1	8.51	40.43	34.04	17.02	0.00	0.00	100
1-10	41.67	25.00	25.00	0.00	0.00	8.33	100
10<	0.00	66.67	33.33	0.00	0.00	0.00	100
total	21.52	38.74	27.81	9.27	1.66	0.99	100

f) Energy inefficiency and sales:

It is expected that efficient firms would be having better sales, since larger firms have better management practices and therefore would be more efficient leading to higher sales. Among the firms in the higher range of inefficiency, the sales value do not exceed 100 crores of rupees. Firms with lesser inefficiency have managed to gain higher sales.

Table 4.16
Distribution of firms of different ranges of sales value across Energy inefficiency levels.

Sales	0	1-20	20-40	40-60	60-80	80-100
0	0 (0)	0 (0)	1 (1.19)	2 (7.14)	1 (20.0)	0 (0)
1-50	35 (53.85)	60 (51.28)	50 (59.52)	19 (67.86)	3 (60.0)	2 (66.67)
50-100	15 (23.08)	23 (19.66)	17 (20.24)	4 (14.29)	1 (20.0)	1 (33.33)
100-200	9 (13.85)	16 (13.68)	9 (10.71)	2 (7.14)	0 (0)	0 (0)
200-1000	5 (7.69)	14 (11.97)	4 (4.76)	1 (3.57)	0 (0)	0 (0)
Above 1000	1 (1.54)	4 (3.42)	3 (3.57)	0 (0)	0 (0)	0 (0)
Total	65 (100)	117 (100)	84 (100)	28 (100)	5 (100)	3 (0)

The Share of firms in each energy inefficiency levels to the different ranges of sales is given in table 4.17 to understand the distribution of firms in different ranges of energy inefficiency in the different levels of sales value.

Table 4.17
Distribution of firms of each energy inefficiency levels across different ranges of sales value.

	Energy inefficiency levels						
Sales	0	1-20	20-40	40-60	60-80	80-100	tot
0	0.00	0.00	25.00	50.00	25.00	0.00	100
0-50	20.71	35.50	29.59	11.24	1.78	1.18	100
50-100	24.59	37.70	27.87	6.56	1.64	1.64	100
100-200	25.00	44.44	25.00	5.56	0.00	0.00	100
200-1000	20.83	58.33	16.67	4.17	0.00	0.00	100
1000<	12.50	50.00	37.50	0.00	0.00	0.00	100
total	21.52	38.74	27.81	9.27	1.66	0.99	100

So far, we have analysed the features of firms with energy efficiency as well as inefficiency at a disaggregated level. The following table summarises many of these characteristics in the firms in different product groups.

For this analysis, we classified each product group as efficient or inefficient in energy use taking the CRS figures. In the five product groups here, the average figures for the sales, GFA, output, age and profits were calculated both for the efficient firms as well as for the inefficient firms. The comparison of the performance of the variables under analysis in both classes give some insight into the possible analysis in the next chapter. Table 4.18 shows the average figures of the variables among the product groups for both efficient as well as inefficient firms.

Table 4.18
The average performance of Firms in some variables in the efficient and inefficient energy use groups.

Product Groups	**Efficient group**	**Inefficient group**
IRON		
Average sales	240.29	58.49
Average GFA	340.38	111.45
Average Age	8.13	10.57
Average net profit	0.07	-0.03
STEEL		
Average sales	110.50	295.39
Average GFA	289.30	373.57
Average Age	14.39	20.26
Average net profit	0.07	0.06
CASTING AND FORGING		
Average sales	36.20	49.59
Average GFA	19.06	11.25
Average Age	17.18	23.71
Average net profit	0.05	0.07

Product Groups	Efficient group	Inefficient group
NFM		
Average sales	121.75	73.25
Average GFA	132.40	57.66
Average Age	17.93	18.20
Average net profit	0.09	0.05
ALL FIRMS		
Average sales	116.79	194.95
Average GFA	209.99	236.33
Average Age	14.94	20.36
Average net profit	0.08	0.06

This table summarises many of the points explained in the analysis carried out so far. For example, in all the product groups, the average age of firms in the efficient firms are less, or inefficient firms are the older ones. The net profit figures shows that the profitability of efficient firms as better in all firms. Energy efficient firms also have better output range.

Concluding Observations

This chapter made an attempt towards estimating the level of energy inefficiency at the firm level in the framework of DEA. It was found that while some firms are highly efficient in the use of energy, others present significant levels of inefficiency. Given such a wide variation, a disaggregated analysis of the various intervals of energy inefficiency levels were made. Analysis carried in this direction across four different product groups revealed that maximum efficient firms are in iron whereas the maximum energy inefficient firms are in the castings and forgings group as well as in the steel.

This was followed by an analysis of the association of energy use inefficiency with inefficiencies in the use of other factors, using nonparametric tests. The non-parametric tests have shown that there is significant positive association between the inefficiencies in the use of different inputs (energy, wages, raw materials and gross fixed assets). We have also examined, as a prelude to the analysis in the next chapter, the association between firm characteristics and the level of energy use inefficiency. Having observed significant inter-firm variation in the level of energy inefficiency, the next chapter seeks to identify the determinants of energy inefficiency.

CHAPTER 5

DETERMINANTS OF INTER-FIRM DIFFERENCES IN ENERGY INEFFICIENCY

Introduction

The analysis of energy inefficiency in the preceding chapter, has shown that there exists wide variations in the levels of energy use inefficiency across firms. While there are a number of firms wherein the excess energy use is zero or negligible, there are also firms with significant amount of excess energy use. The existence of wide interfirm variation, notwithstanding, the available studies (as we have shown in chapter 1) focussed mainly on inter-industry variation in the energy use efficiency. In this context it could be argued that the significance of such studies are undermined by the fact that they have not been preceded by any careful analysis of the behaviour of firms (with respect to energy use) that constitute the industry. In the present chapter, therefore, we address the question of inter-firm variation in energy use efficiency.

The chapter is organised in the following way; the second section presents the issues and identify certain hypotheses for empirical verification. The third section introduces the variables used in the analysis and describes how the variables are constructed. The empirical results are presented in the fourth section followed by some concluding observations.

Issues, Hypotheses and the Method

To recap the findings of previous chapter once again, out of the total number of firms studied 21 per cent reported zero excess use of energy or they are fully efficient in energy use. The question that immediately follows from this finding is; what is the probability that a firm in the Basic Metals and Alloys industry is energy efficient and what are the factors that have a bearing on it? Given the finding that there is wide variation in the levels of inefficiency among those recording excess energy use, the next question is; if a firm is found inefficient what are the factors that determine the observed level of inefficiency or how to account for the inter-firm variation in the energy use efficiency ?

To identify the hypotheses for empirical verification let us now have brief review of relevant studies. It need to be stated at the outset that, to the best of our knowledge, there are hardly any studies that looked into these questions. Nevertheless there are a number studies that examined the factors that determine the overall efficiency of the firms using multiple linear regression models. Our approach is to identify certain hypotheses based on these studies. Such an approach is justified in the light of the results of the non-parametric test carried out in the previous chapter. The non-parametric tests have shown that there is significant positive association between the excess of various inputs (energy, wages, raw materials and gross fixed assets) used. Therefore, it can be expected that the factors which explain the overall technical inefficiency may also explain the variations in energy inefficiency across firms.

Studies that examined the determinants of efficiency of the firms have classified the explanatory variables into two broad categories namely, factors internal to the firm and factors external to the firm. Internal factors include managerial and technical skill, training and education of employees, financing of investments, labour management relations, economies of scale, firm size, age of the firm, incentive structure etc. External factors include the availability of infrastructure facilities, foreign trade, technology, government policies etc (Goldar and Agarwal, 1992). Higher managerial and technical skill and higher standard of training and education of employees are expected to improve the efficiency of firms. High degree of economies of scale is generally associated with large scale production and hence overall efficiency. Apart from enjoying economies of scale, bigger firms have the advantage of better management and co-ordination (Page, 1984). It is generally thought that the age of the firm reduces the overall efficiency since it uses technology of old vintage.

Regarding the external factors influencing efficiency it is argued that while better infrastructure facilities allow the firms to operate efficiently, external orientation necessitates the firm to operate efficiently to maintain competitive position in the international market. A firm with advanced technology is expected to perform more efficiently than a firm with outdated technology.

Technical efficiency of firms in the Indian engineering industry has been analysed by Agarwal and Goldar (1992). The OLS regression results revealed that the size of the firm, R & D intensity, retention ratio and the intensity of foreign trade (exports and imports) are major determinants of technical efficiency. These variables are found to have positive coefficients. Capital intensity variable was found to be insignificant. It was also found that efficiency is lower for public sector firms compared to private sector firms. Goldar and Agarwal (1999) studied the efficiency of Indian engineering firms in the pre- and post-reform period, using both the two stage least square method (2SLS) and OLS method. The results obtained by both the methods were by and large similar. Several explanatory variables like firm size, foreign equity participation, age of the firm, technology imports, energy intensity, labour-capital ratio and export intensity were used to examine the determinants of technical efficiency. Firm size and foreign equity participation were found to be statistically significant and positively contributing to the technical efficiency. The age of the firm, on the other hand, showed a negative influence on technical efficiency.

Drawing from the above studies following hypotheses have been put forward. The first hypothesis considers the age of the firm. It is hypothesised that energy inefficiency would have a positive relationship with the age of the firm on the following ground. In general an older firms would be using a technology of old vintage and therefore will be relatively inefficient in its input use. However, the above hypothesis may not hold good if the older firms are technologically more dynamic and possess financial resources to upgrade their technology.

Another hypothesis links energy use efficiency and the size of the firms. Firm size and energy inefficiency is expected to be negatively related if the bigger firms enjoy economies of scale and the advantage of better management. On the other hand, in a protected market with concentrated market structure, where the large firm has substantial market power, there may not be any incentive to be energy efficient. Hence, while one could postulates a strong relationship the direction of the relationship could be either positive or negative.

Labour-capital ratio can also have a positive relationship with energy inefficiency since a firm with a high ratio of employment to investment would generally be using a technology of old vintage and therefore will be relatively inefficient in energy use. Another hypothesis relates to the external orientation of the firm. There are enough empirical evidence in the literature to suggest that outward oriented firms are more efficient as compared to their inward oriented counterparts. An export oriented firm will be under greater pressure to cut down costs and improve the efficiency of resource use including energy if it has to cope up with global competition. Also an export oriented firm is expected to be more aware of the developments elsewhere. Therefore, a negative relationship is expected with energy inefficiency and export intensity.

It is possible to argue that the import of embodied technology (in the form of capital goods) will have a bearing on the energy use efficiency. If the domestic firms have greater access to imported intermediate inputs and capital goods it could enhance their energy use efficiency. Therefore a negative relation is expected between energy inefficiency and import intensity.

Ultimately what really matters would be the type of technology that the firm uses in the production process. Hence one could assume a strong association between technology orientation of the firm and its energy use efficiency. In a developing country like India where the technology behaviour of firms is manifested both in the in house R&D and imported technology one need to consider both these variables in analysing the impact of technology behaviour on energy use efficiency. It could be argued that if the R&D is energy saving a firm can reduce its inefficiency in energy use by spending more on R&D. Likewise providing domestic firms greater access to imported technology can lead to greater efficiency in resource use (energy use). Therefore, this variable would have a negative relationship with energy inefficiency. While stating these general hypotheses we shall also hasten to add that the actual relationship may vary across industries on account of the varying techno- economic characteristics of the industry and the competitive environment in which they operate.

Having presented the hypotheses to be empirically verified let us now briefly deal with the method of analysis. Let us begin with the first question. Broadly we have two sets of firms either efficient or inefficient. This makes our dependent variable is binary (efficient=1 and inefficient=0). In econometrics such cases could be analysed using a probit model. To address the first question we have estimated a probit model of the following type

Prob (to be efficient) = a_0 + a_1Size + a_2Profitability + a_3 Capital intensity + a_4Age + a_5Import intensity + a_6Export intensity + a_7Technology intensity + w_1

where prob(to be efficient) = $\frac{e^{x\beta}}{1 + e^{x\beta}}$

and wi is the error term.

The second question is approached using an OLS regression. The functional form relating the various explanatory variables on energy inefficiency is presented here. We have chosen a linear function, expressed as:

EI = a_0 + a_1Size + a_2Profitability + a_3 Capital intensity + a_4Age + a_5Import intensity + a_6Export intensity + a_7Technology intensity + w_1

where, EI is the percentage of excess energy used by each firm estimated by using DEA technique. It is assumed that the probability of being efficient and the extent of energy inefficiency are governed by the same set of factors.

Database and the construction of variables

The analysis in this chapter is also based on the data obtained from CMIE. Since we have already dealt with the data at length elsewhere we shall proceed with the description of the construction of variables used in the analysis.

Age of the firm is defined as the year of incorporation minus the current year. Size of the firm is usually measured in terms of either gross fixed investment or sales. In the present study we have taken total sales turnover as a measure of firm size. Capital intensity in usually measured as the ratio of labour to capital. In the absence of data on employment we have measured capital intensity as the ratio of wages to gross fixed assets. While export intensity is measured in terms of the ratio of export to sales, import intensity is measured as the ratio of import to sales. Technology intensity is measured as a ratio of the sum of expenditures incurred for import of technology and in house R&D to sales. Profitability of the firms have been measured as the ratio of net profit to net sales.

Since the data is for only one year the analysis is free from serial correlation. Examination of the correlation matrix (with low correlation between variables) ruled out the possibility of multicollinearity. As all the variables are defined in terms of ratios, the problem of heteroskedasticity is also taken care of.

The Empirical Results:

The results of the estimated models are presented in table 5.1 and 5.2. While table 5.1 presents the results of the probit estimates, table 5.2 presents the results of the OLS estimates. The models are estimated for the whole sample by pooling the observations and also for individual product groups. Since the number of observations in one of the industries (Iron) is found to be only 15 we have not undertaken a separate estimation for this industry.

Now lets look at the results of the probit estimates for the whole industry. Among the variables that are identified in the model only three are found to be statistically significant with the expected signs. They are age of the firm, import intensity and export intensity. This tends to suggest that the probability of a firm recording excess energy use increases with its age. The observed positive coefficients of import intensity tend to suggest that firms which import large amounts of capital and spares are more likely to be efficient in energy use. The significance of export intensity tend to suggest that outward orientation acts as a compelling force for the firms to be efficient. However, it is also possible that the firms which are more efficient turn out to be better exporters. If this is the case, then there is the problem of simultaneity and therefore a strong conclusion is not called for with out more rigorous analysis using a simultaneous equation framework.

Table 5.1
Probit estimate of factors responsible for inter-firm variations in energy inefficiency.

Variables	Co-efficients			
	Pooled	Steel	CF	NFM
Constant	-0.509 (3.244)*	-0.729 (3.008)*	-0.974 (1.442)	-0.682 (1.883)*
Sale (Size)	0.0003 (0.929)	0 (0.070)	0.023 (2.032)*	-0.001 (0.383)
Profit	0.329 (0.858)	0.971 (1.326)	1.006 (0.460)	0.333 (0.374)
Import Intensity	1.988 (1.562)*	-10.228 (1.356)	-497.34 (1.39)	7.727 (1.689)*
Export Intensity	0.763 (1.532)*	1.512 (1.727)*	1.468 (1.664)*	-0.801 (0.298)
Age	-0.022 (2.812)*	-0.025 (2.262)*	-0.036 (1.341)	-0.009 (0.484)
Technology	-0.03 (0.691)	-0.039 (0.570)	2.669 (0.857)	0.331 (0.898)
Capital	-0.009 (0.280)	0.322 (1.846)*	0.194 (0.372)	-0.022 (0.477)
Pseudo R^2	0.0541	0.104	0.311	0.192
Log Likelihood	-141.67	-65.81	-19.843	-26.044
Chi^2	16.19	15.21	17.88	12.37
No: of firms	287	156	61	55

Note: Figures in parentheses are the respective z-values
*** significant at least at ten per cent level**

Coming to the inter product group variation age is found to be significant only in the case of steel whereas export intensity is found to be significant in steel and castings and forgings. While the positive relationship between import intensity and energy efficiency is found only in the case of non-ferrous metals, and size turned out to be significant only in the case of castings and forgings. Finally the postulated relationship regarding capital intensity is found only in steel.

The OLS estimate on the inter-firm variation in energy inefficiency is found to be more in tune with the hypothesis we have put forward. In the estimate using the pooled data all the variables except import intensity , capital intensity and technology factor are found to be significant. It is surprising to note that notwithstanding the liberalised policy measures and resultant competitive environment firms behavior in terms of either technology behavior or imports have any significant influence on the energy efficiency of firms. , The lack of significance of the technology factor is to be viewed against the fact that large number of firms neither do in house R&D nor resort to technology import for upgrading their technology. The estimates also show that larger firms are less efficient in energy use and the profitability of firms comes down as they become more inefficient. This tends to indicate the emergence of a more competitive market environment wherein the inefficient firms find it increasingly difficult to pass the higher cost of production (in the form of higher prices) on account of the high inefficiency to the consumers. More importantly, this finding holds good not only for the whole sample but also for two out of three industries taken up for analysis. Similar to profit and sale, our hypothesis regarding export intensity is found to be holding good for the whole sample and the steel.

Table 5.2
Determinants of inter-firm variations in energy inefficiency Multiple linear regression estimates).

Variables	Coefficient			
	Pooled	Steel	CF	NFM
Constant	16.210	11.764	23.651	22.961
	(9.710)*	(5.838)*	(4.135)*	(5.260)*
Sale(size)	-0.006	-0.008	0.012	0.013
	(1.825)*	(2.725)*	(0.196)	(0.462)
Profit	-9.129	-11.639	-42.779	1.491
	(2.214)*	(1.956)*	(2.162)*	(0.151)
Import Intensity	-20.675	25.541	28.893	-38.588
	(1.384)	(1.017)	(0.267)	(1.895)*
Export Intensity	-14.288	-21.984	-16.215	-1.143
	(2.291)*	(2.659)*	(1.388	(0.035)
Age	0.137	0.337	-0.089	-0.222
	(1.998)*	(3.803)*	(0.525)	(1.206)
Technology	0.194	0.355	-5.001	-3.448
	(0.535)	(1.180)	(0.581)	(0.744)
Capital	0.687	0.596	3.587	0.798
	(2.248)*	(0.485)	(0.861)	(2.128)*
R^2	0.105	0.1732	0.147	0.203
F	4.7	4.43	1.3	1.71
No: of firms	287	156	61	55

Note: Figures in parentheses are the respective t-values.
* significant at least at ten per cent level

However, for the reasons already stated, we would prefer to be cautious in terms of reflecting on the influence of export orientation on energy use efficiency of firms. Finally we find a positive and statistically significant association between energy use efficiency and the age of the firm for the whole sample and for non-ferrous metals. Though this relationship is not found to be significant in two of the product groups the available results tend to under score the need for enhancing the modernisation efforts of the older firms.

Concluding Observations:

The present chapter attempted to examine the factors causing inter firm variations in energy efficiency. To find out the probability that a firm is inefficient a probit estimate was carried out. This was estimated for the whole sample as well as for the three product groups namely steel, castings and forgings and non-ferrous metals separately. The factors responsible for the inter-firm variations were also examined by running a multiple linear regression model. The variables used for the analysis were age, size of the firm, profitability, import intensity, export intensity and Technology intensity.

In the case of the probit estimates only three variables, namely, age of the firm, import intensity and export intensity were statistically significant with the expected signs. The above result was obtained for the whole sample. The probit estimates for each of the product groups reveals that there are inter product group variations. Age was significant in case of steel only. Export intensity was significant only in steel and castings and forgings. Import intensity was significant only in the case of non-ferrous metals and size only in case of castings and forgings. The above variables also showed the expected signs. The results of the OLS estimate were found to be more in tune with the hypothesis put forward in this study. In the case of pooled data all variables except import intensity, capital intensity and technology factor were found to be significant. In general, the study shows that the larger and older firms are less efficient in energy use and the inefficiency has a negative relationship with profitability and export orientation.

CHAPTER 6

SUMMARY AND CONCLUSIONS

The importance of energy management in an energy deficient developing country like India cannot be overemphasised. More so since secondary studies tend to suggest that energy efficiency in the Indian manufacturing industries is very low - a matter of serious implications for the growth potential of the economy. The importance of studies like the present one needs to be viewed in this background.

In the present study an attempt has been made to analyse the firm-level energy efficiency and its determinants against the backdrop of the trends in energy use in the Indian manufacturing sector during the time period 1974-1994. This period witnessed a turmoil in the international oil market with implications for energy used by net energy importing countries like India. It was found that the absolute level of energy use in the Indian manufacturing sector was higher after 1983 when compared to the pre-1983 period and the more energy utilising industries where responsible for the observed increase in the energy-output ratio after 1983. It was also found that the energy labour ratio registered a sharp increase especially after 1983 whereas the energy capital ratio remained more or less constant. Thus it may be inferred that the substitution of labour by energy has been taking place over the years which is partly responsible for the increase in energy intensity in the sector especially after 1983.

An examination of the energy intensity and the share of energy across different industries in the manufacturing sector showed that Basic Metals and Alloys ranked third in both cases. Therefore, for the detailed firm level analysis the Basic Metals and Alloys industry has been selected.

The firms under the Basic Metals and Alloys industry were classified into four product groups `Pig and Sponge Iron´, `Steel´, `Castings and Forgings´ and `Non-ferrous metals´. The excess energy use in all the above four product groups was estimated using Data Envelopment Analysis. The analysis was done at the firm level making use of the CMIE data. It was found that in all the four product groups, both under CRS and VRS assumption, the number of companies decreases as the range of excess energy use increases, with majority of the companies using less than 40 per cent of energy in excess. The study found the simultaneous existence of highly energy efficient and inefficient firms in the same product group.

Two non-parametric tests - rank correlation coefficient (bivariate analysis) and Kendall´s coefficient of concordance (multivariate analysis) were carried out to examine if there exist any significant association between the inefficiency in the use of energy and other inputs (raw material, energy, wages and GFA). Both the tests indicated that in three of the product groups namely - `Castings and Forgings´, `Steel´ and `Non-ferrous metals´, there is significant association between different factor specific inefficiencies.

Given the high inter-firm variation in the level of energy efficiency another question addressed in the study pertained to the determinants of energy (in)efficiency. Here we asked two questions? What is the probability that a firm is efficient in energy use and secondly what are the factors that determine the inter-firm variation in energy use inefficiency. These two questions were analysed using a probit model and OLS. It is found that the probability of a firm recording efficiency in energy use increases with its age, import intensity and export intensity. The major factors that determine the inter-firm variation in energy inefficiency are found to be the age of the firm, size, profitability, export orientation and capital intensity. It is surprising to note that notwithstanding the liberalised policy measures firms' behavior in terms of either technology behavior or imports have any significant influence on the energy efficiency of firms. The lack of significance of the technology factor is to be viewed against the fact that large number of firms neither do inhouse R&D nor resort to technology import for upgrading their technology. In general the study shows that the larger and older firms are less efficient in energy use and the inefficiency has a negative relationship with profitability and export orientation. All these results point towards the imperative of initiating steps to modernise and upgrade the production technology in the Indian manufacturing sector. In bringing about these, the policy framework will have to be tuned in such a way that a competitive environment is created.

Selected Bibliography

Agarwal,R.N and B.N Goldar (1999) : "Technology Imports, Growth, Efficiency and Export Performance of Indian Engineering Firms in the Pre- and Post-Reform Period", **Institute of Economic Growth, Working Paper,** Series No. E/201/99, Delhi University Enclave, Delhi, India.

Ahluwalia,I.J. (1985) : **Industrial Growth in India : Stagnation Since the Mid-Sixties**, New Delhi: Oxford University Press.

Aigner,D.J, C.A.K Lovell and P.J Schmidt (1977) : "Specification and Estimation of Frontier Production, Profit and Cost Functions", **Journal of Econometrics**, 13: 1-138.

Aigner,D and S.Chu (1968): "On Estimating the Industry Production Function", **American Economic Review**, 58: 826-839.

Andrew, Ewing J.(1985): "Energy Efficiency in the Pulp and Paper Industry with Emphasis on Developing Countries", **World Bank Technical Paper,** No:34, The World Bank, Washington D.C, U.S.A.

Antony, Margaret (1998): "Technical Efficiency in Rice Production: A Farm-Level Study on Tamil Nadu", Mphil Dissertation, **Centre For Development Studies**, Thiruvananthapuram.

Apte, P.C (1983): "Substitution Among Energy and Non-Energy Inputs in Selected Indian Manufacturing Industries: An Econometric Analysis", **The Indian Economic Journal**, Vol 31, No.2, Pg.71-90

Banker,R, A.Charnes, W.W Cooper, J.Swarts and D.Thomas (1990) : "An Introduction to Data Envelopment Analysis with Some of its Models and their Uses", **Research in Governmental and Nonprofit Accounting**, 5: 125-163.

Banker,R and Maindiratta (1988), "Nonparametric Analysis of Technical and Allocative Efficiencies in Production", **Econometrica**, 56: 1315-32.

Banker,R and A.Maindiratta (1986) : "Piecewise Loglinear Estimation of Efficient Production Surfaces", **Management Science**, 32: 126-135.

Bauer,P.W (1990) : "Recent Developments in Econometric Estimation of Frontier", **Journal of Econometrics**, 46: 39-56.

Belsley,H.L (1978) : "**Basic Statistics for Business and Economics**", Head, Department of Economics and Finance, University of Arkansas at Little Rock, Grid Inc.' Columbus, Ohio.

Belsley, A.D (1991) : "**Diagnostics : Collinearity and Weak Data in Regression**", New York, John Wiley and Sons, Inc.

Berndt, Ernst,R and O.David, (1975): "Technology, prices and the Derived Demand for Energy", **The Review of Economics and Statistics**, Vol 57, NO.3, Pg.259-268.

Bhavani, T.A (1991): "Technical Efficiency in Indian Modern Small Scale Sector:An Application of Frontier Production Function"; **Indian Economic Review**, Vol.XXVI, No.2, Pg.149-166.

Blois, K.J (1972) : "A Note on X-Efficiency and Profit Maximisation", **Quarterly Journal of Economics**, LXXX VIII: 681-86.

Boyce, J.K (1986) : "Kinked Exponential Models for Growth Rate Estimation", **Oxford Economic Bulletin of Economics and Statistics**, 48, 4, PP. 385-391.

Center For Monitoring Indian Economy (1998) : Economic Intelligence Service: Industry; Financial Aggregates and Ratios.

Chambers, R.G (1988) : "**Applied Production Analysis - A Dual Approach**", Cambridge University Press.

Charnes, A, W.W Cooper and E.Rhodes (1981) : "Evaluating Program and Managerial Efficiency: An Application of Data Envelopment Analysis to Program Follow Through", **Management Science**, 27:668-697.

Das,D.K (1998) : "Trade Liberalisation and Productivity Growth: A Disaggregated Analysis of Indian Manufacturing Sectors", **Institute of Economic Growth Working Paper,** Series No.E/200/98, Delhi University Enclave, Delhi, India.

Evenson,R.E and K.J Joseph (1996): "Foreign Technology and Licensing in Indian Industry - An Econometric Analysis of the Choice of Partners, Terms of Contract and the Effect on Licensees' Performance", **Working Paper, No.273, Centre for Development Studies**, Thiruvananthapuram, Kerala, India.

Farrell, M.J. (1957) : "The Measurement of Productive Efficiency", **Journal of the Royal Statistical Society**, Vol.120, Series A (General), Part III, PP.253-281.

Fuss, Melvyn,A (1977): "The Demand for Energy in Canadian Manufacturing:An Example of the Estimation of Production Structures with many Inputs", **Journal of Econometrics**, Vol 5, Pg 89-116.

Goldar, B.N and Agarwal, R.N(1992): "Technical Efficiency in the Indian Engineering Industry:Deterministic Vs Stochastic Frontier Production Function Approach",**Institute of Economic Growth, Working Paper Series**, E/151/92.

Goldar, Bishwanath and Mokhopadhyay Hiranya (1991); "Substitution among Labour,Capital and Energy in Indian Industries:An Application of the Cost-Price Approach", **Journal of Quantitative Economics**, Vol7, NO.1, Pg 65-78.

Government of India (1979) : **Report of the Working Group on Energy Policy**, Planning Commission, New Delhi.

Griffin, James.M and A. Paul Gregory (1976): "An Inter Country Translog Model of Energy Substitution Responses", **The American Economic Review**, Vol.66, No.5, Pg.845-857.

Gujarati, D.N (1995) : **Basic Econometrics**, Third Edition,Singapore, McGraw-Hill, Inc.

Gunn,Calum (1997) : "Energy Efficiency vs Economic Efficiency?" - New Zealand electricity sector reform in the context of the national energy policy objective",**Energy Policy**, Vol25, PP.241-254.

Howarth, R.B (1991) : "Energy Use in U.S. Manufacturing : The Impact of The Energy Shocks on Sectoral Output, Industry Structure, and Energy Intensity", **The Journal of Energy and Development**, Vol.14, No.2, PP.175-191.

Jha, Raghbendra, M.N Murty, and Satya Paul (1991): "Technological Change, Factor Substitution and Economics of Scale in Selected Manufacturing Industries in India", **Journal of Quantitative Economics**, Vol 7, No.1, Pg.165-178.

John, Binoy (1997) Institutions, Inert Areas and X-efficiency: An Analysis of State Transport Undertakings in India; Centre for Development Studies.

Johnston, J. (1991) : **Econometric Methods**, Singapore : McGraw-Hill, Inc.

Joseph, K.J (1997) : "**Industry Under Economic Liberalization - The Case of Indian Electronics**", Sage Publications, New Delhi.

Kalirajan, K.P and M.B Obwona (1994) : "A Measurement of Firm and Input-Specific Technical and Allocative Efficiencies", **Applied Economics**, 26, P.393-398.

Kilpatrick, A and B.Naisbitt (1988) : "Energy Intensity, Industrial Structure and the 1970's Productivity Slowdown", **Oxford Bulletin of Economics and Statistics**, Vol 50, August, No.3, PP. 229-239.

Leibenstein, H. (1979) : "X-Efficiency: From Concept to Theory", **Challenge**, 22: 13-22.

Leibenstein, H. (1978) : **General X-Efficiency Theory and Economic Development**, New York: Oxford University Press.

Leibenstein, Harvey (1966) : "Allocative Efficiency vs. 'X-Efficiency", **The American Economic Review**, Vol. LVI. No.3, June, PP. 392-415.

Lynk, Edward l (1983): "Long Run Constraints to Industrial Development in India:KLEM Substitution/Complementarily", **The Indian Economic Journal**, Vol 31, No.2, Pg.27-42.

Maddala, G.S.(1989): "Introduction to Econometrics", University of Florida, Macmillan Publishing Company, New York.

Majumdar, K.S. (1996): "Fall and Rise of Productivity in Indian Industry - Has Economic Liberalisation Had an Impact?", **Economic and Political Weekly**, November 30, Pg.M46-M53.

Maurice, Y Meunier and Oscar, de Bruyn Kops (1984): "Energy Efficiency in the Steel Industry with Emphasis on Developing Countries", **World Bank Technical Paper**, The World Bank, Washington D.C, U.S.A.

Mogens ,H Fog and L.Nadkarni Kishore (1983):"Energy Efficiency and Fuel Substitution in the Cement Industry with Emphasis on Developing Countries", **World Bank Technical Paper**, Washington D.C, U.S.A.

Monga, G.S. and Sanctis, V.J.(1994): "India's Energy Prospects, Vikas Publishing House Private Limited, New Delhi.

Pabibandla,M.(1995) : "Firm Size and Export Behaviour: An Indian Case Study," **Journal of Development Economics**, Vol.31, No.6, pp.868-82.

Pachauri, R.K.(1980): "**Energy Policy for India: A Interdisciplinary Analysis**, Macmillan Publications, New Delhi.

Page,J.M, Jr.(1984) "Firm Size and Technical Efficiency: Applications of Production Frontier to Indian Survey Data," **Journal of Development Economics**, Vol.16, No. 1-2, pp.129-152.

Parikh,J.K and A.K Chaitanya (1980) : "Are Our Industries Energy Efficient?", **Economic and Political Weekly**, March 15.

Patterson, Murray,G. (1996): "What Is Energy Efficiency? - Concepts, indicators and methodological issues.", **Energy Policy**, vol 24, Issue 5, Pg.377-390.

Pendse,D.R. (1980) : "Energy Crisis and Its Impact on Energy Consumers in Third World-1", **Economic and Political Weekly**, Vol 15, Issue No: 1-13, Jan-March.

Pindyck, Roberta,S. (1979): "Inter-Fuel Substitution and the Industrial Demand for Energy: An International Comparison", **The Review of Economics and Statistics**, Vol 61, Pg.169-179.

National Productivity Council Research Section (1991 b): "Energy Productivity in Indian Manufacturing Industries", **Productivity**, Vol 32, April - June, No.1.

Salib (1983) : Energy, GDP, And The Structure Of Demand : An International Comparison Using Input-Output Techniques", **Journal of Energy And Development**, Vol.9, No.1, PP. 55-61.

Schmidt, P.J. (1986) : "Frontier Production Functions", **Econometric Reviews**, 4: 289-328.

Sengupta, Ramprasad (1992) : "Energy Planning for India : A Critique of the Existing Methodology", **Indian Economic Review**, Special Number, PP. 425-437.

Sengupta, Ramprasad (1993) :" **Energy Modelling For India - Towards A Policy for Commercial Energy**", Planning Commission, Govt of India, New Delhi.

Stigler, G.H. (1976) : "The Existence of X-Efficiency", **American Economic Review**, Vol. 66, No. 1, March, PP. 213-216.

Supriya Satyanarayana (1995) : "Energy Management in the Indian Manufacturing Sector", M.phil Thesis, **Centre For Development Studies**, Thiruvananthapuram.

United Nations (1984) : "**Energy Planning in Developing Countries**", UN's Department of Technical Cooperation for Development, Oxford University Press.

Varian, H. (1984) : "The Non-parametric Approach to Production Analysis", **Econometrica**, 52: 579-597.

Vashist, D.C. (1984): "Substitution Possibilities and Price Sensitivity of Energy Demand in Indian Manufacturing", **Indian Economic Review**, Vol 32, No.2, Pg.84-97.