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A STUDY OF ENERGY USE

IN INDIA'S MANUFACTURING INDUSTRIES

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This work in progress is issued with the dual purpose of informing the policy community of the state of knowledge and of eliciting comments on our efforts. The views expressed in this paper are those of the author alone and should not be interpreted as representing the views of either A.I.D. or Resources for the Future.

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Executive Summary

A STUDY OF ENERGY USE IN INDIA'S MANUFACTURING INDUSTRIES

Introduction

Energy, along with capital and labor, is a key input into most production processes. Recent studies carried out in industrial nations indicate that substantial substitution possibilities exist between factor inputs and among energy sources, but little work has been directed towards the industrial sectors of less developed countries. The possibilities for substituting labor or capital for energy have important implications for government policy. In particular, the energy prices established by the government of India will affect the relative demand for coal, petroleum, and electricity, etc., and for other factor inputs. A clear picture of the relationships between factor inputs may aid policy makers in developing investment and employment strategies as well as energy pricing policy.

The main objective of this study is to examine the underlying relationship among capital, labor and energy in the industrial sector. Possibilities for substitution between energy and the other factor inputs are tested on an industry by industry basis using correlation coefficients and other statistical methods. The study analyzes the pattern of energy use in India's manufacturing sector, and examines the possibilities for interfuel substitution and the impact of energy prices on the demand for different fuels. Understanding the relationships between both factor inputs and energy types may help to suggest opportunities for conservation of energy and other factors in the manufacturing sector.

Approach

The data collected for this study cover sixteen major industry groups in India for four years--1963, 1966, 1969, and 1971 (see table 1). Most

Table 1. Major Industry Groups Selected for Study

1.	Sugar and gur
2.	Tobacco manufacturing
3.	Spinning and weaving of textiles
4.	Other textiles
5.	Paper and paperboards
6.	Rubber products
7.	Basic chemicals
8.	Petroleum refining
9.	Miscellaneous products of coal and petroleum
10.	Cement
11.	Iron and steel
12.	Nonferrous metal
13.	Shipbuilding and repairs
14.	Railroad equipment
15.	Motor vehicle manufacture and repair
16.	Aircraft manufacture

major industry groups in India have been covered, except for machinery and metal products, which were excluded due to lack of data. The data include factor inputs consumed in production, value added in manufacture, output levels, and consumption and expenditure of different fuels. Factor inputs here include capital (fixed, productive and invested), labor, energy (by fuel) and raw materials, and are derived from the Annual Survey of Industries conducted by the Central Statistical Organization of the Government of India.

The study is divided into two parts. In the first, factor input intensities and other parameters of production are calculated for each of these industry groups. In the second, cost share equations for the factor inputs and for each fuel are estimated in order to derive elasticites of substitution and price elasticities for seventeen four-digit industries selected from the three-digit industry groups mentioned above. Both of the steps are discussed in detail below.

The first part of the study assesses the interrelationships between factor inputs based on factor input intensities and the degree of association between these parameters. Factor input intensities, calculated as the value or amount of the factor input consumed divided by the value added in manufacture, are computed for capital, labor, energy (quantity),

energy cost, and materials cost. In addition, capital to labor ratios and a composite index of energy (based on relative weights of energy use and price) are calculated for each industry group. These parameters reflect the technology choices underlying the structure of production in India's manufacturing industries.

The sixteen major industry groups are then ranked based on each of these factor intensities. If the ranking of a particular industry group or several groups are similar for two or more factor intensities, then the rankings will be positively correlated. Statistical tests are used to measure the degree of association between the different parameters and the industry rankings. For example, a significant positive correlation between capital intensity and the capital to labor ratio confirms the expected close relationship between the two in many industries.

The structure of energy use in India's manufacturing industries is examined by calculating the energy cost intensity by fuel for each of the industry groups. Energy cost intensity is computed for coal, coke, coal gas, firewood, charcoal, petroleum products, fuel oil and electricity for the years 1963, 1966, 1969, and 1971. Although coal, petroleum and electricity provide the majority of energy used in these industries, their relative shares vary both between and within industry groups.

In the second part of the study, the effects of changes in relative energy prices on energy consumption and the extent of substitution among the aggregate factor inputs are analyzed for the seventeen four-digit industries. A translog production function is used to estimate own- and cross-price elasticities for the different fuels and elasticities of substitution between factor inputs. The model used draws on recent work both in industrial and developing nations. The model assumes that output (Y) is a function of four inputs--capital (K), labor, (L), energy (E), and raw materials (M). The production function is characterized by constant returns to scale and is weakly separable among inputs, meaning that the marginal rates of substitution between individual fuels are independent of the quantities of each input. The energy input to production is in turn a function of the inputs of the five principal industrial fuels (coal, coke, petroleum products, fuel oil, and electricity).

A study of this kind contains a number of limitations. Data accuracy is important, though data on the industrial sector in India are generally extensive and accurate. The patterns of factor input consumption are dependent on the technology choices available, though these choices may be limited by availibility or other constraints. A developing country is also unlikely to be on its production possibility frontier, that is, due to infrastructure constraints and other limitations, the economy is not operating in the most economically efficient way. Along with the limitations of analysis in a developing country, the translog model specified in this study must make certain simplifying assumptions. In particular, the assumptions concerning aggregate production functions, the availability of capital and other inputs, and technology choices may not be entirely appropriate for the Indian economy.

Results

Factor input intensities and energy use patterns vary across industries in India but a steady expansion and capital deepening of the manufacturing sector is clearly observed over the time period studied. Industry groups which are generally machine-dominated, such as basic chemicals, petroleum refining, iron and steel, and cement are capital intensive and tend to have a high capital to labor ratio. Those industry groups high in capital intensity in 1963 also tended to be high in 1971. In most industry groups, the capital intensity ratio (value of capital to value added in manufacture) increased between 1963 and 1971. All three types of capital examined--fixed, productive and invested--showed this increase. Government policy in India, documented in the National Plans of this period, called for large investments in the manufacturing sector. Both the creation of new industries and the expansion and modernization of existing ones generally added to the trend of increasing capitalization throughout the Indian economy. At the same time, for most industry groups studied, capital to labor ratios increased and labor intensity declined. Clearly, the Indian manufacturing sector shifted toward an increased use of capital over this period, partly at the expense of labor. Even in more labor-intensive industries such as cotton and other textiles and sugar production, capital intensity generally increased and labor intensity declined.

Along with a general trend of capital deepening, the structure of energy use in India's manufacturing sector underwent changes between 1963 and 1971. In most industries, energy cost intensity (energy cost per unit of value added) increased, but energy intensity (quantity of energy consumed per unit of value added) declined. Further, in many industries, the share of energy in the cost of energy and material inputs increased. Despite this declining energy intensity, many of India's industries appear energy intensive by international comparison. The energy intensity decline could also have been brought about by an advance along the learning curve in new industries.

Statistical tests (such as correlation coefficients) were made to evaluate the degree of association between the parameters of production. A substitution effect between capital and labor was evidenced by a weak negative correlation between capital intensity and labor intensity, and a significant positive correlation between capital intensity and capital/labor ratio in many industries. In contrast, a positive correlation between capital intensity and energy cost intensity suggests that capital intensive industries also tend to be energy cost intensive. This relationship may have important implications for government policymaking for industrial expansion, given high energy costs. A weak negative correlation was found between energy cost and labor intensities for about half of the industries, suggesting that some substitution possibilities may exist between these factors.

A number of other general trends in the factor relationships are worth noting. Over the time period studied, an increase in materials cost intensity occurred in most industries along with the increase in energy cost intensity. Consumption of raw materials in production usually varies directly with output level, suggesting that raw materials prices increased between 1963 and 1971 and resulting in the increase in materials cost intensity. Further, the degree of association between materials cost intensity and capital intensity increased in many industries over the time period. A similar increases occurred in the degree of association between capital intensity and energy cost intensity.

Selected results of our statistical analysis for five of the seventeen industries examined are given in tables 2 and 3. A positive elasticity of substitution indicates that two fuels are substitutes and a negative one

Table 2. Allen Partial Elasticities of Substitution for Key Industry Groups

Interfuel Substitution

	e_{13}	e_{14}	e_{15}	e_{35}	Key	
Sugar	0.1123	-0.0205	-0.0553	-0.2364	Coal	-1
Cotton textiles	0.0200	0.1039	-0.2454	-0.6369	Coke	-2
Inorganic fertilizers	-0.0158	-0.1434	0.2063	-0.7824	Petroleum products	-3
Cement	0.0035	-0.0070	0.0202	-0.0386	Fuel oil	-4
Iron and steel	-0.1164	2.1854	-1.3463	0.4241	Electricity	-5

Interfactor Substitution

	e_{KL}	e_{KE}	e_{LE}	e_{EM}	Key
Sugar	0.1205	-1.0242	-2.2679	0.4620	
Cotton textiles	0.5090	-2.1050	5.0346	-0.3350	K = capital
Inorganic fertilizers	0.2237	0.1900	-0.3995	0.1463	L = labor
Cement	0.3434	-0.2012	0.0116	-0.0756	E = energy
Iron and steel	-0.0920	-0.2068	0.0890	0.0537	M = materials

Note: The parameters estimated for each of the seventeen industries for three time periods are available to the interested reader at Resources for the Future.

indicates complementarity. Many of the elasticities of substitution are low, suggesting that there are only weak possibilities for substitution or complementarity. Coal and fuel oil show the highest potential for substitutability (as represented by a high positive correlation) in the iron and steel industry. The results indicate at least some potential for substitution of coal for oil in several industries. Weak substitutability is suggested between electricity and coal.

The model also examines possibilities for substitution between factor inputs (see tables 2 and 3 for the Allen partial elasticities of substitution and price elasticities). The positive elasticity between capital and labor indicates substitution effects in most of the industries studied, confirming the earlier result. The negative elasticity for capital and energy suggest that these two factors tend to be complements in most industries. Energy and labor, however, appear to be equally likely substitutes and complements, as the elasticity is slightly negative in

about half of the industries in this study. In the industries of the textiles group, however, there is a fairly strong potential for substitution between labor and energy, evidenced by a high positive elasticity of substitution. Energy and labor show significant own-price elasticities, particularly in the sugar and cotton textiles, while the own-price elasticities of capital and materials are fairly low.

It is clear from this study that the Indian economy experienced a trend toward increasing capitalization during the time period studied. Further, the production relationships examined here indicate a potential for capital/labor substitution and capital/energy complementarity. The increasing cost of energy in most industries, as evidenced by an increasing energy cost intensity even before 1973, emphasizes the importance of rational energy pricing policies in India. In addition, the impact on energy consumption should be considered if government policies continue to encourage large increases in capitalization. The close interaction between energy and other factor inputs in production also suggests the importance of factor costs and technology choices in determining the overall structure of energy use in the industrial sector.

Table 3. Price Elasticities for Energy and Other Factors for Key Industry Groups

	n_{KK}	n_{KL}	n_{KE}	n_{LL}	n_{LK}	n_{LE}	n_{EE}	n_{MM}	3_{KM}
Sugar	0.2152	0.0121	-0.0163	-0.6104	0.0099	-0.0362	-0.0563	-0.0661	-0.2110
Cotton textiles	-0.1428	0.0894	-0.0906	-0.3323	0.0321	0.2169	-0.4567	0.0076	-0.1371
Inorganic fertilizers	-0.0874	0.0271	0.0225	-0.0322	0.0227	-0.0473	-0.0671	-0.0336	0.0377
Cement	-0.0103	0.0355	-0.0551	-0.0350	0.0463	0.0032	0.0635	0.0154	0.0300
Iron & steel	-0.0100	-0.0077	-0.0186	-0.0072	-0.0133	0.0260	-0.0309	-0.0076	0.0163

Note: The results for each of the industries for time periods are available at Resources for the Future.

Key:

K = capital
L = labor
E = energy
M = materials

Chapter 1

INTRODUCTION

Need for the Study

Prices of energy in India, as in many other developing countries, are administered by the government and often deviate substantially from social costs as well as market-determined levels. The subject of energy prices, therefore, is of great concern to policymakers, because prices not only determine revenues and rates of return on invested capital for the energy supply industry, but also have a major impact on the long-run demand for energy.

This impact on energy demand in the aggregate and particularly in the industrial sector has not been adequately investigated in the developing countries. Recent research in the industrial nations has revealed important substitution effects between capital, labor, energy, and materials in the industrial sector, as well as between different forms of energy. Similar research for the less developed countries would be very useful and would add to the growing evidence of the price elastic nature of demand for energy in developing countries.

Industrial energy demand has to be viewed both within a macroeconomic general equilibrium framework and in terms of technological choices of production. Whereas the overall levels of production are dictated by various market and nonmarket forces, the actual use of different factors of production is subject to possibilities of substitution between them. In particular, the impact of energy prices on inter-factor substitution is an important element in the structure of industrial production.

A study carried out by Noel Uri (1979) for the India manufacturing sector focused mainly on measuring the extent of energy substitution and indicated the effects of relative changes in energy prices on energy

consumption. Williams and Laumas (1980) have provided a sharper focus in their study by examining the substitution possibilities among energy inputs and other factors of production in response to price changes. Unfortunately, an in depth view was not presented on interfuel substitution possibilities. Also, both the earlier studies failed to show the interrelationships linking various factors of production and the manner in which they have changed over time.

Most official analyses and academic research on the demand for energy in the industrial sector in India have relied on the hypothesis that demand for energy rises proportionately with industrial output. Wherever allowance has been made for changes in energy coefficients, the basis for estimation has generally been related to explicit changes in technical processes. Little has been done to model or estimate price-induced changes in the employment of the aggregate factors of production, namely, capital, labor, energy, and raw materials, and specific fuels such as electricity, coal, oil, etc.

The manufacturing sector in India accounts for about 40 percent of the total commercial energy consumption of the country. This share has remained almost steady over the past three decades, going only from 37.3 percent in 1953-54 to 38.5 percent in 1978-79 (Planning Commission, Government of India, 1980). But shifts have occurred in the composition of the manufacturing sector's energy consumption in recent years. In 1978-79, electricity comprised 47.55 percent of the three major types of energy, while coal and oil comprised 44.53 percent and 7.93 percent, respectively. The shares in 1975-76 consisted of 42.53 percent, 50.05 percent, and 7.42 percent for electricity, coal, and oil, respectively (Planning Commission, Government of India, 1980).

There are clear indications of the gradual movement toward a highly energy intensive structure of production in the manufacturing sector. The Working Group on Energy Policy (Planning Commission, Government of India, 1980) has shown that the intensity of energy use for 10 million rupees of value added by manufacture at 1960-61 constant prices has gone up from 1.86 in 1960-61 to 2.11 in 1970-71 and to 2.40 in 1975-76. Table 1-1 lists ten industries in which power and fuel expenses constitute 5 to 20 percent of the total value of production, and which have been identified as energy intensive. Among them, aluminum, cement, paper and pulp, and industrial

Table 1-1. Power and Fuel Consumption in Manufacturing Industries in India (power and fuel as percentage of value of production)

Industry	1965-1966	1966-1967	1967-1968	1968-1969	1969-1970	1970-1971	1971-1972
Cement	17.3	15.9	15.6	17.5	17.5	20.0	19.6
Aluminum	10.5	11.5	11.6	12.7	12.9	16.7	17.5
Paper and paper product	9.2	9.5	9.8	9.9	9.4	10.2	9.9
Minerals	8.4	8.8	10.7	8.9	8.8	8.5	8.7
Pottery	7.0	7.7	7.8	8.1	8.3	8.0	7.6
Basic industrial chemicals	5.6	5.4	5.4	5.6	5.3	6.1	6.4
Engineering workshops	6.4	6.6	7.3	7.2	7.6	6.7	6.2
Silk and rayon textiles	5.5	5.4	5.4	5.5	5.4	6.1	6.2
Coal mining	4.4	4.7	4.5	4.4	4.3	4.6	5.2
Cotton textiles	4.2	4.4	4.3	4.4	4.3	4.6	4.4

Source: Reserve Bank of India, Reserve Bank of India Bulletin: Finance of the Public Limited Companies, January 1974 and September 1972 (Government of India), various years.

chemicals including fertilizers, figure prominently. In general, power and fuel costs in proportion to the total value of production have increased fairly steadily over the years 1965 to 1972 in most industries. In the case of aluminum, however, the sudden and steep increases in power tariffs had a somewhat more pronounced effect, pushing up the cost of fuel consumption from 10.5 percent of total cost in 1965-66 to 17.5 percent of the total in 1971-72.

Table 1-2 reviews trends in expenditures on energy and in value of production for different manufacturing units in the two years 1965-66 and 1971-72. This is not comparable with the earlier series (table 1-1) as data are derived from two different sources. But the ratio of relative growth of energy costs to the value of production in most cases is above unity, indicating that more energy is required per unit of output.

Table 1-2. Energy Consumption in Relation to Value of Production in the Manufacturing Sector, 1965-66 to 1971-72

Industrial classification	Ratio of energy value in 1971-2 to energy value used in 1965-66	Ratio of value of production in 1971-2 to value of production in 1965-66	Ratio of energy value used to ratio of value of production
Agriculture and related activities	1.71	1.34	1.276
Mining and quarrying	1.50	1.46	1.027
Process manufacturing	1.81	1.63	1.110
Tobacco	2.00	1.34	1.492
Textiles	1.78	1.67	1.066
Processing	2.80	1.96	1.429
Iron and steel	1.74	1.06	1.641
Aluminum	4.39	2.62	1.676
Transport equipment	2.05	1.74	1.178
Electrical machinery	3.31	2.20	1.504
Machinery	2.58	2.44	1.057
Foundry	5.71	5.92	0.964
Ferrous metals	1.64	1.46	1.123
Chemicals	3.43	2.53	1.356
Cement	1.83	1.61	1.137
Rubber products	2.26	1.82	1.242

Source: Reserve Bank of India, Reserve Bank of India Bulletin: Finance of the Public Limited Companies, January 1974 and September 1972 (Government of India), various years; and Chitale M. Roy, Energy Crisis in India, (1975) p. 34.

One question that explicitly arises when we view this growing intensity of energy use is whether it represents optimal choices in the deployment of resources for production. The answer to this question is complex, but if technological choices are not optimal, then improvements would depend largely on the degree of substitutability of capital, labor, and energy in the long run. Thus only in the long run would we arrive at an optimal choice of technology so that the country's endowment of resources is well utilized. Hence, determining the long-run relationship between capital, labor, energy, and materials in aggregate production is an

important objective. Before any such attempt is made, it is crucial to determine the trends of the various factors of production in a dynamic framework for each of the industries and understand exactly the 'technology choices' confronting each industry. Technology is to be viewed in a broader perspective involving the economic relationships between various factor inputs of production.

Development of the Study

The Administrative Staff College of India (ASCI) has had a deep involvement in various issues of national concern, and has developed its expertise in issues of national importance. The efforts of the institution in the energy sector have been substantial. In keeping with this direction, the former director of the Consulting and Applied Research Division of ASCI, Dr. R. K. Pachauri, submitted a proposal for research on the subject of energy use in India's manufacturing industries to Resources for the Future. Discussions with staff at RFF lead to a revised proposal to test the methodology outlined in the proposal by applying it to some specific industry groups, thus proceding with the study in two phases.

The major objectives of this study can be outlined as follows:

1. To carry out an analysis of energy consumption by types of energy in the major industry groups of India's manufacturing sector.

2. To assess the extent of influence that relative energy prices exert on the demand for various sources of energy in the industry groups covered in the study.

3. To study the possibilities of interfuel substitution in these industry groups and assess the scope of conservation of specific sources of energy, particularly petroleum products.

4. To assess the industry-by-industry possibilities for substitution of energy versus other major inputs such as labor and capital, particularly in the long run.

The first phase consists of a study on energy and other resource use in manufacturing industries in India. The second and larger phase covers an economic analysis of production relationships for manufacturing

activities and suggests conservation measures based on technical choices for production.

The study was undertaken after careful selection of a number of industry groups in India's manufacturing sector. During the first three months of the study, data requirements were identified relating to those relationships to be studied, various governmental agencies were approached (the Bureau of Economics and Statistics, the Central Statistical Organization, the Director General of Technical Development) and published and unpublished sources of data checked. Concurrently, estimation of various relationships were also started by feeding properly compiled and tabulated data into computer programs developed for this study. As is normal, some time was spent in validating and debugging the programs. In some cases, the need for new data was revealed during the process of estimation when certain tentative results indicated that alternative methods and formulations would prove superior to what had been tried.

The first exercise was an in-depth study of energy and other resource use for sixteen major industry groups in the manufacturing sector. It also included an estimation of the interaction and relationships between various factor inputs of production. An analysis based on these estimations indicated the need for disaggregated levels of data for various industries belonging to the industry groups studied earlier. Thus in the next stage, disaggregated data were collected covering various indices of production for seventeen selected industries. The estimation of the translog production functions carried out in this second phase was preceded by the compilation and computation of data in the correct form and correct units. For instance, in dealing with various economic data such as the rate of price of capital to price of materials input, we had to reduce data which are generally available in price terms using an appropriate index. Some of these operations are described in chapter 3. The selection of the final relationships to be used in the model was made on the basis of economic theory and statistical significance.

The econometric estimation of the transcendental logarithmic production function was carried out using the recently developed approach for solving systems of equations developed by P. N. Misra and Puneet Handa of the India Institute of Management. ASCI entirely developed the computer program as it relates to the translog function and relationships estimated

and adopted in this study, using the Reyad-1030 computer at the college and the PDP-11/70 computer available at the India Institute of Management. We obtained elasticities for a large number of variables related to different equations. As such, the results obtained and reported in this study provide policymakers with a fairly wide insight into the aspects of energy and resource pricing, and technology choice for production activities so as to optimize use of the country's resources. The econometric analysis was based on the estimation of translog cost sharing equations following Fuss (1977) and Berndt and Wood (1975), with several notable alterations in estimation technique.

The correlation coefficients estimated clearly bring out the interrelationships among various factor inputs of production. The techniques employed also lend support to the trend analysis of factor intensity indicators carried out for the period 1963 to 1972. In an attempt to classify the industries based on the intensiveness of factor inputs, the industry groups were ranked and the trend of these indicators over time have been analyzed. The interrelationships between factor intensity indicators have been evaluated graphically to show the directional movement of various industry groups. This helps identify industry subgroups which may be using a scarce resource intensively and heading toward an undesirable range of production. Such identification of industry groups would help policymakers with regard to choice of technology (used in the broader sense of the term to include various factor inputs of production such as capital, labor, energy, and materials) that would optimize the country's use of resources. An effort in this direction has not been made to date, particularly in developing nations.

This study also focuses on estimating the degree of substitution between fuel and nonfuel inputs in the production process in response to price changes on lines similar to those of Williams and Laumas (1980). The uniqueness of this study lies in exploring the possibilities of substitution between different fuels, a subject which has not been explored in detail in India, or for that matter, in developing nations in general. This is a subject of special interest since the results of the study can help in suggesting conservation possibilities in the manufacturing sector with respect to energy and other resource inputs by determining substitution possibilities.

Layout of the Report

This report describes the results of an econometric estimation involving production relationships for the manufacturing industries of India. Our approach has been to specify and estimate relationships for different industry groups at the disaggregated level, since the characteristics of energy demand vary considerably across industries. Chapter 2 describes the methodology adopted to study the major trends in the use of factor inputs with respect to time and industry subgroups. The first subsection of chapter 2 covers the methodological approach with a discussion of the three statistical techniques used (rank correlation, correlations of concordance, and correlation coefficients), the econometric analysis employed to study the major trends, and a survey and discussion of the limitations of some important studies which have appeared in the literature. The second subsection of chapter 2 describes the specifications of the translog model adopted and the estimation technique employed and elasticity calculations.

Chapter 3 contains a detailed note on the availability of data used in the study. We have included a description of data collected and computed along with their definitions. This chapter also provides a description of the various classifications of industry groups covered in the study.

The results of the study are presented in chapter 4. The relative changes in the structure of production over time are analyzed using the various intensity indices developed in the study. Individual sections cover the analysis of the major trends in use of factor inputs, and the analysis used in identifying the energy intensity of production over time and determining the interaction and interrelationships among the various parameters considered. A detailed analysis of the estimates of elasticities of substitution among energy, capital, labor, and materials is included. We also analyze the elasticities of total energy demand, as well as own and cross-price elasticities for individual fuels consumed in each of the industries.

Summary results are provided in chapter 5, along with a detailed analysis of the substitution possibilities in the manufacturing sector and and outline of the policy imperatives.

Chapter 2

METHODOLOGY

Approach

The industry groups to be studied correspond to the census sector in the Annual Survey of Industries (ASI). We first collected data covering the four factors of production: capital, labor, energy, and materials consumed. Data collected also included the contribution of various industry groups to national income, output levels, and other indicators of production. A detailed note on the data available and used in this study appears in chapter 3 along with the corresponding sources.

Using data from 1963 to 1971, we have constructed various intensity indices for the inputs (capital, labor, energy, and materials consumed) for each of the different industry groups covered. These are essentially ratios of expenditure on a particular input to the value added by manufacture. For example, fixed capital employed per unit value added by manufacture has been termed 'fixed capital intensity.' Similar computations were made for the total value of individual fuels, and indices were developed with the value of materials consumed and the total number of laborers employed in manufacture for each of the industry groups.

A principal objective of this exercise was to arrive at some conclusions concerning the trends in energy consumption per unit of value added, labor and capital employed, etc., in various industry groups. Using value added by manufacture as the measure of total output avoids the double counting of inputs and outputs. The output from one sector is often the input of another sector, and, therefore, the true measure of industrial activity is the value added in manufacture. Further, any externalities which reduce or enhance production will be reflected in the value added,

since this is calculated as the difference between the gross value of output and the gross value of input.

In order to study the energy intensiveness of production both with respect to its costs as well as its physical consumption, a composite index of energy (CIE) was developed for all industry groups. CIE represents the weighted index of energy cost to aggregate energy consumed per unit value added by manufacture. In addition, the ratios of energy cost by source to aggregate energy expenditure for manufacturing were examined and the price intensity of different forms of energy computed as the ratio of unit price of a particular fuel consumed in manufacturing to value added. The unit prices of different forms of energy were arrived at using data on energy consumption expenditure (in value terms) and quantity consumption (measured in original units of consumption) for various industry groups, since the extent of energy consumption varies across industries depending on the nature of the process. The relative importance of different forms of energy for each industry group was investigated using the ratio of energy consumption by source to aggregate energy consumed. In this study we measure all energy quantities in quadrillion joules (10^{15} joules). The conversion factors used are presented in table 2-1.

Table 2-1. Conversion Factors

Type of fuel	Conversion factors
Coal	6,640 kilocalories/kilogram
Coke	5,000 " "
Fuelwood	4,750 " "
Charcoal	6,900 " "
Petroleum products	10,000* " "
	(approximately 8,000 kilocalories/kiloliter)
Electricity	860 kilocalories/kilowatt hour

*Arrived at by using the average specific gravity of petroleum products as equal to 0.8, since the reported data were all in liters.

Note: Mega or million = 10^6
Crore = 10^7
Giga or billion = 10^9
Quadrillion = 10^{15}
1 rupee = US$0.10

The technology choice confronting each industry group was identified through the intensity ratios of different factor inputs, considered in a dynamic framework. The nature of interaction between any two factor intensity indicators was analyzed using the graphical methods discussed in chapter 4. The factor indicators considered for this analysis include the interaction between the following:

- capital intensity versus labor intensity
- capital intensity versus energy cost intensity
- capital intensity versus materials costs intensity
- labor intensity versus energy cost intensity
- materials cost intensity versus energy cost intensity.

Factor Intensity and Rank Correlation

Examination of the relative positions of the industry groups with respect to factor input intensities would explicitly show the trends of various industry groups as well a indicate the change in technology as a function of the proportion of factors employed over time. To provide this clearer picture, the industry groups were ranked based on the following parameters: capital intensity (K/V), labor intensity (L/V), capital/labor ratio (K/L), materials cost intensity (M/V), energy cost intensity (F/V), energy (quantity) intensity (E/V), and the composite index of energy (CIE). They were ranked from one to sixteen, with one denoting the lowest rank and sixteen the highest industry group. Based on the ranks obtained using these ratios, a rank matrix was developed covering four years: 1963, 1966, 1969, and 1971. The statistical validity of association among different

sets of combinations of these parameters was tested using the Kendall coefficient of concordance, 'W,' commonly referred to as the 'W-test.'[1]

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1. The W-test is computed as follows (Siegal, 1956):

$$W = \frac{S}{\frac{1}{12} K^2 (N^3 - N)}$$

where S = sum of squares of the observed deviations from the mean of R_j, that is

$$S = \Sigma (R_j - \frac{\Sigma R_j}{N})^2$$

where R_j refers to the sum of ranks of the industry groups. We total the R_j and divide that sum by 'N' to obtain the mean value of R_j.

k = the number of sets of rankings, for example, the number of combinations of the parameters for which the degree of association is measured.

N = the number of entities ranked, for example, the number of industry groups ranked.

The W-test may be employed to suggest policy directions based on the association of different sets of combinations of the ratios estimated. For example, if we consider the ranking of a number of industry groups based on two parameters--say, capital intensity and labor intensity--and compute 'W' statistics, we find that the 'W' statistics lie between zero and unity. If W = 0, this indicates that the ranking based on these two parameters is completely random, and therefore that capital intensity and labor intensity for this set of industries are exactly opposite in relationship. On the other hand, if W = 1, this indicates a perfectly stable ranking for the parameters and implies that a capital intensive industry is labor intensive as well. For large samples (when N is greater that 7), 'W' follows the 'Chi-square' distribution with (N - 1) degrees of freedom. In our study, N = 16 (the number of industry groups ranked), and hence we calculated the Chi-square values as well as W values for the different combinations of ratios--namely, capital intensity, labor intensity, energy intensity, energy cost intensity, capital/labor ratios, and materials cost intensity.

To further investigate the general implications inferred using the W-test for the industry groups as a whole, the rankings calculated based on these ratios have been intercorrelated and analyzed for the years 1963, 1966, 1969, and 1971. The statistical hypothesis that the rank correlations of the parameters are significantly different from zero was tested through the estimation of the well known 't-statistic' at 5 percent and 1 percent levels of significance or 95 percent and 99 percent levels of confidence, respectively.

Correlation Coefficients

At the next stage, the interaction and interrelationships between factors of production were studied through an analysis of intercorrelation among various parameters, conducted for each of the industry groups included in the study. Analysis of this kind gives an aggregated picture of the trend of the parameters and the nature of relationships existing between them over the time period. The sensitivity of energy use to price changes and the extent of directional impact that the prices of different forms of energy have on consumption have also been assessed using estimated intercorrelations of energy intensity, energy cost intensity, and the composite index of energy. The price intensity of different forms of

energy studied earlier were used to support the correlations estimated at the aggregate level of energy. Here again, 't-statistics' computed at 5 percent and 1 percent levels of significance show that the correlations are significantly different from zero within 95 percent and 99 percent confidence limits.

Econometric Analysis

In the second phase of the study, econometric estimations of transcendental logarithmic price possibility frontiers have been carried out for the various industries individually, both for aggregate inputs (capital, labor, aggregate energy and materials), and for the different fuels. Pooled data were used for various states covering the period 1963-64 to 1973-74. This step attempted to measure the extent of substitution among the inputs, and to measure the effects of relative price changes on energy consumption.

In the past, many economic systems have been analyzed on the basis of production functions with certain restrictive features. In earlier studies, the Cobb-Douglas production provided a simple, maintainable hypothesis with the facility of its input exponents adding up to unity and a unitary elasticity of substitution. Magnus (1979) used the generalized Cobb-Douglas production function in estimating substitution between capital and labor inputs in Dutch manufacturing. Murthy and Shastry (1957) and Dutta (1955) also estimated Indian production functions in the Cobb-Douglas form. The only feature under investigation in these studies was the question of returns of scale estimated as appropriate parameters using aggregate data on production and other variables.

The discovery of theoretically and empirically and more representative production functions embracing a wide variety of hypotheses resulted in the widespread use of another production function, namely, the constant elasticity function (CES), which includes both Cobb-Douglas as well as the Leontief production functions as special cases. Examples of studies using the CES method include Diwan and Gujarathi (1968), Shankar (1970), and Kazi (1976). The majority of these studies reveal substitution elasticities greater than unity in manufacturing. Nevertheless, the elasticity of substitution of parameters in the CES production function is not variable along an isoquant, although they can take different values for different

industries. This aspect of the CES production function imposes a constraint on productivity relationships.

The variable elasticity of the substitution production function or homothetic production function overcomes this defect of the CES, as it explicitly permits the capital/labor ratio to be an explanatory variable. Furthermore, with energy acquiring importance as a factor of production, recent studies have sought to account for the substitution of energy with other inputs. There has been a great increase in interest in the possibilities for substituting energy for the nonenergy inputs in the manufacturing sectors of both industrialized and developing nations. Numerous studies have appeared on the long-run response of energy demand to changing prices and other economic variables. The main approach adopted by researchers in the estimation of the production function and substitution responses is the 'transcendental logarithmic price possibility frontier.' The price possibility frontier is a transcendental function of the logarithms of the prices of inputs. This was first introduced by Christensen, Jorgenson and Lau (1975) and later used extensively by Berndt and Wood (1975), Pindyck (1980), and others (see, for example, Fuss, 1977; Griffin and Gregory, 1976; and Halverson, 1977) in studying the structure of production.

An alternative method of estimating interfuel substitution is the 'multinominal logit model,' as done for the Canadian economy by Fuss, Hyndman, and Waverman (1977). The translog utility function, however, is preferable because the estimates of cross-price and own-price elasticities are restricted in the multinominal logit model and not so in translog models. Furthermore, in logit models, estimates obtained become inefficient when there are zeros in the share data. Hence, in current literature there is an extensive use of translog models as compared to logit models.

A backdrop to our study is provided by reviewing and reporting on some of the earlier studies which used translog functions covering the manufacturing sector of various countries, particularly developed countries. Studies of energy substitution in the U.S. economy include Berndt and Wood (1975), Hudson and Jorgenson (1976), Vermetten and Planting (1953), Halverson (1977), Halvorsen and Ford (1978), and Field and

Grebenstein (1980). Apart from these, there are numerous other studies available in the literature.

A number of these studies report similar results. Berndt and Wood (1975) empirically tested a translog cost function with the four factor inputs (capital, labor, energy, and materials) for U.S. manufacturing using time series data for the 1947-1981 period. The study provides evidence of limited possibilities for substitution between energy and nonenergy inputs. In its findings, the study concludes that energy and labor are slightly substitutable, and energy and capital are complementary. In one of his later publications (1979), Berndt provides a common analytical framework for engineering and econometric evidence and reconciles the engineering evidence of capital-energy complementarity with the econometric evidence. Using quite similar data and a different estimation procedure, Hudson and Jorgenson (1974) estimate a translog cost function for the U.S. manufacturing sector as part of their input-output matrix for their long-range energy model. This study also concludes that energy does in fact substitute for other inputs, and in particular that energy is a substitute for labor and a complement for capital. Similar results are obtained by Fuss (1977) using time-series data for Canadian manufacturing pooled by region, and Magnus (1979), using capital, labor, and energy time-series data for Dutch manufacturing.

The results of these studies do not always confirm each other, however. In a study using capital, labor, and energy time-series data for the manufacturing sector pooled by the member countries of the Organization for Economic Cooperation and Develoment (OECD), Griffin and Gregory (1976) report on energy-capital substitutability. They conclude that in the short run higher energy prices would induce an increase in labor and material inputs and a corresponding reduction in the utilization of capital since for the existing capital equipment, the energy input per hour of capital service is likely to be fairly constant. In other words, short-run cost functions are likely to show energy, labor, and materials to be substitutes, and energy and capital as complementary. On the other hand, in the long run, capital and energy may be substitutes since new equipment could be designed to achieve energy efficiency but at greater capital costs. Robert Pindyck (1979), in his study also based on international pooled data, reports on energy-capital substitutability. Similarly, using

cross-sectional data on capital, two types of labor, and three types of energy by state for eight industries, Halvorsen and Ford (1978) find evidence of either significant energy-capital substitutability or insignificant complementarity.

In most of these studies mentioned above, the differences that have generated the greatest controversy are in the relationship between capital and energy. Griffin and Gregory (1976) suggest one reason for these different empirical findings is that their study as well as studies by Pindyck (1979) and Halvorsen and Ford (1978) were based on cross-sectional data, while the studies by Bernd and Wood (1975) and Berndt and Jorgenson (1973) were time series investigations. Cross-sectional analysis generally reflects long-run adjustment possibilities while time series data yield short-run estimates, so the discrepancy might be resolved if energy and capital are treated as short-run complements but as long-run substitutes.

The different ways of treating the capital input in these studies also contributes to arriving at divergent results. Griffin and Gregory (1976) and Fuss (1977) follow the earlier procedure of using value added to estimate the cost of capital (cost of capital equals value added less payroll). On the other hand, Berndt and Wood (1975) question the validity of the value added approach, since both Leontief and Hicksian aggregation are violated. Hence, they used another approach--'service price'--in which the residual difference between nonlabor value added (value added less payroll) and the service cost of reproducible capital (quantity of physical capital times service price) are used to estimate the cost of capital. In other words,

cost of capital = (value added - payroll) -
(quantity of physical capital x service price)

The service price approach accounts for a large proportion of the total capital cost, whereas the findings of the value added studies would be dominated by the presence of working capital. Thus the different results could in part be due to the fact that two quite different types of capital inputs are involved. These two forms of capital--physical capital and working capital--behave in different ways, at least as regards their relationship with energy inputs.

A recent study by Field and Grebenstein (1980) of the U.S. manufacturing sector added yet another dimension to the treatment of capital. They take into consideration the prices of physical and working capital separately along with the prices of labor and energy to explore the behavior of these factor inputs. Of particular interest in this study are the cross-elasticities of physical and working capital with energy inputs. For seven sectors of this study, energy and physical capital showed complementarity, but in no sector did they show substitutability. The results for elasticities of working capital and energy were just the opposite, in that five sectors showed a significant indication of substitution between energy and working capital, and in no sector did working capital and energy appear complementary to each other.

In summary, the conflicting evidence from econometric studies regarding energy-capital substitution might be due to (1) differing data sets and approaches to measuring input quantities and prices, (2) varied treatment of excluded inputs, and (3) distinctions between short-run and long-run elasticities.

There are also studies using translog normalized profit functions where the interfuel substitution in steam electric power generation has been studied in order to decide on the fuel choice in existing power plants (see, for example, Atkinson and Halverson, 1976). Yet another interesting area where the translog production function and cost function are explicitly used is to find out (1) whether natural products are strictly complementary in production with either capital or labor, and (2) whether resource products are typically less substitutable with capital than with labor.

The study conducted by Humphrey and Moroney (1975) provides evidence to this effect. The study investigates the degree to which capital and labor may be substituted in production for a resource product aggregate, which is regarded analytically as a third explicit factor of production. The authors have constructed for each manufacturing industry an input aggregate of nineteen natural resource products used in production. The list of these resource products are documented in the study. The evidence in this paper suggests that labor and, to a lesser degree, capital are substitutable for natural resource products among most of the resources-using product groups in American manufacturing.

Jorgenson and Fraumeni (1981) analyzed the rate of sectoral technical change and the distribution of the value of sector output in terms of possibilities for substitution among capital, labor, energy, and materials, (and inputs and changes in these substitution possibilities over time) using a transcendental logarithmic price possibility frontier for the U.S. economy. The majority of industries in their study showed nonnegative elasticities of the shares of capital with respect to the price of labor, indicating that the shares of capital do not decrease with an increase in the price of labor in all these industries. The study also showed that the shares of energy do not decrease either with the price of capital or with the price of materials for most of the industries and that the shares of materials do not decrease with the price of capital for all the industries.

A somewhat different and broader framework for substitution possibilities is offered by Lakshmanan, Anderson, Jourabchi, and Chaubey (1980) in one of their recent studies. The study highlights the importance of regional variation in price responsiveness and factor substitution in a multiregional framework. It also emphasizes the need to know more about regional factor supply, vintage, capacity utilization, etc., in order to interpret the spatial patterns of regional interfactor and interfuel distributions. The study, besides arriving at conclusions of strong complementarity and weak substitutability of capital and energy for different industry groups, also makes a comparison of the various states of the United States and several Western European countries.

In order to measure the extent of energy substitution for the Indian economy, Noel Uri (1974) applied a translog price possibility frontier to a pooled sample consisting of major sectors (such as agriculture, transport, mining and quarrying, and manufacture). The results indicate that relative changes in energy prices have significant effects on energy consumption. Williams and Laumas (1980) examined the substitution possibilities among energy inputs and other nonenergy factors of production in response to price changes in India's manufacturing industries. For most industries in the study, factors other than labor exhibited a high degree of substitution with energy, indicating that lack of energy alone cannot be a severe bottleneck to the continued growth of India's manufacturing sector. Their conclusion throws light on the possibility of substituting energy with other nonenergy factors of production.

This review of current literature indicates that specific information regarding substitution among capital, labor, energy, and materials, and among major energy inputs is not yet available for the Indian manufacturing sector. Indeed, no systematic study has, to our knowledge, been attempted to link the two-stage optimization process, that is, optimizing the mix of fuel that makes up the energy input, and then optimally choosing quantities of capital, labor, energy, and materials. Accordingly, our objective is to investigate these relationships using, first, an explicit four-factor input production function and, second, a model of constrained cost minimization. The specification of the translog models adopted and various assumptions made for the model are described in the following section. The technique employed for estimating the share equations derived from the models is principally the method of perfect least squares (PLSM). The estimation procedure and the methodological issues involved in estimating are dealt with the detail in subsequent sections. Allen's own and cross-price elasticities of substitution for the inputs, and partial price elasticities of different forms of energy have been calculated using the estimated coefficients of the respective share equations.

Econometric estimation was carried out for seventeen major industries covering the periods 1963-1969, 1970-1974, and 1963-1974. The results were compared across industries in order to analyze the impact of energy price changes on energy consumption, and to study the nature of factor substitution in the manufacturing sector.

The methodology adopted for this study consisted of the following separately identified, but interrelated steps:

Part 1, Step 1: Collection of data for the different industry groups from the census sector of the ASI on the four factors of production--capital, labor, energy, and materials--and collection of data on output levels, value added, and other economic indicators of production.

Step 2: Computation of factor input intensity and other ratios such as capital/labor ratios, composite index of energy, weighted costs of different forms of energy, proportion of different forms of energy consumed in manufacturing, and price intensity of energy for different industry groups.

Step 3: Evaluation of interaction between factors using the intensity ratios over the years studied.

Step 4: Ranking of industry groups based on the intensity ratios and other parameters, and identifying the trends in the movements of these parameters measuring the degree of association among different combinations of ratios using the concordance the coefficient, 'W'.

Step 5: Rank correlation of the rankings calculated for 1963, 1966, 1969, and 1971, and showing statistically the significance of the rank correlations using t statistics.

Part 2: Intercorrelation of factor input intensity ratios and other parameters using t statistics to measure the significance of correlations.

Part 3: Step 1: Selection of major industries from within the industry groups based on different intensities of production, and collecting data for these major industries on a disaggregated level pooled over various states.

Step 2: Econometric estimation of the share equations derived from both aggregate production functions involving capital, labor, energy, and materials, and energy submodels involving different forms of energy using the method of perfect least squares (PLSM).

Step 3: Estimation of Allen's partial elasticities of substitution among the inputs, and partial price elasticities of different forms of energy.

Model Specification

In our model we hypothesize that gross output (Y) of goods and services is an aggregated function of four inputs--capital (K), labor (L), energy (E), and materials (M). The model assumes that production is characterized by constant returns to scale and that technical change affecting the four inputs is Hicks-neutral. Second, we assume that the production function is weakly separable in the major categories of capital, labor, materials, and all energy. This implies that the marginal rates of substitution between individual fuels are independent of the quantities of capital, labor, and materials. Finally, we assume that capital, labor, aggregate energy, and materials are homothetic in their components--in particular, that the energy aggregate is homothetic in its fuel inputs: coal (F_1), coke (F_2), petroleum products (F_3), fuel oil (F_4), and electricity (F_5). As shown by Pindyck (1979) and others, the second and third assumptions above help the two-stage optimization process, that is, to optimize the mix of fuels that

make up the energy input, and then optimally choose quantities of capital, labor, energy, and materials. Hence, under these assumptions, the production function is:

$$Y = f[K, L, e(F_1, F_2, F_3, F_4, F_5), M] \quad (1)$$

where:

e = a homothetic function of five fuels.

Determining factor prices and output levels exogenously, the production structure described by equation (1) can alternately be expressed as a cost function:

$$C = G[Y, P_K, P_L, P_E (P_{F_1}, P_{F_2}, P_{F_3}, P_{F_4}, P_{F_5}), P \quad (2)$$

where:

C = total cost

P_K, P_L, P_E, P_M = price of capital, labor, energy, materials, respectively

P_E = an aggregate price of energy, that is, a function that aggregates the fuel prices P_{F_i}

Equation (2) can be estimated in stages (for details, see Pindyck, 1979 and 1980):

1. First, represent the price of energy (which is the unit cost of energy to a producer choosing fuel inputs) by a homothetic translog cost function with constant returns to scale. Estimation of the share equations implied by this cost function gives us the own- and cross-partial price elasticities for the different forms of fuels.

2. Next, we represent the cost of industrial output by a nonhomothetic translog function. Estimation of the share equations implied by this cost function gives us the elasticities of

substitution and the own- and cross-price elasticities for capital, labor, aggregate energy, and materials.

Now we have the cost function specified:

$$C = G[Y, P_K, P_L, P_E (P_{F_1}, P_{F_2}, P_{F_3}, P_{F_4}, P_{F_5}), P]$$

$$= G(Y, P_K, P_L, P_E, P_M) \quad (3)$$

$$P = g(P_{F_1}, P_{F_2}, P_{F_3}, P_{F_4}, P_{F_5}) \quad (4)$$

for the five different fuels.

Thus C is stated as two separate submodels, one in which capital, labor, aggregate energy, and materials are determined (equation 3), and a second submodel in which specific energy inputs are determined (equation 4).

Our approach in specifying the translog price possibilities frontier for the energy submodel (equation 4) is similar to that used by Uri (1979) in estimating the demand for energy in Indian manufacturing. The function can be expressed:

$$\log P_E = \alpha + \sum_i \alpha_i \log P_i + \frac{1}{2} \sum_i \sum_j \beta_{ij} \log P_i \log P_j \quad (5)$$

for i, j = 1, 2, 3, 4, 5 (representing five different fuels: coal, coke, petroleum products, fuel oil, and electricity, respectively).

P_E = the price of energy

P_i s = the price of each energy input

The translog cost function adopted in estimating the aggregate function (equation 3) is similar to that used by Pindyck (1979):

$$\log C = \alpha_0 + \alpha_y \log Y + \sum_i \alpha_i \log P_i + \frac{1}{2} \gamma_{yy} (\log Y)^2$$

$$+ \frac{1}{2} \sum_i \sum_j \gamma_{ij} \log P_i \log P_j + \sum_i \gamma_{yi} \log Y \log P_i \quad (6)$$

for i,j = K, L, E, M, representing capital, labor, energy, and materials

C = total cost
Y = output
P_i = the factor price of the inputs

In order to correspond to a well-behaved production function, a price possibility frontier must be homogenous of degree one in input prices, that is, for a fixed level of output, total expenditures must increase proportionately when all input prices increase proportionately. This implies certain restricted relationships among the parameters of both the energy price possibility frontier (equation 5) (see Christiansen, Jorgenson, and Lau, 1971 and 1973; and Fuss, 1977). That is, for the energy price possibility frontier (equation 5),

$$\sum_i \alpha_i = 1$$

and

$$\sum_i \beta_{ij} - \sum_i \beta_{ij} = \sum_i \sum_j \beta_{ij} = 0$$

where:

i, j = the five fuel inputs[2]

Similarly, for the aggregate factor input translog cost function (equation 6), the restrictions are as follows:

$$\sum_i \alpha_i = 1$$

and

$$\sum_j \gamma_{ij} = \sum_j \gamma_{ij} = \sum_i \sum_j \gamma_{ij} = 0$$

---

2. It is true that the condition $\sum_i \sum_j \beta_{ij} = 0$) is superfluous at this stage, and this condition automatically follows from the earlier condition. However, it has been specified to ensure vector addition by row and column of the parameters together becoming equal to zero.

where:

$i, j = K, L, E, M$

The heterogeneity condition (positivity condition) for a well-behaved production function required nonnegative input levels and hence nonnegative cost shares, that is, the cost shares must be positive. This is ensured on the basis of the parameters, and is imposed on the translog cost functions of both energy share equations and aggregate input share equations.

Differentiating both the energy translog price possibility frontier (equation 5) and factor input cost function (equation 6) with respect to prices and applying Shepard's Lemma (Diewart, 1971), the derived demand function for both energy inputs and factor inputs of production are found. The share equations for the energy cost function are given by:

$$S_i = \frac{\partial \log P_E}{\partial \log P_i} = \frac{P_i X_i}{\sum_j P_j X_j}$$

that is,

$$S_i = \alpha_i + \sum_j \beta_{ij} \log P_j \qquad (7)$$

where:

$i,j = 1, 2, 3, 4, 5$, representing five forms of fuel
S_i = the cost share of ith fuel

and for the factor input cost function,

$$S_i = \frac{\partial \log G}{\partial \log P_i} = \frac{P_i X_i}{C}$$

that is,

$$S_i = \alpha_i + \gamma_{yi} \log Y + \sum_j \gamma_{ij} \log P_j \qquad (8)$$

where:

S_i = cost share of ith input
$i, j = K, L, E, M$

Note that the aggregate factor input cost function specified (equation 6) in nonhomothetic, and may have nonconstant returns to scale. The cost function would be homothetic if it could be written as a separable function of output and factor prices. Thus the following parameter restrictions can be added to earlier restrictions to impose homotheticity:

$$\gamma_{yi} = 0 \text{ for each } i$$

and

$$\sum \gamma_{yi} = 0$$

The second and third assumptions of the translog production function (specified in the beginning of the next chapter) together are referred to as homothetic separability.

Weak separability of factor inputs--K, L, E, and M--from output Y here means that the marginal rates of substitution between individual inputs are independent of quantities of output. Weak separability of the (homogenous) factor input function in K, L, E, and M implies weak separability of the unit cost function in P_K, P_L, P_E, and P_M from output Y, and is specified by the condition that

$$\gamma_{yK} = \gamma_{yL} = \gamma_{yM} = 0$$

That is,

$$\gamma_{yi} = 0$$

With the above restriction imposed, the cost function could be written as a separable function of output and factor prices. Further, the consistent estimation of the share equations (equation 8) required the

exogeneity of both the prices P_j of inputs and output (Y). It is indeed reasonable to assume that factor prices are exogenous and it may be less valid to assume total output (Y) to be exogenous. Hence the restriction

$$yi = 0$$

Using this restriction, the share equations of factor inputs specified in equation 8 become:

$$S_i = \alpha_i + \sum_i \gamma_{ij} \log P_j \qquad (9)$$

where:

i = the cost share of the ith factor input similar to the share equations of the energy submodel.

The aggregate factor input cost function (equation 6) is also homogenous if the elasticity of cost with respect to output is constant. This implies the following restriction:

$$yy = 0$$

Consequently, the share equations of both the energy cost function (equation 7) and factor inputs of production (equation 9) were estimated imposing the restriction of linear homogeneity and symmetry in cross-price terms and by using the method of perfect least squares (PLSM). Estimation procedure of PLSM and the methodological issues involved in estimation of the share equations of both energy inputs and aggregate factor inputs of production are discussed later.

Uzawa (1962) has shown that Allen's partial elasticities of substitution between energy inputs are given by:

$$_{ij} = (g \times g_{ij})/g_i \times g_j$$

where g indicates partial differentiation of the energy submodel (equation 4) with respect to energy prices; that is,

$$g_{ij} = \frac{\partial^2 g}{P_i \quad P_j}$$

and

$$g_i = \frac{g}{P_i}$$

Corresponding to this, the partial differentiation of the aggregate production function (equation 3) with respect to input prices gives:

$$_{ij} = \frac{G \times G_{ij}}{G_i G_j}$$

where

$$G_{ij} = \frac{\partial^2 G}{P_i \quad P_j}$$

and

$$G_i = \frac{G}{P_i}$$

The partial elasticities ($_{ij}$ or $_{ii}$) are invariant with respect to the ordering of both fuel inputs and factor inputs. That is,

$$_{ij} = \ _{ji}$$

Reformulating Allen's partial elasticity of substitution expressed for the energy submodel, one obtains:

$$_{ii} = \frac{(\ _{ii} + S_i^2 - S_i \ )}{S_1^2}$$

$$\sigma_{ij} = \left(\frac{\beta_{ij} + S_i S_j}{S_i S_j} \right)$$

where $i \neq j$.

Similarly, for the translog cost function of factor inputs, one has:

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

$$\sigma_{ij} = \frac{(\gamma_{ij} + S_i S_j)}{S_i S_j}$$

where $i \neq j$, for $i, j = K, L, E, M$, representing capital, labor, energy, and materials.

We have calculated Allen's partial elasticities of substitution for energy inputs using the fitted cost shares of the parameters at the means.

The elasticities of substitution are related to price elasticities of demand (n_{ij}) for energy inputs and factor inputs, and thus the own- and cross-price elasticities of demand are given by:

$$n_{ii} = \sigma_{ii} S_i$$

and

$$n_{ij} = \sigma_{ij} S_j$$

where $i \neq j$ and where it is assumed that

$$\sum_j n_{ij} = 0$$

The estimated values of the parameters β_{ij}'s and γ_{ij}'s obtained from the share equations (7) and (9) and the average values of the cost share data have been used to calculate Allen's partial elasticity of substitution

and own- and cross-price elasticities for the periods 1965-1969, 1970-1974, and 1965-1974. The effects of relative changes in energy prices on energy consumption and the extent of substitution among aggregate factor inputs for the various industries over these periods will be analyzed in a later section.

Estimation Technique and Methodological Issues in Estimation

A comprehensive review of the literature concerning the estimation of translog models of energy demand and aggregate input demand reveals that most researchers have employed either iterative (Zellner's) procedure or iterative three-stage least squares in order to arrive at the parametric estimates of the share equations of the model (see, for instance, Berndt and Wood, 1975; Field and Grebenstein, 1980; Griffin and Gregory, 1976; Halverson, 1977; Lakshmanan, Anderson, Jourabchi and Chaubey, 1980; Pindyck, 1980; and Williams and Laumas, 1980). There is also evidence in the literature of the use of two-stage least squares employed by Humphrey and Moroney (1975) and Moroney and Toevs (1977) to estimate the system of equations. These methods have built-in sophistication in terms of their ability to maintain enough stochastic specifications for which the error terms are heteroscedastic, autocorrelated both across time and across states with each equation, and correlated across equations in the system. However, there is a degree of arbitrariness always involved in such specifications. For example, the use of additive error terms on the share equations may itself be a misspecification. Though these errors are added to the first order conditions of a cost-minimization process, they need not result in additive error terms in the translog share equations. Thus there is an inherent degree of arbitrariness, and this makes the use of a more simple error structure more appealing, such as in the studies by Pindyck (1980), Fraumeni and Jorgenson (1982), Berndt and Wood (1975), and Berndt (1976).

Our approach has been to strike a balance between the possible gain in efficiency resulting from a complete specification of the model and lower computational cost. In our search for an alternative econometric approach, we adopted the method of perfect least squares (PLSM) as yet another approach to solving a system of equations while maintaining the complete

specification of the model. We have found this method to be much simpler than other models. The same procedure is applied to the particular case of share equations of both energy demand and aggregate input demand. We briefly discuss below some of the methodological issues involved in the estimation of our share equations.

Estimation Techniques: The Method of Perfect Least Squares (PLSM)

The perfect least squares method is an extension of the ordinary least squares method (OLSM) with the specific advantage of applicability to the system of simultaneous equations as well. The method has been designated as perfect least squares by the principal formulators (Misra and Handa, 1979) because there is no other method known to the authors that provides lower magnitudes of optimality criterion. That is, the PLS estimator is the only estimator that provides the smallest error sum of squares in the general case since the interdependence among the elements of the error vector are considered in a functional sense. Such a consideration will hold true irrespective of whether the data are a sample, the population or part of the population, and whether the sample is with or without replacement. This is true because of the inherent dependence exhibited in the functional dependence while minimizing the error sum of squares. The method holds good for data using any sampling or census method. The method is attractive for its ease of application. Also, this method has the advantage of direct applicability to dynamic models of all kinds since it is capable of incorporating in itself the dependence among the observations.

Before enumerating the various interconnected steps, we give below the notations used to describe the estimation procedure.

In the system of equations, we have ´nf´ equations, each having ´nf´ number of independent variables (number of equations equals the number of independent variables), and ´n´ number of observations for each variable (sample equals ´n´). That is,

n = number of observations (sample)
nf = number of equations, or the number of independent variables in each equation of the system

$nf + 1 = n\gamma$ = number of variables in each equation including the constant term.

Let us denote our general linear model as

$$Y_i = \beta_i X_i + u_i$$

Where:

Y_i = the independent variable of vector length 'n'
X_i = the independent variables, the matrix of n x n
u_i = a vector of length 'n'
β_i = a vector of length 'n'

The steps of the estimation procedure are:

Step 1: Applying OLS procedure of estimation, the regression coefficients (β_i) of the independent variables of each equation of the given system of equations are determined.

$$\beta_i = (X_i^1 X_i)^{-1} X_i^1 Y_i$$

Step 2: The estimated values ($\hat{Y}_i$) of the dependent variables for 'n' observations of each equation are determined.

Step 3: The error vector of length 'n' for each equation of the system is constructed.

$$u_i = Y_i - \hat{Y}_i$$

Step 4: The 'S' matrix of 'nf X nf' is constructed such that

$$S_{ij} = \frac{u_i \quad u_j}{n}$$

where S_{ij} is an element of 'S' matrix

$i = 1, 2, \ldots nf$
$j = 1, 2, \ldots nf$

Step 5: The inverse of each element in 'S' matrix is determined.[3]

Step 6: Using the 'S' inverses of 'S' matrix, the V matrix is constructed such that

$$V_{ij} = I_{nxn} \times S_{ij}^{-1}$$

for

$$i = 1, 2, \ldots nf$$
$$j = 1, 2, \ldots nf$$

---

3. For example, in the case of input of four fuels, that is, nf = 4,

$$S = \begin{bmatrix} S_{11}^{-1} & S_{12}^{-1} & S_{13}^{-1} & S_{14}^{-1} \\ S_{21}^{-1} & S_{22}^{-1} & S_{23}^{-1} & S_{24}^{-1} \\ S_{31}^{-1} & S_{32}^{-1} & S_{33}^{-1} & S_{34}^{-1} \\ S_{41}^{-1} & S_{42}^{-1} & S_{43}^{-1} & S_{44}^{-1} \end{bmatrix}$$

V is a matrix of $n_1 \times n_1$ where $n_1 = n \times nf$, and V_{ij} is a matrix of $n \times n$ such that V_{ij}'s will be $nf \times nf$ in the matrix V.[4]

---

4. $V_{ij} = I_{nxn} \times S_{ij}^{-1}$

for all

$i = 1, 2, \ldots nf$
$j = 1, 2, \ldots nf$

Denoting $S^{-1} = P$,

$$V_{ij} = I_{nxn} \times P_{ij}^{-1}$$

For example, when n = 5,

$$V_{11} = \begin{bmatrix} P_{11} & 0 & 0 & 0 & 0 \\ 0 & P_{11} & 0 & 0 & 0 \\ 0 & 0 & P_{11} & 0 & 0 \\ 0 & 0 & 0 & P_{11} & 0 \\ 0 & 0 & 0 & 0 & P_{11} \end{bmatrix}$$

and

$$V = \begin{bmatrix} V_{11} & V_{12} & V_{13} & V_{14} & V_{15} \\ \vdots & & & & \\ V_{51} & V_{52} & V_{53} & V_{54} & V_{55} \end{bmatrix}$$

Step 7: The complete system model is specified in terms of 'n' observations on each one of the endogenous Y and predetermined X variables. Rewriting the nf equations together, we get

$$Y^* = X^* \quad {}^* + u^*$$

where

$$Y^* = \begin{bmatrix} Y_1 \\ Y_2 \\ \cdot \\ \cdot \\ \cdot \\ Y_{nf} \end{bmatrix}$$

$$X^* = \begin{bmatrix} X_1 & 0 & 0 & 0 & \cdots & 0 \\ 0 & X_2 & 0 & 0 & \cdots & 0 \\ 0 & 0 & X_3 & 0 & \cdots & 0 \\ \cdot & \cdot & \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdots & \cdot \\ 0 & 0 & 0 & 0 & 0 & X_{nf} \end{bmatrix}$$

and

$$\beta^* = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \cdot \\ \cdot \\ \beta_{nf} \end{bmatrix}$$

Step 8: Now, using the constructed matrices of X^*, Y^*, and V, the PLS estimator $\tilde{\beta}^*$ - unrestricted can be specified as follows:

$$\tilde{\beta}^* = (X^{*\prime} V X^*)^{-1} (X^{*\prime} V Y^*)$$

where

β^* = the PLS estimator without any restrictions of the parameters. $\tilde{\beta}^*$ will be of the order of nf x nf.

Step 10: Then, we compute the PLS estimator $\hat{\tilde{\beta}}^*$- restricted. The formula for it is specified as follow:

$$\begin{bmatrix} \hat{\tilde{\beta}}^* \\ \\ \lambda \end{bmatrix} = \begin{bmatrix} X^{*\prime} V X^* & R^{\prime -1} \\ \\ R & 0 \end{bmatrix} \begin{bmatrix} X^{*\prime} V Y^* \\ \\ r \end{bmatrix}$$

where R is the restricted matrix of the order of NR x NB, where

NW = the number of restrictions posed
NB = nf x nf
r = an array of value specifications imposed for the restricted matrix of order NR
λ = a working vector

In essence, the relationship between the PLS estimator $\hat{\tilde{\beta}}^*$- restricted and the restriction matrix is specified in the following manner:

$$R \hat{\tilde{\beta}}^* = r$$

that is,

$$\begin{bmatrix} R_{11} & R_{12} & \cdot & \cdot & \cdot & R_1 & NB & \hat{\tilde{\beta}}^*_1 & \gamma \\ R_{21} & R2_2 & \cdot & \cdot & \cdot & R_2 & NB & \hat{\tilde{\beta}}^*_2 & \gamma \\ \cdot & & & & & & & \cdot & \cdot \\ \cdot & & & & & & & \cdot & \cdot \\ \cdot & & & & & & & \cdot & \cdot \\ R_{NR\ 1} & R_{NR\ 2} & \cdot & \cdot & \cdot & R_{NR} & & \hat{\tilde{\beta}}^*_{NB} & \gamma_{NB} \end{bmatrix}$$

For instance, the restriction on the parameters is imposed in the following manner:

Let

$$\beta_1 + \beta_2 + \beta_3 = 15 \quad \ldots \quad \text{condition (1)}$$

$$\beta_4 + \beta_5 + \beta_6 = 20 \quad \ldots \quad \text{condition (2)}$$

$$\beta_7 + \beta_8 + \beta_9 = 10 \quad \ldots \quad \text{condition (3)}$$

$$\beta_1 + \beta_2 + \beta_3 + \beta_5 + \beta_6 + \beta_7 + \beta_8 + \beta_9 = 45 \ldots (4)$$

Then, the R matrix is written as

$$R = \begin{bmatrix} 1 & 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix} \quad \text{and } r = \begin{bmatrix} 15 \\ 20 \\ 10 \\ 45 \end{bmatrix}$$

<u>Note</u>: The fourth condition specified above is superfluous, and need not be given. However, it has been specified to ensure addition by row and column.

Chapter 3

DATA COLLECTION AND COMPUTATION

The Annual Survey of Industries (ASI) is the principal source of data on various aspects of the registered industrial sector in India. The Central Statistical Organization (CSO) is responsible for the publication of data on various aspects of industrial activity.

ASI covers two different levels. Units employing fifty or more workers and operated on power, and those employing 100 or more workers and operating without power are covered under what is called the "census sector." Other factories categorized as "noncensus sector" or "sample sector" are surveyed on a scientific sample basis.

The industrial classification adopted in the survey for classifying various factories is the National Industrial Classification (NIC) and a report of the ASI presents estimates at the three-digit level of this industrial classification.

The detailed data of the census sector are brought out in ten volumes with a complete breakdown of data at the state level. As far as the noncensus sector is concerned, the publication of results from this sector was discontinued after 1969. But publication of results from the factory sector continues. They are arrived at by adding the aggregates in the census sector to the corresponding estimates on the noncensus sector.

The data collected on the items from the census sector cover most of the major industry groups at the aggregate level, and for selected industries at the state level. Although it would be better to collect data from the factory sector in order to encompass all the registered factories of the country, the problem was that they do not include details on energy consumption in comparable units or by fuel, which are essential for a study focusing on interfuel substitution. However, the industries in the study

do belong to the major groups selected from the industrial classification. No reliability should have been lost even though data collection was restricted to the census sector alone, since these industries extend uniformly to both the census and factory sectors.

Detailed results for the census sector data are available only through 1971-72, so that our sample has been restricted to aggregate figures for the various industry groups modelled only up to 1972. Time series data were also collected covering various aspects of the industry groups covering the period 1963-64 to 1971-72 in order to identify the relationships between industry groups based on energy intensiveness of production and other parameters, to analyze the price sensitivity of the energy mix in manufacturing, and to establish the interrelationships among factor inputs.

The characteristics of specific forms of energy demand and aggregate input demand vary across industries. There are also significant variations in the price of energy across the same industry group in different states due to transportation costs, different tariffs, and variations in the fuel mix and technology employed. Hence, for the econometric estimation of the transcendental logarithmic price possibility frontiers for energy demand and aggregate input demand, a disaggregated framework was adopted. Data were collected at a disaggregated state level for the various major industries selected from the industry groups. The method employed was pooling time series and cross-sectional data to increase the size of the data set. This is the most valid approach to follow in order to capture the long-run effects of price changes on energy demand and aggregate input demand. Pooling the data also shows significant and sufficient variation in the input prices of both energy demand and aggregate input demand to enable us to estimate substitution possibilities between these inputs. In addition, unpublished data for all the major industries of the industry groups chosen for the year 1973-74 were made available by the CSO, thereby expanding the period covered from 1965-66 to 1973-74.

Table 3-1 lists the industry groups included in the study and the major industries belonging to each of these groups for which translog estimation of energy demand and aggregate input demand were carried out. Most of the major industry groups were covered except the machinery and metal products industries, which were omitted due to the lack of

aggregate data for some years. It was not possible to build up aggregate data for these industries since they cover a vast number of small industries, and because the industrial classification was changed in 1970. Sixteen major industry groups were covered for the first and second parts of the study, and in the third part, where econometric estimation of translog models of energy demand and aggregate input demand were carried out, seventeen major industries were selected from these sixteen industry groups, and disaggregated data were then collected for each.

The translog models break down production costs into expenditures on capital, labor, materials consumed, and energy, and break down energy expenditures into expenditures on individual fuels. The estimation of these models required data for capital, labor, materials, and energy prices, expenditure shares and quantities of different forms of energy used by the various industries. The ASI details different forms of capital used, labor employed, materials consumed (both in quantity and value terms) in manufacturing, and also reports on eight different forms of fuels that are consumed in each industry group, including coal, coke, coal gas, firewood, charcoal, petroleum products, fuel oil, and electricity. Data on petroleum products cover all forms including high sulfur distillate, low sulfur distillate, aviation fuel, and motor gasoline. Data on fuel oil include both furnace oil and other types of oils used in manufacturing. At the aggregate level, data pertaining to all eight forms of energy consumed and other economic indicators of production, such as output levels, value added by manufacture, and capital and labor employed, were collected in order to study the dynamics of manufacturing for the industry groups selected. For the econometric estimation of the translog models of energy demand, the data gathered on energy consumption included five major fuels: coal, coke, petroleum products, fuel oil, and electricity. The remaining three fuels were disregarded since their contribution to the overall energy consumption for these industries was found to be negligible, and hence computation of price elasticities for them would have no significant impact. Appendix A contains a detailed list of the data collected and their definitions.

Table 3-1. List of Industry Groups Covered

Sl. No.	Name of the industry group	ASI industry group code no.	Industries included in the group
1	2	3	4
1.	Sugar and gur	207	207.1.1, 207.1.2, & 207.2
	*Vacuum pan sugar factories	(207.1.1)	
2.	Tobacco manufacturing	220	220.1 to 220.6
	*Cigarette tobacco mfr.	(220.3)	
3.	Spinning, weaving, and finishing of textiles	231	231.1 to 231.9
	*Cotton textiles	(231.1)	
	*Jute spinning, weaving	(231.2)	
	*Woolen textiles	(231.3)	
4.	Other textile-related activities	232, 233, 239	232, 233, 239.1 to 239.9
	*Cotton ginning, cleaning and pressing	(231.1)	
5.	Paper and paper boards and products	271	271.1 to 271.7
	*Paper manufacturing for writing, printing and wrapping	(271.2)	
	*Paper boards & straw board	(271.4)	
6.	Rubber products	300	300.1 to 300.4
	*Rubber tires and tubes	(300.1)	
7.	Basic chemicals including fertilizers	311	311.1.1 to 311.1.3, 311.2.1, 311.2.2, 311.3 to 311.10
	*Inorganic fertilizers	(311.1.1)	
	*Inorganic heavy chemicals	(311.2.1)	
	*Organic heavy chemicals	(311.2.2)	
8.	Petroleum refineries	321	
9.	Miscellaneous products of coal and petroleum	329	
10.	*Cement (hydraulics)	334	
11.	Iron and steel	341	341.1 to 341.6
	*Iron and steel (metal)	(341.1)	
	*Iron and steel castings and forgings	(341.3)	

Table 3-1. (Cont.)

1	2	3	4
12.	Shipbuilding and repairs	381	381.1 to 381.2
13.	Railroad equipment	382	382.1 to 382.3
14.	Motor vehicles manufacture and repair	383	383.1 to 383.3, 384
15.	Aircraft manufacture	386	

*Major industries belonging to the respective industry groups for which econometric estimation of transcendental logarithmic possibility frontier of both energy demand and aggregate input demand have been carried out covering the period 1965-66 to 1973-74.

Construction and Computation of the Data Series Used in the Econometric Estimation

The data required for estimating the energy demand transcendental logarithmic price possibility frontiers are the prices and cost shares of the various energy inputs. Similarly, the estimation of aggregate input demand (KLEM) translog cost functions requires data on the prices and cost shares of the four inputs: capital (K), labor (L), energy (E), and materials (M).

Fuel Prices

Energy expenditure in the fuel submodel for the various industries was divided into expenditures on the five different forms of energy (coal, coke, petroleum products, fuel oil, and electricity). For some of the industries, only four forms of energy have been considered by excluding coke, which turned out to be negligible in the overall energy consumption. The quantities of fuels used by industry were all obtained from ASI publications (census sector). Fuel prices have been computed using expenditure values and their respective quantities as follows:

$$P_i = \frac{F_i}{E_i}$$

where:

P_i is the price of ith fuel input
F_i is the expenditure of ith fuel
E_i is the quantity (in the original units) of the ith fuel.

The fuel prices thus calculated relate to different units of energy. Using appropriate conversion factors, the unit of measurement for all energy quantity data were converted into quadrillion joules. In some earlier studies (Pindyck, 1979; Uri, 1979), the different forms of petroleum were treated under one heading as 'oil.' We have instead treated oil in two different forms, namely petroleum products and fuel oil, respectively. This was done mainly because the unit prices calculated for these two forms showed significant variations and hence, separate treatment was warranted to arrive at separate price elasticities and estimate the exact nature of price changes and related energy consumption.

Fuel Cost Share Data

Using the data collected for total energy expenditures and individual energy expenditures for each of the fuels, the fuel cost share data were computed as follows:

$$S_i = \frac{F_i}{\sum_i F_i}$$

where:

i = 1, 2, ...5 for five different fuels
S_i = the cost share of the ith fuel input
F_i = the expenditure of the ith fuel.

Price of Capital (P_k)

The measure of capital stock used in the analysis is the value of fixed capital at a given time. The price of capital services was assumed as 12 percent. Twelve percent was chosen as the social discount rate on fixed capital investments in our analysis for the following reasons:

1. The social discount rate, which is also the yield from marginal public sector investment of the economy, is estimated at around 12 percent. This discount rate is being effectively used as the social discount rate for project selection by the Government of India. The social discount rate also determines the quantity and timing of private sector investments so this rate is being used as a surrogate for the price of capital.

2. Alternate studies (Williams and Laumas, 1980; Pindyck, 1980; Halvorsen and Ford, 1978; and Lakshmanan and coauthors, 1980) assume that the price of capital is a function of the rate of interest on capital and the rate of depreciation. Depreciation is an accounting concept devised to allocate the one-time expenditure over the useful life of a project. Alternately, the role of depreciation is perceived as a statutory regulation in fixing the tax payments and there are different depreciation models applicable in different cases (see Pindyck, 1980; Halvorsen and Ford, 1978). Also in any developing economy, it is observed that the interest rates on long-term loans do not accurately reflect the cost of capital. (On many occasions, the interest rate is low compared to the cost of capital and the demand for these funds is far in excess of the supply.) It is also known that interest rates do not reflect the cost of capital when there is significant inflation in the economy, as the replacement cost keeps increasing while the interest is paid on 'cheap' loans obtained earlier. Thus any combination of those rates cannot be expected to reflect the cost or price of capital. Since the social discount rate is obtained by considering the second best option (which is the only feasible option), this study assumes the social discount rate, which is a nationally accepted parameter, as a surrogate for the price of capital.

3. The various approaches toward the estimation of opportunity cost of capital (OCC) in border prices are summarized below:

Using macro data:

Marginal Productivity of Capital: 'q'

$$\frac{\text{(Incremental output)}}{\text{(Capital)}} - \frac{\text{(Incremental employment)}}{\text{(Capital}} \times \frac{\text{Marginal productivity)}}{\text{of labor}} =$$

$$= \text{(in domestic prices)}$$

The above adjusted for variance in market and social prices (due to market distortions) equals

$$q \times \frac{SCF}{CF_k} = q^*$$

where:

SCF = standard conversion factor
CF_k = conversion factor for capital goods

q* x a = opportunity cost of capital in border prices (OCC).

Where ´a´ is the ratio of net to gross capital output ratios to account for the loss of productivity of capital.

A preliminary estimate obtained using a macro model indicates q* as 0.19 and the opportunity cost of capital as 0.12 (12 percent), which is the social rate of discount (SRD) used.[1]

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1. The computation of SRD using macro data (from Gupta, 1979) is as follows:

Incremental output capital ratio

$$\left(\frac{Y}{I}\right) = 0.25$$

Incremental employment capital ratio) to marginal productivity of labor) = 0.023

$$\left(\frac{L}{I} \times MP_L\right)$$

Therefore, marginal productivity of labor 'q' = 0.25 - 0.023 = 0.22.

Conversion factor for capital goods (CF_k) = 0.76

Standard conversion factor (SCF) = 0.66

Therefore, 'q' adjusted for variance between market and social prices.

$$q^* = q \times \frac{SCF}{CF_K} = 0.22 \times \frac{0.66}{0.76} = 0.19$$

Therefore, opportunity cost of capital (OCC) after accounting for usage of capital and rental charges is around 0.12 (12 percent).

Estimate of Accounting Rate of Interest (ARI)

For evaluation of public sector investments, Deepal Lal (1980) has arrived at an alternate estimate of the social rate of discount of 11 percent using the accounting rate of interest technique.

Social Rates of Return Using Effective Protective Rates

The weighted average of the social rates of return computed for fifty industries of the census sector of the Annual Survey of Industries using effective protective rates is 10 percent (Lal, 1975). However, this estimate needs further revision and updating since the data employed for computation pertains to 1968. The alternate estimate arrived at using the accounting rate of interest shows social rates of return of 11 percent. The studies conducted by the World Bank (1980) for Turkey and by Partha Das Gupta (1979) for the Indian economy using macro data have shown the social rate of discount (SRD) as ranging from 12 to 13.5 percent. Hence there appears to be no significant departure from other established estimates in our use of 12 percent as the cost of capital.

Price of Labor (P_L)

The price of labor has been determined implicitly for each industry by dividing labor expenditures by the total man hours of employees. Expenditures on labor include wages and salaries plus supplements paid to the manufacturing sector. The data regarding the expenditures on labor and total man hours of employees in the manufacturing industries are reported in the Report on Labor Statistics published by the Central Statistical Organization (CSO).

$$P_L = \frac{\text{Total Labor Expenditure}}{\text{Total Man Hours of Employees}}$$

Price of Aggregate Energy Use (P_E)

Some of the earlier studies (Pindyck, 1980; Lakshmanan and coauthors, 1980) have implicitly used the energy demand translog cost function itself to specify and estimate an aggregate price index of energy. Another approach followed is to construct an approximate index of energy as a means

of aggregation (Jorgenson, 1977; Berndt and Wood, 1975). In our study, we have adopted a simple approach by dividing total energy expenditure ($\sum_i F_{it}$) by the aggregate energy quantity index (E_t^*). All of the energy input sources were coverted into quadrillion joules and aggregated using relative price weights to obtain the aggregate energy quantity index. In other words:

$$P_{E_t} = \frac{\sum_i F_{it}}{E_t^*}$$

where:

i = fuel type, 1, ..., 5

P_{Et} = aggregate energy price index at time 't'

$\sum_i F_{it}$ = total expenditure on different forms of fuel inputs at time 't'

E_t^* = weighted sum of individual energy types at time 't'

$$= \lambda_{it} E_{it} + \lambda_{2t} E_{2t} + \cdots\cdots + \lambda_{nt} E_{nt}$$

Where the weights are denoted as

$$\lambda_{it} = \frac{P_{it}}{P_{1t}}$$

where P_1 = price of energy type 1 in the base year

Hence,

$$E_t^* = E_{1t} + \left(\frac{P_{2t}}{P_{1t}}\right)E_{2t} + \left(\frac{P_{3t}}{P_{1t}}\right)E_{3t} + \ldots + \left(\frac{P_{nt}}{P_{1t}}\right)E_{nt}$$

<u>Note</u>: See Turvey and Nobay (1965) for use of a similar aggregate energy quantity index.

Price of Materials Input (P_n)

The data reported on the total expenditure on all basic materials and the quantities used in manufacturing by the various industries have been collected from the Annual Survey of Industries. The price of materials inputs was obtained by dividing the total expenditures by the quantities used. That is,

$$P_M = \frac{\sum E_{Mi}}{\sum_i Q_{Mi}}$$

where:

i = 1, ... n materials consumed
E_{Mi} = expenditure on i^{th} material
Q_{Mi} = quantity of ith material

In those cases where the units of measure for quantities of materials were not comparable, units which comprises at least 85 percent of the total materials were viewed as an approximate measure of the total and accordingly, P_M was computed using these in each case. The raw materials inputs used in the analysis exclude intermediate products, that is, goods produced within the factory and consumed for further manufacture.

Cost Share Data of KLEM Inputs

The total cost of the fours inputs: capital (K), labor (L), energy (E), and materials (M) were obtained as the summation of the expenditures on these four inputs by manufacturing. That is,

$$\text{Total costs } 'G' = P_K K + P_L : + P_E E + P_M M$$

Where $P_K K$ is the expenditure on capital. Expenditures on capital services were obtained by subtracting labor expenditures from value added.

$P_L L$ = the expenditure on labor
$P_E E$ = the expenditure on energy
$P_M M$ = the expenditure on materials

The cost shares of each of the four inputs have been computed as follows:

Cost share of capital $S_K = \frac{P_K K}{G}$

Cost share of labor $S_L = \frac{P_L L}{G}$

Cost share of energy $S_E = \frac{P_E L}{G}$

Cost share of materials $S_M = \frac{P_M M}{G}$

Table 3-2 provides a detailed list of all the factor input intensity indices and other parameters developed in the study, along with data constructed for the econometric estimation. The description of computation in each has also been discussed. Table 3-3 gives details on the sample size of data used for econometric estimation of translog models of energy demand and aggregate input demand for the three time periods, 1965-1969, 1969-1974, and 1965-1974.

Table 3-2. Computation of Factor Input Intensities and Other Parameters

No.	Parameters	Definition	Units
1	2	3	4
1.	Capital Intensity (K/V)		
	Fixed capital intensity	$\frac{\text{Fixed capital}}{\text{Value added}}$	$\frac{\text{Rs. in millions}}{\text{Rs. in millions}}$
	Productive capital intensity	$\frac{\text{Productive capital}}{\text{Value added}}$	
	Invested capital	$\frac{\text{Invested capital}}{\text{Value added}}$	
2.	Labor Intensity (L/V)	$\frac{\text{Total number of employees}}{\text{Value added}}$	$\frac{\text{Thousands (Nos)}}{\text{Rs. in millions}}$
3.	Capital/Labor Ratios (K/L)		$\frac{\text{Rs. in millions}}{\text{Thousands (Nos)}}$
	Fixed capital/labor ratio	$\frac{\text{Fixed capital}}{\text{Total number of employees}}$	
	Productive capital/labor ratio	$\frac{\text{Productive capital}}{\text{Total number of employees}}$	
	Invested capital/labor ratio	$\frac{\text{Invested capital}}{\text{Total number of employees}}$	
4.	Materials Cost Intensity (M/V)	$\frac{\text{Material cost}}{\text{Value added}}$	$\frac{\text{Rs. in millions}}{\text{Rs. in millions}}$
5.	Energy Cost Intensity (F/V)	$\frac{\text{Total expenditure of fuels}}{\text{Value added}}$	$\frac{\text{Rs. in millions}}{\text{Rs. in millions}}$
		$= \frac{\sum_i F_i}{V}$	
		$i = 1, \ldots, 8$ = 8 forms of fuel inputs	
		F_i = the expenditure on i^{th} fuel	

Table 3-2. (Cont.)

1	2	3	4
6.	Proportion of energy cost by source to aggregate energy Expenditures	$\frac{\text{Expenditure on each fuel}}{\text{Overall expenditure on energy}}$ $= \frac{F_i}{\sum_i F_i}$ Where $i = 1, \ldots, 8$ = 8 forms on i^{th} fuel F_i = the expenditure on i^{th} fuel	$\frac{\text{Rs. in millions}}{\text{Rs. in millions}}$
7.	Energy intensity (E/V)	$\frac{\text{Aggregate energy consumed}}{\text{value added}} = \frac{\text{Quadrillion joules}}{\text{Rs. in millions}}$ $\frac{\sum_i F_i}{V}$ $i = 1, \ldots, 8$ = eight different forms of fuel inputs where E_i is the energy is the ith fuel input.	
8.	Proportion of energy consumption by source to aggregate energy consumption	$\frac{\text{Quantity consumption of each fuel input}}{\text{Aggregate energy consumption}} = \frac{\text{Quadrillion joules}}{\text{Quadrillion joules}}$ $\frac{E_i}{\sum_i E_i}$ Where $i = 1, \ldots, 8$ = 8 different forms of fuel inputs Where E_i = the quantity consumption of ith fuel input	
9.	Composite index of energy (CIE)	$\frac{\sum_i W_i E_i}{V}$ where $i = 1, \ldots, 8$ = 8 different forms of fuel inputs where W_i = the weightage of ith expenditure E_i = quantity of ith fuel consumed V = value added by manufacture	

Table 3-2. (Cont.)

1	2	3	4
10.	Price intensity of energy by source	$\frac{\text{Expenditure of each fuel input}}{\text{Value added}}$ = $\frac{\text{Quantity of each fuel consumed}}{\text{Value added}}$ $\frac{F_i}{\frac{E_i}{V}}$ where F_i = the expenditure on i^{th} fuel; E_i = the expenditure on the same i^{th} fuel; V = the value added by manufacture	Rs. in millions / Million tonnes or Quadrillion joules
11.	Data computation made for econometric estimation of translog functions		
	Energy cost function:		
	a. Prices of different forms of energy	$\frac{\text{Expenditure on different forms of energy}}{\text{Quantity consumption of different forms of energy}}$ = $\frac{F_i}{E_i}$ where F_i = the expenditure on i^{th} fuel; E_i = the quantity of the same i^{th} fuel	Rs. in millions / Quadrillion joules
	coal (P_1) coke (P_2) petroleum products (P_3) fuel oil (P_4) electricity (P_5)		
	b. Cost share of energy inputs	$\frac{\text{Expenditure on each form of fuel}}{\text{Overall expenditure on energy}}$ = $\frac{F_i}{\sum_i F_i}$ where i = 1,2,3,4 or i = 1,2,3,4 different forms of fuel inputs	
	coal (S_1) coke (S_2) petroleum products (S_3) fuel oil (S_4) electricity (S_5)		

Table 3-2. (Cont.)

1	2	3	4
	Aggregate Input Cost Function:		
	a. Prices of factor inputs		
	Capital (P_K)	Using 12% as the social discount rate of fixed capital	Rs. in millions
	Labor (P_L)	$\frac{\text{Total wages and salaries to all employees}}{\text{Total man hours worked}}$	$\frac{\text{Rs. in millions}}{\text{Hours in millions}}$
	Aggregate energy (P_E)	$\frac{\text{Total expenditure of fuels consumed}}{\text{Aggregate quantity consumption index}}$	$\frac{\text{Rs. in millions}}{\text{Quadrillion joules}}$
	Materials (P_M)	$\frac{\text{Total cost of materials consumed}}{\text{Quantity consumed}}$	$\frac{\text{Rs. in millions}}{\text{Million tonnes}}$
	b. Cost share data of LEM inputs		
	Capital (S_K)	$\frac{P_K K}{G}$ where G = total cost = $P_K K + P_L L + P_E E + P_M M$ and P_K, P_L, P_E, and P_M = prices and inputs of KLE & M respectively	
	Labor (S_L)	$\frac{P_L L}{G}$	
	Energy	$\frac{P_E E}{G}$	
	Materials (S_M)	$\frac{P_L L}{G}$	

Table 3-3. Sample Size by Industry for the Econometric Estimation of Translog Cost Functions of Energy Demand and Aggregate Input Demand

Sl. No.	Name of the industry	ASI code number	Sample size 1965-69	1970-74	1965-74
1.	Vacuum pan sugar factories	207.1.1	43	44	87
2.	Cigarette & tobacco mfr.	220.3	9	9	18*
3.	Cotton spinning, weaving - textiles	231.1	54	54	108**
4.	Jute spinning, weaving	231.2	15	16	31
5.	Woollen spinning, weaving - textiles	231.3	26	27	53
6.	Cotton ginning, pressing, etc.	239.1	35	33	68
7.	Paper manufacture for writing, wrapping, etc.	271.2	26	31	57
8.	Paper boards & straw boards	271.4	25	31	56
9.	Tires and tubes	300.1	18	35	53
10.	Inorganic fertilizers	311.1.1	18	22	40
11.	Inorganic heavy chemicals	311.2.1	27	33	60
12.	Organic heavy chemicals	311.2.2	13	16	29
13.	Petroleum refineries	321	11	11	22
14.	Cement (hydraulics)	334	26	28	54
15.	Iron & steel (metal)	341.1	47	53	100
16.	Iron & steel - casting and forgings	341.3	44	47	91
17.	Nonferrous metal	342	24	21	45

Note * Minimum sample size.
**Maximum sample size.

Chapter 4

DYNAMICS OF MANUFACTURING

The empirical investigation consists of the three stages. The first is a study of the trends in factor input intensities and other parameters of production. In the second stage, the interaction and interrelationships between factor inputs are estimated. Estimating the price elasticity and interfuel substitution possibilities of different forms of energy, and determining substitution possibilities among major factor inputs form the last stage of our analysis. Below we discuss each of these stages in detail.

Factor Input Intensities and Industry Rank

Capital Intensity

Since their inception, the national plans have called for substantial investment in the manufacturing sector. In this process, the industrial sector of India has experienced a significant degree of capital deepening, clearly observed in the increase in capital intensity (K/V), which is computed as the relative contribution of various forms of capital employed to value added by manufacture.

Three forms of capital--fixed capital, productive capital, and invested capital--have been considered in our analysis. The intensity factors for each form of capital have been calculated and are shown in table 4-1 for the sixteen major industry groups. Most of the industry groups experienced an increase over the years in the value of the three forms of capital intensity. This implies that the rate of capital expansion was greater than the expansion of value added. While the capital intensity factor computed for the period 1963 to 1971 varies considerably,

Table 4-1. Factor Input Intensities and Other Parameters of Production: India's Manufacturing Sector, 1963-64 to 1971-72

Industry groups	ASI code no.	Years	Capital intensity (K/V): Fixed capital intensity	Capital intensity (K/V): Productive capital intensity	Capital intensity (K/V): Invested capital intensity	Labor intensity (L/V)	Capital/labor ratio (K/L): Fixed capital/labor ratio	Capital/labor ratio (K/L): Productive capital/labor ratio	Capital/labor ratio (K/L): Invested capital/labor ratio	Materials cost intensity	Energy cost intensity (E/V)	Energy intensity (E/V)	Composite index of energy (CIE)
Sugar	207	1963	1.253	1.340	1.162	0.287	4.325	11.601	7.512	3.346	0.376	0.013	1.745
		1966	1.728	2.854	4.631	0.213	8.110	13.392	21.728	3.543	0.055	0.010	0.737
		1969	1.309	2.110	3.747	0.128	10.350	16.679	29.614	3.674	0.063	0.009	0.683
		1971	2.083	3.136	6.104	0.187	11.122	16.744	32.587	4.393	0.101	0.011	0.866
Tobacco, cigarette manufacture	220	1963	0.228	0.010	1.114	0.106	2.141	9.718	10.454	1.430	0.014	0.002	0.569
		1966	0.275	0.011	1.087	0.232	1.186	4.830	46.790	2.488	0.020	0.002	0.439
		1969	0.194	0.011	1.112	0.165	1.171	6.762	67.114	2.427	0.015	0.001	0.270
		1971	0.187	0.642	0.918	0.141	1.326	4.553	65.154	2.024	0.015	0.0009	0.231
Cotton spinning, weaving	231	1963	0.988	1.595	1.987	0.330	2.990	4.825	6.012	1.909	0.130	0.019	1.248
		1966	1.204	1.736	2.229	0.346	3.476	5.013	6.639	2.187	0.153	0.017	1.234
		1969	1.071	1.532	2.192	0.224	4.781	6.840	9.788	2.199	0.154	0.012	1.137
		1971	0.937	1.394	2.157	0.199	4.702	6.997	10.673	2.563	0.152	0.011	0.6769
Other textiles	232 233 239	1963	1.141	1.951	2.013	0.310	1.408	2.409	2.485	5.941	0.171	0.052	1.225
		1966	1.198	2.041	2.161	0.585	2.048	3.489	3.694	5.790	0.159	0.036	1.165
		1969	1.279	2.198	2.211	0.573	2.231	3.834	3.557	6.750	0.201	0.032	1.309
		1971	0.945	1.698	2.063	0.380	2.484	4.438	5.424	6.510	0.144	0.016	0.754
Paper & paperboards	271	1963	2.879	3.830	4.047	0.213	13.483	17.934	18.949	1.804	0.168	0.139	2.475
		1966	3.427	4.133	4.705	0.200	17.068	20.584	23.429	1.844	0.175	0.129	2.551
		1969	2.716	3.364	3.779	0.134	20.215	25.037	28.125	1.691	0.139	0.071	1.311
		1971	2.318	3.065	3.353	0.115	20.055	26.521	29.011	1.796	0.111	0.095	2.317
Rubber products	300	1963	0.751	1.467	1.560	0.123	6.086	11.883	12.642	1.913	0.064	0.009	1.194
		1966	0.839	1.672	1.849	0.127	6.585	13.117	14.507	2.649	0.087	0.009	1.508
		1969	0.766	1.520	1.631	0.095	8.056	15.95	17.148	2.402	0.082	0.007	1.214
		1971	0.925	1.520	1.830	0.083	11.037	18.126	21.827	2.376	0.085	0.007	1.634
Basic chemicals	311	1963	3.739	5.005	5.036	0.129	28.911	38.590	38.832	1.626	0.116	0.066	4.627
		1966	4.679	6.085	6.198	0.108	43.310	56.327	56.722	1.972	0.153	0.045	3.147
		1969	4.734	5.822	5.993	0.073	64.376	79.168	81.503	1.905	0.127	0.026	5.721
		1971	3.688	4.787	4.826	0.058	63.000	81.771	82.434	1.710	0.109	0.020	5.303
Petroleum refineries	321	1963	2.695	5.593	3.219	0.029	92.494	191.957	11.030	2.115	0.038	0.0002	0.338
		1966	5.139	7.078	5.900	0.029	173.126	238.447	198.742	3.613	0.032	0.0002	0.210
		1969	3.586	4.489	4.269	0.022	156.263	195.618	186.011	3.896	0.033	0.0002	0.100
		1971	2.940	3.738	3.758	0.018	158.617	200.061	200.038	3.708	0.040	0.0003	0.021
Miscellaneous products of coal & petroleum	329	1963	6.451	6.992	6.950	0.130	49.434	53.574	53.958	4.451	0.090	0.011	0.673
		1966	23.463	25.941	25.063	0.330	71.046	78.548	75.890	11.688	0.124	0.009	0.550
		1969	15.282	10.990	16.680	0.174	87.482	62.913	95.484	3.533	0.232	0.003	0.757
		1971	11.258	12.527	12.542	0.147	75.187	84.769	84.875	8.090	0.224	0.009	0.337
Cement	334	1963	2.648	3.644	3.857	0.150	17.631	24.259	25.680	1.526	0.033	0.415	5.182
		1966	2.053	2.781	3.081	0.099	20.729	28.081	31.106	1.389	0.151	0.257	12.399
		1969	3.019	4.127	4.253	0.097	31.015	42.403	43.696	1.734	0.157	0.237	4.176
		1971	4.349	5.621	5.993	0.105	41.363	53.453	56.999	2.467	0.257	0.312	5.311
Iron & steel	341	1963	6.417	7.592	7.990	0.214	29.990	35.471	37.333	1.983	0.144	0.175	1.260
		1966	6.130	7.844	8.193	0.187	32.750	41.903	43.768	2.103	0.184	0.107	1.487
		1969	6.410	8.237	8.641	0.184	34.722	44.618	46.803	2.664	0.146	0.102	1.300
		1971	5.255	7.478	8.056	0.175	30.022	42.723	46.021	3.198	0.121	0.079	1.483
Nonferrous metal	342	1963	1.724	3.523	3.704	0.103	16.562	34.401	35.791	2.013	0.206	0.031	2.562
		1966	2.218	4.097	4.345	0.068	32.447	59.938	63.572	1.621	0.229	0.020	2.654
		1969	1.607	3.516	3.703	0.056	28.311	61.944	65.934	1.396	0.193	0.018	3.130
		1971	2.756	7.628	8.009	0.077	35.674	98.716	103.645	1.125	0.181	0.018	3.736
Shipbuilding & repairing	381	1963	0.843	1.739	2.956	0.357	2.359	4.863	8.264	0.871	0.060	0.008	0.5795
		1966	0.837	1.940	3.093	0.280	2.906	6.918	11.027	0.805	0.042	0.003	0.2332
		1969	1.233	2.209	2.935	0.229	5.328	10.001	13.590	1.136	0.141	0.002	0.1039
		1971	1.229	1.995	3.260	0.169	7.254	11.775	19.236	1.161	0.038	0.003	0.1159
Railroad equipment	382	1963	1.300	1.863	2.145	0.323	4.022	5.764	6.696	1.354	0.175	0.012	1.315
		1966	1.406	2.361	2.433	0.309	4.547	7.635	7.866	1.520	0.188	0.010	1.258
		1969	1.366	2.098	2.293	0.296	4.613	7.083	7.740	1.573	0.103	0.008	0.345
		1971	0.959	1.623	1.736	0.212	4.526	7.655	8.186	1.191	0.093	0.005	0.717
Motor vehicle manufacture	383 384	1963	1.151	1.955	2.536	0.218	5.265	8.941	11.595	2.202	0.144	0.0005	1.193
		1966	1.666	2.544	3.201	0.179	9.287	14.734	17.840	2.156	0.156	0.0005	1.034
		1969	1.547	2.759	3.047	0.156	9.905	17.659	19.503	2.115	0.160	0.0004	0.749
		1971	1.260	2.752	3.116	0.095	13.208	28.836	32.648	2.459	0.177	0.0003	0.347
Aircraft manufacture	386	1963	1.333	7.450	4.101	0.153	8.670	48.361	26.678	0.590	0.025	0.00001	0.140
		1966	0.710	2.454	2.441	0.113	6.269	21.668	21.551	0.672	0.031	0.000008	0.151
		1969	0.567	2.946	2.376	0.094	6.024	31.287	30.543	0.710	0.034	0.000009	0.409
		1971	0.345	4.752	4.759	0.074	11.297	63.486	63.588	0.706	0.035	0.000008	0.170

the overall increase for all industry groups can be traced to the performance of the industrial sector and the investment climate that prevailed from 1966 to 1969 and the earlier planning periods.

A retrospective look into the Second Five Year Plan (1956-1961) indicates that there was a strong emphasis during this period on broadening the industrial base of the economy. Priority was given to investment goods industries. The share of planned investment in the organized manufacturing sector during the second plan period was over three times (about 19 percent) the investment in this sector during the first plan period (1951-1956) (Planning Commision, Government of India, 1960). Consequently, a larger share of fixed capital investments were pumped into the organized industrial sector of the economy. However, during the eight years which comprised the third plan (1960-61 to 1965-66) and the subsequent annual plans (1966, 1967, 1968), industrial progress was markedly uneven. The economy was subjected to considerable stress and strain and the growth rate of industrial production declined, first slowly and then steeply until it reached virtual stagnation. The annual increase in industrial output (using 1960 as the base) was

Percent increase	Period
8.2%	1961-62
9.6%	1962-63
9.2%	1963-64
8.2%	1964-65
4.3%	1965-66
1.7%	1966-67
0.3%	1967-68

The sharp deterioration in the rate of growth which occurred in the last three years was attributable to two main factors: serious dislocations caused by the Indo-Pakistan hostilities in 1965-66, and two successive droughts. Related to the decline in the rate of growth of output, the rate of growth of value added also slowed sharply, resulting in an increase in the relative share of capital employed to value added in manufacturing during the period 1966-1969. In other words, the capital that was pumped into the economy during the earlier periods was not put to productive use due to underutilization of capacity.

Labor Intensity

The labor intensity factor (L/V) (computed as the relative contribution of total workers employed to value added by manufacture) showed a consistent decline over the years 1960-1970 for most industry groups. This phenomenon could be explained by:

1. a significant increase in the rate of growth of value added compared to the increase in the rate of growth of total workers employed;

2. a decrease in the rate of growth of both value added and labor employed, but the rate of growth of labor employed decreasing at a higher rate than the decrease in the rate of growth of value added;

3. a decrease in the rate of growth of total workers employed associated with an increase in the rate of growth of value added.

For the period in question, the decline in labor intensity observed for the manufacturing industry groups considered in our analysis provides an example of all the three above-mentioned circumstances. For example, the decline observed for the period 1963-64 and for the period 1968-1970 was attributable to the significant increase in the rate of growth of value added compared to the increase in the rate of growth of total workers employed; the period 1964-1967 exhibited a decrease in the rate of growth of both labor employed and value added, but growth in labor employed decreased at a faster rate compared to value added; and the decrease in labor intensity for the period 1962-63 resulted from a decrease in the rate of growth of total workers employed associated with an increase in the rate of growth of value added. The data given in table 4-2 for the sixteen industry groups considered provides evidence of these three sets of circumstances.

The decrease in labor intensity over this period, while disturbing, is not altogether unexpected in view of the industrial policies and programs followed. As pointed out earlier, starting with the Second Five Year Plan (1956-1961), and especially since the Third Five Year Plan (1961-1966), much of the investment expenditure in the organized manufacturing sector

Table 4-2. Percent Increase in Total Workers Employed and Value Added by Manufacture Over Preceding Year (1962-1970)

Year	Total workers employed	Value added
1962	7.5	9.3
1963	4.8	11.3
1964	7.8	15.6
1965	3.7	12.8
1966	1.2	8.6
1967	-0.7	3.3
1968	2.3	9.0
1969	3.3	18.2
1970	4.6	20.4

went into basic and heavy industries such as iron and steel, paper, engineering, chemicals, cement, and nonferrous metals. This policy resulted in a high degree of capital deepening in the industrial sector, and coupled with the relatively long gestation periods of the projects undertaken, it substantially decreased labor to value added ratios for Indian industry as a whole. This trend was also representative of the constraints in choice of technology that a developing country faces when importing technologies suitable only for very different factor price ratios.

Capital/Labor Ratios

The ratio of capital employed to total workers is also a useful indicator of changes in factor intensity resulting from technical progress and can be seen as a measure of the relative performance of both the factors in question. The capital/labor ratio computed for the industry groups in our analysis showed a continuous and pronounced upward trend for the period in question (see table 4-1). This came about in part on account of considerable emphasis by the government during the second and third plans on the growth of process-oriented industries, which are basically capital intensive. As would be expected, the increase in capital/labor ratios due to increasing application of capital in the manufacturing industries was not accompanied by matching increases in the total number of workers employed.

Materials Cost Intensity

The materials cost intensity factor (M/V) computed for different industry groups showed a steady increase over the period covered for most industries (see table 4-1). Both in labor-dominated and machine-dominated manufacturing processes, materials requirements tend to vary directly with output levels. The increase in materials cost intensity is attributable mainly to the expansion and diversification of capacity in the heavy engineering and engineering goods industries over this time period. Further, these capacity increases took place at a time when domestic demand was at a lower level and the value of output did not keep pace with materials costs due to depressed product prices and demand. Increases in raw materials prices consequent to devaluation, however, also led to an increase in the materials costs intensity of various industry groups.

Energy Cost Intensity and Energy Intensity

The energy cost intensity factor (F/V) observed for the industry groups analyzed showed an increasing trend over the period, while the energy intensity factor (E/V) showed a declining trend for most industries. This occurred in part due to the rise in prices of energy relative to industrial products during this period. From a common base of 100 in 1961, fuel and energy costs rose to 132.5 in 1966 as against 125.5 for manufactured products. Another important factor behind this phenomen was the decline in industrial production which took place in 1966-67, resulting in underutilized capacity and higher energy consumption per unit of output in some industry groups.

The decline in the energy intensity factor (E/V) observed for the industry groups over the period, though a favorable feature, is not altogether a reflection of real energy savings for the sector as a whole. Full energy savings potential can only be realized with further utilization of industrial capacity. The period between 1966-1969 witnessed virtual stagnation in the growth of the industrial sector and prevented the exploitation of industrial potential. Consequently, even though the real demand for energy remained suppressed it did not result in full energy efficiency because output was disproportionately lower. Nevertheless, despite a decline in the rate of growth of value added, the energy intensity factor declined over the years covered.

Composite Index of Energy (CIE)

Besides the energy cost intensity and energy intensity parameters, the composite index of energy (CIE) has been introduced as yet another parameter of energy analysis. As a single parameter, it has the advantage of taking into account both energy consumption and energy cost aspects of different forms of energy consumed by the industry groups. Any change in the unit cost of different forms of energy consumed by an industry group results in either an increase or decline of CIE depending on the proportion of different forms of energy consumed by that industry group. In short, CIE is sensitive to:

1. weight of each fuel expenditure to total expenditure on energy
2. percentage contribution of each fuel to aggregate energy consumption
3. unit cost of different forms of energy.

The CIE computed for the sixteen industry groups exhibited a varying trend over the years (see table 4-1). A number of industry groups--sugar, tobacco manufacture, cotton and other textiles, petroleum refineries, miscellaneous products of coal and petroleum, cement, iron and steel, shipbuilding, railroad equipment, and motor vehicle manufacture--showed a decreasing trend over the years, while the remaining industry groups showed an increasing trend. The increases observed in some cases and decline in others in the computed value of CIE are attributable to the nature of industry groups, their energy consumption patterns, and their associated cost of energy.

The two energy factor intensities observed for the industry groups showed varying trends, but aggregate energy (E/V) mostly declined, while the aggregate energy cost intensity factor (F/V) increased for most of the industry groups. In many cases where the increase in the energy cost intensity factor was significant despite a decrease in the energy intensity factor, the CIE showed an increasing trend. On the other hand, for those industry groups for which the increase in the energy cost intensity factor has not been significant, there is a decrease in the computed value of CIE. Much of these variations in CIE observed for the industry groups are

explained by studying the extent of influence that the prices of fuels exert on energy consumption. An analysis of energy cost intensity by source and proportion of energy cost (by source) to aggregate energy expenditure was carried out in order to shed light on the sensitivity of energy consumption to energy pricing (see the next major section in this chapter).

Performance Evaluation of Industry Groups Using Factor Input Intensities and Other Parameters of Production

The rankings for the sixteen industry groups based on the factor input intensities and other parameters covering four years (1963, 1966, 1969, 1971) are presented in table 4-3. The rank matrix determines the comparative roles of various input factors which have a bearing on the relative performance of each industry group. While indicating the performance of the industry groups over these years, the rank matrix also provides information on the nature of the production process.

The ranks observed for each industry group related to specific factor input intensities considered independently do not show perceptible change (see table 4-3). This implies that over the years the industry groups have more or less maintained their relative positions. A detailed analysis of the ranks based on each of the factor input intensities and other parameters is presented below.

All three forms of the capital intensity factor (K/V) resulted in a high ranking for the machine-dominated industries like sugar, paper, basic chemicals, petroleum refineries, miscellaneous products from coal and petroleum, iron and steel, and cement, indicating the relatively large amounts of capital used in these industries. On the other hand, industries like tobacco manufacture and rubber and rubber products rank very low based on these capital factors. Since plantation activity forms an integral part of these two industry groups, capital requirements are relatively low and hence the capital intensity factor is correspondingly low. Plantation activity involves a relatively high labor input and accordingly, the labor intensity factor (L/V) associated with tobacco and rubber was found to be moderately high. The textile industry group showed the highest labor intensity ratio among all sixteen industry groups. Spinning and weaving, which is part of this industry group, is a labor-dominated process, and as

Table 4-3. Rank Matrix of Factor Intensities and Other Parameters of Production: India's Manufacturing Sector, 1963-64 to 1971-72

Industry groups	ASI code no.	Years	Capital intensity: Fixed capital intensity	Capital intensity: Productive capital intensity	Capital intensity: Invested capital intensity	Labor intensity (L/V)	Capital/labor ratio: Fixed capital/labor ratio	Capital/labor ratio: Productive capital/labor ratio	Capital/labor ratio: Invested capital/labor ratio	Materials cost intensity (M/V)	Energy cost intensity (F/V)	Energy intensity (E/V)	Composite index of energy (CIE)
Sugar & gur	207	1963	10	8	5	12	8	7	4	14	8	5	10
		1966	9	1	11	10	8	7	9	13	5	9	6
		1969	7	5	10	7	9	7	9	13	6	9	5
		1971	9	9	13	13	7	6	8	14	8	10	9
Tobacco & cigarette manufacture	220	1963	1	1	1	3	2	6	6	4	1	4	3
		1966	1	1	1	11	1	2	2	11	1	4	4
		1969	1	1	1	10	1	2	2	11	1	4	2
		1971	1	1	1	9	1	2	2	6	1	4	3
Cotton textiles	231	1963	4	3	3	14	4	2	2	8	10	10	8
		1966	6	3	4	15	4	3	3	10	9	10	9
		1969	4	3	3	14	4	3	4	9	9	10	10
		1971	4	2	5	14	4	3	4	10	10	9	6
Other textiles	232, 233, 239	1963	5	6	4	16	1	1	1	16	11	12	7
		1966	5	5	3	16	2	1	1	15	10	12	8
		1969	6	6	4	16	2	1	1	15	10	13	8
		1971	5	5	4	16	2	1	1	15	9	11	8
Paper & paperboards	271	1963	13	11	12	9	10	9	9	7	14	14	13
		1966	12	12	12	9	10	9	10	6	14	15	13
		1969	11	10	11	8	10	9	8	4	14	14	13
		1971	10	8	8	8	10	8	7	5	13	15	13
Rubber & rubber boards	300	1963	2	2	2	4	7	8	8	9	6	6	6
		1966	4	2	2	6	7	6	6	12	7	6	12
		1969	3	2	2	5	7	6	6	10	7	7	11
		1971	3	3	3	5	6	7	6	7	6	7	12
Basic chemicals	311	1963	14	12	14	5	13	13	14	6	13	13	15
		1966	13	13	14	4	14	13	13	7	13	13	15
		1969	14	14	14	3	14	15	14	7	13	12	16
		1971	13	12	11	2	14	13	13	4	12	13	16
Petroleum refineries	321	1963	12	13	9	1	16	16	16	12	3	2	1
		1966	14	14	13	1	16	16	16	14	3	2	1
		1969	13	13	13	1	16	16	16	14	2	2	1
		1971	12	10	9	1	16	16	16	13	4	2	1
Miscellaneous products of coal & petroleum	329	1963	16	14	15	6	15	15	15	15	9	7	5
		1966	16	16	16	14	15	15	15	16	12	7	5
		1969	16	16	16	11	15	14	15	16	11	6	7
		1971	16	16	16	10	15	14	14	16	11	8	4
Cement	334	1963	11	10	11	7	12	10	10	5	16	16	16
		1966	10	9	7	3	11	11	11	3	16	16	16
		1969	12	12	12	6	12	11	11	5	16	16	15
		1971	14	13	12	7	13	11	11	9	16	16	15
Iron & steel	341	1963	15	16	16	10	14	12	13	10	15	15	11
		1966	15	15	15	8	13	12	12	8	15	14	11
		1969	15	15	15	12	13	12	12	12	15	15	12
		1971	15	14	15	12	11	10	10	12	15	14	11
Nonferrous metals	342	1963	9	9	10	2	11	11	12	11	12	11	14
		1966	11	11	10	2	12	14	14	5	11	11	14
		1969	10	11	9	2	11	13	13	6	12	11	14
		1971	11	15	14	4	12	15	15	11	14	12	14
Shipbuilding & repairing	381	1963	3	4	8	15	3	3	5	2	5	5	4
		1966	3	4	8	12	3	4	5	2	4	5	3
		1969	5	7	7	13	5	5	5	2	4	5	3
		1971	7	6	7	11	5	5	5	2	3	5	2
Railroad equipment	382	1963	7	5	6	13	5	4	3	3	7	8	12
		1966	7	6	5	13	5	5	4	4	8	8	10
		1969	8	4	5	15	3	4	3	3	9	8	9
		1971	6	4	2	15	3	4	3	3	7	6	7
Motor vehicle manufacture	383, 384	1963	6	7	7	11	6	5	7	13	4	3	9
		1966	8	8	9	7	9	8	7	9	6	3	7
		1969	9	8	8	9	8	8	7	8	5	3	6
		1971	8	7	6	6	9	9	9	8	5	3	10
Aircraft manufacture	386	1963	8	15	13	8	9	14	11	1	2	1	2
		1966	2	7	6	5	6	10	8	1	2	1	2
		1969	2	9	6	4	6	10	10	1	3	1	4
		1971	2	11	10	3	8	12	12	1	2	1	5

Note: The ranks specified in the above matrix for the diferent industry groups are in increasing order, that is, Rank 1 denotes the lowest and Rank 16 the highest.

a consequence of government policies encouraging handloom weaving on a large scale, the rate of growth of labor employed in this industry has increased at a rate greater than the rate of growth of value added. On the other hand, petroleum refineries, being process oriented, exhibited the lowest labor intensity in these years. The basic chemicals and nonferrous industry groups also showed low levels of labor intensity.

Among the sixteen industry groups, the other textile group showed the lowest capital/labor ratio (K/L) for all three forms of capital considered. This, coupled with the fact that it has the highest level of labor intensity among all industry groups, confirms that the nature of processes used to be predominantly labor intensive. The highest capital/labor ratio occurred in petroleum refineries, confirming the capital intensity of the oil refining process.

The ranks observed for the industry groups based on the materials cost intensity factor (M/V) showed industries which are basically fabricating units--such as aircraft manufacture, railroad equipment, and shipbuilding and repairing--as relatively less materials cost intensive compared to those industries which are process oriented, such as iron and steel, nonferrous metals, sugar, chemicals, and predictably, petroleum refineries. Fabricating industries are dominated by capital and labor inputs, the main elements in the production process. On the other hand, the operations of process industries are materials dominated and accordingly they show higher materials cost intensity.

The ranking of industry groups based on the three energy factors--energy cost intensity (F/V), energy intensity (E/V) and composite index of energy (CIE)--exhibited considerable consistency in relative terms despite the varying trends observed when considering the factor ratios themselves. As expected, the ranks for process industries--sugar, paper mill, basic chemicals, coal and petroleum products, cement, iron and steel, and nonferrous metals--were found to be relatively high for both the energy parameters. This obviously reflects the high degree of dependency on energy inputs in the processes of these industry groups. In contrast, the lower level of energy intensity seen for the petroleum refineries group is surprising. The tobacco and cigarette manufacture industry group also exhibited low levels of energy intensity. Basically, the raw materials

input in this industry group does not undergo any major process change and hence energy consumption is relatively low.

Measurements of Association Among Factor Input Intensities and Other Indicators of Production

Production involves integration of the basic major inputs like capital (K), labor (L), energy (E), and materials (M). Determining the measure of association among these major categories of inputs can provide valuable insight for decisionmakers in evaluating the performance of each industry group and assessing measures which would be most desirable for use of the country's resource endowment.

Measures of association among the parameters of production have been estimated in two different ways, by using:

1. a rank correlation of the ranks established for the industry groups, based on factor input intensities and other indicators

2. the Kendall coefficient of concordance, W.

Rank correlation measures the degree of association between two ranking schemes. For example, if there is perfect conformity in the order of ranks between different parameters, then the rank correlation is significantly positive, implying that the ranks of one parameter tally with that of the other. On the other hand, if the rank correlation is significantly negative, then the ranks between the parameters are perfectly opposite. W-statistics also measure the degree of association among several ranking factors. W-statistics computed usually lie between 0 and 1, with W = 0 indicating the ranks based on the two factors to be completely random, meaning the ranks of the parameters are exactly opposite; and W = 1 indicating perfectly stable rankings for the parameters. The significance of W-statistics can be determined by computing Chi-square values, since the W-statistic follows the Chi-square distribution for large samples (n greater than 7).

The basic difference between the two techniques is that W-statistics determine the degree of association among several ranking factors, whereas rank correlation expresses the degree of association between two ranking

factors only. However, in our study one technique has been employed as a conformity test for the other in order to measure the degree of association.

The rank correlation of parameters applicable for each year (1963, 1966, 1969, and 1971) is presented in appendix B. Table 4-4 indicates the W-coefficient and Chi-square values computed for various combinations of parameters of production. Given below is a detailed analysis of the measure of association among these parameters.

The productive capital intensity factor (K/V) showed poor negative correlation with the labor intensity factor (L/V) significant positive correlation with the capital/labor ratio (K/L), and poor positive correlation with materials cost intensity (M/V), energy intensity (E/V), and composite index of energy (CIE). The negative correlation observed indicates an opposite relation existing between capital intensity (K/V) and labor intensity (L/V). The W-statistics computed showed W = 0.37 for 1963, and W = 0.31 for 1971, and the corresponding Chi-square values indicated a very poor degree of association between the two parameters. This clearly shows the opposite trend of capital intensity (K/V) and labor intensity (L/V); that is, high (low) capital intensity is associated with low (high) labor intensity.

The significant positive correlation observed between capital intensity and the capital/labor ratio (K/L) and between capital intensity and energy cost intensity (F/V) indicates conformity of ranks. This, coupled with significant W-statistics, indicates the high degree of association of the two parameters K/L and F/V and capital intensity (K/V). This implies that a capital intensive industry is energy cost intensive, and an increase in the capital intensity factor leads to a corresponding increase in the capital/labor ratio.

Even though factors like materials cost intensity (M/V), energy intensity (E/V), and composite index of energy (CIE) have shown poor positive correlations with the capital intensity factor (K/V), the increase in correlation observed over the years indicates an increasing association between K/V and the other factors in question. The increase observed in W-statistics computed between capital intensity and materials cost intensity and energy cost intensity, respectively, further supports the finding of increased association, implying improved conformity of ranks

Table 4-4. The Kendall Coefficient of Concordance 'W'

Parameters (Criteria)	Years 1963	1966	1969	1971
1. Capital intensity (K/V) vs. labor intensity (L/V) (K = 2, N = 16, Df = 15)	0.37 (11.25)	0.317 (9.52)	0.324 (9.74)	0.310 (9.30)
2. Capital intensity (K/V) vs.capital/labor ratio (K/L) (K = 2, N = 16, Df = 15)	0.72# (26.12)	0.77# (26.95)	0.83* (31.6)	0.81* (30.04)
3. Capital intensity (K/V) vs. energy cost intensity (F/V) (K = 2, N = 16, Df = 15)	0.61 (23.49)	0.79# (27.91)	0.80# (29.76)	0.78# (27.35)
4. Capital intensity (K/V) vs. materials cost intensity (M/V) (K = 2, N = 16, Df - 15)	0.50 (16.49)	0.43 (13.05)	0.48 (14.47)	0.52 (18.04)
5. Capital intensity (K/V) vs. energy intensity (E/V) (K = 2, N = 16, Df = 15)	0.51 (16.57)	0.53 (19.94)	0.57 (21.66)	0.578 (21.79)
6. Labor intensity (L/V) vs. capital/labor ratio (K/L) (K = 2, N = 16, Df = 15)	0.46 (13.94)	0.30 (8.57)	0.32 (9.72)	0.28 (8.22)
7. Energy cost intensity (F/V); energy intensity (E/V) and composite index of energy (CIE) (K = 3m N = 16, Df = 16)	0.61# (31.12)	0.65# (31.33)	0.78# (38.14)	0.73# (36.14)

Note: Figures in parentheses indicate Chi-square values.

* indicates significance at 99 percent and 95 percent confidence.

\# indicates significance at 95 percent confidence.

K = number of combinations of parameters.

N = number of entities or industry groups.

Df = degrees of freedom = (N - 1).

between capital intensity and other factors considered. Hence, it can be said that high (low) capital intensive manufacture leads to high (low) materials cost intensity and high (low) energy cost intensity.

Considering the rank correlation of the labor intensity factor (L/V) with other factors, L/V showed a consistently significant negative correlation with the capital/labor ratio (K/L) over the years, signifying an opposing trend between the two parameters. A low (high) labor intensive industry often possesses a high (low) capital/labor ratio. In other words, capital employed per unit of labor is relatively low (high) in a high (low) labor intensive manufacture. The very low value of the W-statistic observed for L/V and K/L further validates this point. This phenomenon, coupled with our earlier finding of an opposite relationship existing between capital intensity and labor intensity, indirectly indicates the high degree of substitution possibilities prevailing between capital and labor inputs of the manufacturing industries.

The rank correlation observed for the remaining parameters such as materials cost intensity (M/V), energy cost intensity (F/V), and composite index of energy (CIE), does not show any perceptible link with the labor intensity factor (L/V) implying that no definite relation can be identified between labor intensity and the parameters in question. However, labor intensity did show a very weak negative correlation with the energy intensity factor (E/V) over the years, indicating the poor levels of substitution existing between these two factors. While it may be expected that a similar trend exists between labor intensity, and energy cost intensity, and energy cost intensity also, it is not obvious.

As such, the productive capital/labor ratio (K/L) bears no significant relation with other parameters (such as M/V, F/V, E/V, and CIE) and hence no significant correlation can be expected. The poor correlation exhibited for the parameters in question indicate a varying degree of association between them. Similarly, materials cost intensity (M/V) exhibited poor correlation with parameters such as energy cost intensity (F/V), energy intensity (E/V), and CIE, signifying a varying pattern of association between these variables across industries.

The rank correlation observed over the years between any two of the three energy parameters, namely energy cost intensity (F/V), energy intensity (E/V), and composite index of energy (CIE), showed a significant

positive correlation. This correlation indicates perfect conformity of ranks among these ratios. The significant W-statistics of the three factors taken together lend support to the high degree of agreement in the ranks of these parameters. The strong correlation and high degree of association observed for the energy parameters is consistent with the fact that high (low) energy intensity leads to a corresponding high (low) energy cost intensity. Since the composite index of energy (CIE) has been computed reflecting both cost and quantity aspects of energy, it is natural that its ranking is consistent with the other two parameters.

Nature of The Interaction Between Factor Inputs in Manufacturing

Trends in the interaction of various factor input intensities are further analyzed in this section. This analysis provides insight into the changes in input costs and their implications for optimal use of factor inputs. Furthermore, insight is also obtained on the structural changes in industry groups over time in addition to evaluating the technologies employed.

Looking back at table 4-1 and at appendix B, the relative changes between productive capital intensity and labor intensity factors can be seen. There is evidence that there has been a continuous shift toward increasing capital intensity and decreasing labor intensity. Basic chemicals, miscellaneous products of coal and petroleum, cement, iron and steel, and nonferrous metals are some of the basic industries exhibiting these trends. None of the industry groups showed significant movement toward greater labor intensity.

In contrast, over the years, both energy cost and capital intensities showed an increasing trend in many industries, due in part to modernization of production processes. The high energy and capital intensive pace of production in the cement industry is clearly visible. The movement of the nonferrous metals industry toward the high capital intensity axis is also significant. Similarly, materials cost and capital intensities have increased in many industries. This is partly a consequence of the expansion of capacity in most of the industry groups.

The labor intensity (L/V) versus energy cost intensity (F/V) relationship over time can also be seen in table 4-1. Most industries

have shifted toward higher energy cost intensity. The cement, iron and steel, and nonferrous metals industries have become highly energy cost intensive. One exception is the sugar industry group. The significant change observed for the sugar industry in energy cost intensity is clearly seen from the movement of the industry over the years toward a lower energy cost intensity. This is attributable mainly to the use of bagasse, a waste product of the industry, for its own energy purposes. Furthermore, none of the industry groups showed a significant increase toward labor intensity. The variations in materials cost intensity (M/V) versus energy cost intensity (F/V) over time indicate an increase in the intensity ratios of both the parameters. Energy intensive industries (such as cement, iron and steel, and nonferrous metals), however, experienced a sharp increase in energy cost intensity compared to the materials cost intensity. The other textiles, sugar, and miscellaneous products of coal and petroleum industry groups showed the opposite trend, indicating a comparatively higher dependence on materials.

The movement of industries toward higher energy and materials intensities clearly shows the increasing importance of these two parameters. Efforts should be initiated in terms of identifying new research programs for energy and resource conservation. For example, energy cost intensive industries can undertake research to develop alternative processes which consume less energy. Similarly, materials cost intensive industries can direct their research efforts toward developing new production processes and efforts such as waste reduction, waste recycling, and materials substitution.

Interaction and Interrelationship Between Factor Inputs of Production

In the previous section, we were concerned with the problem of measuring the degree of association among major factor inputs of production based on the relative ranking of different industry groups. The aim of this section is to study interindustry variations in the ratio of factor inputs to value added and to analyze the interaction between factor input intensities and the structure of production.

The relationships between various factor input intensities and other parameters were estimated by computing simple correlation coefficients for

the different industry groups using data for the years 1963 to 1971. Simple correlation coefficients were computed (in addition to rank correlation coefficients) for the parameters because simple correlation measures the degree of association between variables on a nominal scale. Any variations in nominal value of the parameters are reflected in the coefficients, whereas a rank correlation coefficient is computed using relative ranking of the parameters. Further, simple correlation, besides indicating the nature of relationships between any two parameters, indicates the extent of directional impact of the parameters in question. For example, an increase (decrease) in the nominal value of one parameter associated with an increase (decrease) in the nominal value of another parameter leads to a positive correlation, whereas an increase (decrease) in one parameter associated with a decrease (increase) in another parameter leads to a negative correlation.

Simple correlation coefficients estimated between various factor input intensities and other parameters for different industry groups are shown in appendix C. The detailed analysis with respect to each one of the factors in question is given below.

Productive Capital Intensity (K/V)

Appendix C-1 gives the correlation coefficients of the productive capital intensity factor (K/V) with respect to labor intensity (L/V), capital/labor ratio (K/L), materials cost intensity (M/V), energy cost intensity (F/V), energy intensity (E/V), and composite index of energy (CIE). The labor intensity factor and capital intensity factors showed negative correlation in the following capital intensive industries: petroleum refineries, shipbuilding, and motor vehicle manufacture. A possible explanation for the negative relationship between these two parameters may be that these process industries are machine dominated, and hence involve large amounts of physical capital and relatively lower levels of labor input. The positive correlation observed between capital intensity (K/V) and labor intensity (L/V) in some of the labor intensive industries (such as the cotton and other textiles group, tobacco manufacture, and rubber products has been due to the increase in the labor intensity factor associated with more or less constant levels of capital intensity.

The correlation observed between capital intensity and the capital/labor ratio was positive for many of the industries. This occurred due to the increase in both the capital intensity factor and the capital/labor ratio. In other words, with the increase in capital intensity consequent to enlarged capacity levels, capital employed per unit of labor also increased, leading to a positive relationship between the two parameters. The negative relationship observed between capital intensity and the capital/labor ratio for tobacco manufacture, paper, textiles, and rubber products is attributable to the decrease in the capital/labor ratio as a result of increased involvement of labor in these industry groups.

The increase in the capital intensity factor associated with the increase in materials cost intensity (M/V), energy cost intensity (F/V), energy intensity (E/V), and composite index of energy (CIE) is clearly evident from the positive correlations observed between the factors in question for most industries. This implies that a high capital intensity factor leads to an increase in the materials cost factor as well as in energy related factors.

Labor Intensity Factor (L/V)

The correlation matrix of the labor intensity factor with other variables (such as K/L, M/V, F/V, E/V, and CIE) is given in appendix table C-2. The significant negative correlation observed between labor intensity and the capital/labor ratio for most the industry groups indicates the opposite relation existing between these two factors. This came about due to an increase in the capital/labor ratio and decrease in the labor intensity factor. The interaction between the capital/labor ratio (K/L) and the labor intensity factor (L/V) indirectly reflects the capital deepening of some of the industry groups. This also indicates that as investment is increased, there is not always an increase in employment potential consonant with the increased level of capital investment in the manufacturing sector. In other words, machines have to a considerable extent substituted for labor.

The correlations observed for the remaining parameters (such as M/V, F/V, E/V, and CIE) do not exhibit any definite relation between intensity and the parameters in question. In operations approximating a "labor-dominated extreme" (labor intensive processes), materials would play

a less dominant role than in less labor intensive ones, but no definite direct relationship can be associated between the materials intensity factor (M/V) and the labor intensity factor (L/V). Similarly, the energy parameters showed varying relationships with the labor intensity factor (L/V). However, a significant positive correlation existed between labor intensity (L/V) and energy intensity (E/V) in several industry groups, including sugar, tobacco, cotton and other textiles, rubber, petroleum refining, and railroad equipment.

Productive Capital/Labor Ratio (K/L)

Representing the size of an industry by the total capital employed per unit of labor engaged in production, there are clear indications of an increase in the capital/labor ratio for most of the industry groups, because of large-scale expansion or due to an increase in the number of units. Consequent to these factors, materials requirements increased over the years, since these are dependent on the capacity and output levels. Increased materials requirements led to increased materials cost intensity and hence the correlations observed between the capital/labor ratio and materials cost intensity showed a positive relationship (see appendix table C-3). The significant negative correlation seen for the tobacco industry between these two parameters, namely K/L and M/V, despite increased capacity levels, can be explained in the light of the decreased capital/labor ratio observed for that industry over the years owing to its high use of labor.

In most large, machine-dominated industries (such as nonferrous metals, miscellaneous products of coal and petroleum, motor vehicle manufacture, and iron and steel), the correlation observed between capital/labor ratio and energy cost intensity has been positive. This clearly indicates that the increase in capacity of plants has taken place through mechanization and machine-dominated production, resulting in increased levels of energy consumption and, hence, increased energy cost. However, poor positive correlations or negative correlations seen between these factors, namely K/L and F/V or K/L and E/V for other industry groups (such as tobacco, aircraft manufacture, and paper and paperboards), could indicate the responsiveness of these industries to relative factor costs.

Materials Cost Intensity (M/V)

The materials cost intensity factor (M/V) showed a positive relationship with energy cost intensity (F/V), energy intensity (E/V), and composite index of energy (CIE) for most industries (see appendix table C-4). The materials requirement and energy requirement of an industry tend to vary with output levels and operational efficiencies. The increased levels of capacity indicated by the increase in capital/labor ratios have concurrently led to increases in materials requirements as well as energy requirements.

Table 4-5 provides data showing the percentage of energy cost in relation to the sum of materials cost and energy cost for some of the industry groups in the manufacturing sector. It is evident that energy prices have gone up over the years for the majority of the industry groups and this makes it necessary to find ways and means for controlling energy costs in industries.

Table 4-5. Percent of Energy Input Costs in Relation to Total Materials and Energy Costs

	1971-72	1973-74
	Fuel cost divided by raw materials cost and fuel cost	Fuel cost divided by raw materials cost and fuel cost
Motor vehicles mfr.	2.02	2.20
Cement	39.58	43.67
Basic chemicals	11.81	13.44
Nonferrous metals	16.68	29.75
Paper & paperboards	23.66	28.10
Shipping	21.28	16.45
Textiles	8.40	12.62

Because of increased levels of both materials and energy consumption, the correlation observed between materials cost intensity (M/V) and other energy-related parameters showed a significant positive relationship.

Price Sensitivity of Energy Consumption in Manufacturing

In order to analyze the sensitivity of energy use to price changes, two series were built: one deals with consumption of various forms of energy and the other with prices. Two approaches were taken: (1) an analysis of the correlation between energy consumption and price levels through the use of various indicators such as energy intensity, energy cost intensity, unit cost intensity, and composite index of energy; (2) finding the energy cost intensity in manufacturing and the amount spent for different forms of energy in relation to aggregate energy expenditure. Appendix tables C-5 and C-6 give the correlation coefficients of the energy parameters.

An increase in energy cost in manufacturing is associated with an increase in energy consumption as evidenced by the positive correlation observed for the majority of the industry groups between energy cost intensity and energy intensity. Process-oriented industries (such as iron and steel, petroleum refineries, and nonferrous metals) have significant positive correlations with regard to these two parameters. The increase in the price per unit of energy leading to corresponding increases in energy cost is evident from the positive correlation between the unit cost intensity factor and energy cost intensity. However, the negative correlation observed for some of the industry groups between these two parameters may be due to the increase in the growth of value added by manufacture which reduces the intensity factors involved. The energy intensity factor and unit cost intensity factor showed negative correlations in most of the industry groups. This clearly indicates that an increase in the price per unit of energy reduces the energy intensity factor in manufacturing. This shows that price could be used to encourage energy conservation in manufacturing.

The sugar and tobacco industries showed a significant positive relation between energy intensity and unit energy cost intensity, since both these industry groups utilize much of their own waste products as fuels without incurring any cost. The significant positive correlation observed between the energy intensity factor and the composite index of energy for these two and most other industries clearly indicates the dominance of the energy consumption factor in the formulation of the index. It also throws light on the directional movement of energy consumption in

relation to price changes. That is, an increase in the price per unit of energy led to an increase in energy cost, and along with the increases in energy consumption in many industries over these years, led to a positive correlation with CIE.

Table 4-6 gives the energy cost intensity for different energy sources by industry for 1963, 1966, 1969, and 1971. The energy cost intensity factors for different forms of energy have increased over the years at varying rates, indicating in part the extent of influence that relative prices exert on consumption. For most of the industry groups considered in the analysis, the increase in the energy cost intensity factor for coal, petroleum products, fuel oil, and electricity is significant. In addition, table 4-7 gives the proportion of energy cost to aggregate energy expenditure by fuel and industry for the four years.

Both tables 4-6 and 4-7 give an indication of the structure of energy demand in manufacturing. For example, the proportion of individual fuel cost to aggregate fuel expenditure in manufacturing indicates the importance of a particular fuel. In Indian manufacturing, coal, petroleum products, and electricity make up the majority of fuel expenditures. Coal, in particular, and also to a large extent oil, have proved to be important sources of energy. The share of coal in the overall energy cost in manufacturing is on average about 40 percent. Fuel oil and petroleum products together make up about 20 to 30 percent of total energy cost for some industries. This kind of energy analysis throws light on the structure of production, and in particular, the technology employed in process manufacturing, providing valuable inputs for energy policy planning with regard to the manufacturing sector.

Econometric Estimation

It should be emphasized that any analysis of industrial activity in a developing country is liable to suffer from a number of limitations that arise out of the general state of industrialization in most less developed countries (LDCs). The most important of these limitations would be those related to:

Table 4-6. Energy Cost Intensity for Manufacturing Industries (By Source), 1963-64 to 1971-72

Industries	ASI code no.	Year	Energy source							
			Coal	Coke	Coal gas	Firewood	Charcoal	Petroleum products	Fuel oil	Electricity
1. Sugar	207	1963	0.0130	0.0050	Ng	0.0219	0.00005	0.0021	0.0198	0.0147
		1966	0.0082	0.0043	Ng	0.0109	0.0001	0.0077	0.0098	0.0141
		1969	0.0070	0.0034	Ng	0.0168	0.00002	0.0077	0.0110	0.0172
		1971	0.0108	0.0068	Ng	0.0243	0.00003	0.0177	0.0166	0.0313
2. Tobacco & cigarette manufcture	220	1963	0.0024	0.00003	NA	0.0009	0.0002	0.0017	0.0040	0.0047
		1966	0.0034	0.00009	NA	0.0008	0.0002	0.0057	0.0042	0.0059
		1969	0.0024	0.000007	NA	0.00006	0.00005	0.0041	0.0030	0.0055
		1971	0.0020	0.00002	NA	0.0002	0.0002	0.0046	0.0025	0.0054
3. Cotton spinning weaving	231	1963	0.0337	0.0002	0.00006	0.0002	0.0002	0.0010	0.0174	0.0779
		1966	0.0338	0.0002	0.00005	0.0003	0.0001	0.0031	0.0212	0.0944
		1969	0.0322	0.0004	0.00008	0.0003	0.0001	0.0020	0.0215	0.0977
		1971	0.0302	0.0002	0.0001	0.0003	0.0001	0.0021	0.0228	0.0981
4. Other textiles	232	1963	0.0961	0.0003	0.000005	0.0304	0.0006	0.0033	0.0290	0.0399
	233	1966	0.0607	0.0009	0.0001	0.0098	0.0002	0.0096	0.0230	0.0539
	239	1969	0.0711	0.0014	0.0001	0.0117	0.0001	0.0137	0.0223	0.0809
		1971	0.0391	0.0003	0.0003	0.0074	0.0001	0.0094	0.0182	0.0692
5. Paper & paperboards	271	1963	0.1961	0.0001	Ng	0.0009	Ng	0.0025	0.0355	0.1328
		1966	0.1660	0.0009	Ng	0.0098	Ng	0.0096	0.0238	0.0538
		1969	0.1386	0.0001	Ng	0.0007	Ng	0.0058	0.0515	0.1413
		1971	0.1840	0.0001	Ng	0.0008	Ng	0.0051	0.0511	0.1297
6. Rubber products	300	1963	0.01407	0.0001	0.00001	0.0002	0.00003	0.0021	0.0119	0.0355
		1966	0.0136	0.0001	0.00001	0.0001	0.00008	0.0035	0.0176	0.0519
		1969	0.0140	0.0001	0.000004	0.0001	0.00003	0.0044	0.0161	0.0472
		1971	0.0131	0.0002	0.000006	0.0002	0.00004	0.0039	0.0216	0.0461
7. Basic chemicals	311	1963	0.0885	0.0065	0.00004	0.0029	0.0013	0.0060	0.0519	0.1595
		1966	0.0723	0.0045	0.00001	0.0001	0.0005	0.0062	0.0572	0.2127
		1969	0.0522	0.0046	0.00002	0.0001	0.0004	0.0072	0.0689	0.1942
		1971	0.0416	0.0038	0.0021	0.0001	0.0002	0.0062	0.0737	0.1815
8. Petroleum refineries	321	1963	Ng	Ng	Ng	Ng	NA	0.0021	0.0011	0.0351
		1966	Ng	Ng	Ng	Ng	NA	0.0014	0.0010	0.0304
		1969	Ng	Ng	Ng	Ng	NA	0.0027	0.0025	0.0285
		1971	Ng	Ng	Ng	Ng	NA	0.0020	0.0011	0.0369
9. Miscellaneous products of coal and petroleum	329	1963	0.0087	0.00003	Ng	0.00002	Ng	0.0108	0.0129	0.0631
		1966	0.0076	0.00008	Ng	0.00001	Ng	0.0054	0.0247	0.2364
		1969	0.0039	0.00005	Ng	0.00001	Ng	0.0056	0.0248	0.1976
		1971	0.0146	0.0002	Ng	0.00001	Ng	0.0101	0.0153	0.1842
10. Cement	334	1963	0.7305	0.0007	Ng	0.00007	0.00002	0.0020	0.07040	0.1997
		1966	0.4826	0.0005	Ng	0.0001	0.00001	0.0107	0.1521	0.1865
		1969	0.6889	0.0019	Ng	0.00008	0.00001	0.0192	0.0733	0.2608
		1971	0.7453	0.0037	Ng	0.00008	0.000005	0.0194	0.1114	0.3770
11. Iron and steel	341	1963	0.2722	0.0403	0.0022	0.0013	0.0049	0.0026	0.0345	0.0857
		1966	0.1891	0.0320	0.0029	0.0007	0.0037	0.0182	0.0334	0.1041
		1969	0.2269	0.0402	0.0039	0.0012	0.0036	0.0199	0.0475	0.1589
		1971	0.2098	0.0494	0.0049	0.0014	0.0035	0.0218	0.0474	0.1327
12. Nonferrous metals	342	1963	0.0332	0.0134	0.00004	0.0010	0.0005	0.0012	0.0344	0.1225
		1966	0.0207	0.0232	0.000002	0.0003	0.0002	0.0046	0.0416	0.1385
		1969	0.0300	0.0008	0.0001	0.0003	0.0004	0.0024	0.0532	0.2057
		1971	0.0317	0.0012	0.00007	0.0004	0.0004	0.0048	0.0793	0.3634
13. Shipbuilding & repairing	381	1963	0.01353	0.0032	Ng	0.00008	0.0006	0.0071	0.0107	0.0245
		1966	0.0042	0.0032	Ng	0.00004	0.0001	0.0085	0.0059	0.0199
		1969	0.00292	0.0030	Ng	0.0003	0.0003	0.0076	0.0074	0.0193
		1971	0.00278	0.0020	Ng	0.00006	0.0001	0.0057	0.0064	0.0206
14. Railroad equipment	382	1963	0.0121	0.0076	0.0009	0.0003	0.00008	0.0013	0.0216	0.0310
		1966	0.0115	0.0076	0.0011	0.0010	0.00001	0.0048	0.0200	0.0425
		1969	0.0117	0.0085	0.0010	0.0003	0.00002	0.0070	0.0164	0.0586
		1971	0.0071	0.0087	0.0011	0.0002	0.0003	0.0052	0.0154	0.0554
15. Motor vehicle manufacture	383, 384	1963	0.0004	0.0008	0.0000003	0.00006	0.0002	0.0040	0.0130	0.0255
		1966	0.0004	0.0012	0.000001	0.00006	0.0001	0.0103	0.0135	0.0291
		1969	0.0005	0.0013	0.00003	0.00006	0.0003	0.0149	0.0077	0.0352
		1971	0.0011	0.0012	0.00001	0.00001	0.0003	0.0195	0.0119	0.0427
16. Aircraft manufacture	386	1963	NA	NA	NA	NA	NA	0.0065	0.0003	0.0132
		1966	NA	NA	NA	NA	NA	0.0080	0.0002	0.0231
		1969	NA	NA	NA	NA	NA	0.0135	0.0006	0.0207
		1971	NA	NA	NA	NA	NA	0.0142	0.0006	0.0207

Note: Ng denotes 'negligible' intensity.
NA denotes 'not applicable,' since that particular energy source was not being used in the process manufacture.

Table 4-7. Proportion of Energy Cost Intensity by Source to Aggregate Energy Expenditure in Manufacturing, 1963-64 to 1971-72

Industries	ASI code no.	Year	Energy source							
			Coal	Coke	Coal gas	Firewood	Charcoal	Petroleum products	Fuel oil	Electricity
1. Sugar	207	1963	0.171	0.066	Ng	0.287	0.0007	0.027	0.260	0.185
		1966	0.148	0.079	Ng	0.197	0.002	0.140	0.177	0.254
		1969	0.111	0.053	Ng	0.266	0.0004	0.122	0.173	0.272
		1971	0.106	0.067	Ng	0.239	0.003	0.115	0.163	0.307
2. Tobacco & cigarette manufacture	220	1963	0.171	0.002	NA	0.065	0.014	0.122	0.287	0.334
		1966	0.167	0.004	NA	0.041	0.010	0.280	0.206	0.289
		1969	0.157	0.004	NA	0.003	0.003	0.264	0.194	0.374
		1971	0.134	0.001	NA	0.013	0.015	0.302	0.181	0.350
3. Cotton spinning weaving	231	1963	0.257	0.002	0.0005	0.001	0.001	0.007	0.133	0.595
		1966	0.220	0.001	0.0003	0.002	0.0009	0.020	0.138	0.615
		1969	0.209	0.002	0.0005	0.001	0.0006	0.012	0.139	0.632
		1971	0.198	0.001	0.0008	0.002	0.0008	0.014	0.149	0.630
4. Other textiles	232	1963	0.406	0.002	Ng	0.177	0.003	0.019	0.157	0.233
	233	1966	0.381	0.005	Ng	0.016	0.001	0.060	0.149	0.338
	239	1969	0.352	0.002	Ng	0.058	0.0007	0.068	0.111	0.401
		1971	0.271	0.002	Ng	0.051	0.0007	0.065	0.126	0.480
5. Paper & paperboards	271	1963	0.532	0.0005	Ng	0.002	0.0002	0.006	0.096	0.360
		1966	0.442	0.0008	Ng	0.002	0.00007	0.019	0.123	0.410
		1969	0.409	0.0005	Ng	0.002	0.0002	0.017	0.152	0.417
		1971	0.398	0.0004	Ng	0.002	0.0003	0.016	0.164	0.417
6. Rubber products	300	1963	0.219	0.001	0.0001	0.004	0.0005	0.033	0.186	0.553
		1966	0.156	0.001	0.0001	0.001	0.0009	0.040	0.202	0.595
		1969	0.170	0.002	0.00006	0.001	0.0004	0.053	0.196	0.574
		1971	0.154	0.002	0.00007	0.002	0.0005	0.045	0.253	0.539
7. Basic chemicals	311	1963	0.279	0.020	0.0001	0.009	0.004	0.016	0.163	0.503
		1966	0.204	0.021	0.00004	0.0005	0.001	0.017	0.161	0.601
		1969	0.159	0.014	0.000008	0.0003	0.001	0.022	0.210	0.592
		1971	0.134	0.012	0.006	0.0003	0.0006	0.020	0.239	0.586
8. Petroleum refineries	321	1963	Ng	Ng	Ng	Ng	NA	0.055	0.029	0.914
		1966	Ng	Ng	Ng	Ng	NA	0.044	0.030	0.924
		1969	Ng	Ng	Ng	Ng	NA	0.081	0.076	0.841
		1971	Ng	Ng	Ng	Ng	NA	0.049	0.028	0.920
9. Miscellaneous products of coal and petroleum	329	1963	0.096	0.0003	Ng	0.0002	Ng	0.011	0.141	0.749
		1966	0.023	0.0002	Ng	0.00005	Ng	0.016	0.076	0.882
		1969	0.016	0.0002	Ng	0.00008	Ng	0.024	0.107	0.851
		1971	0.016	0.0002	Ng	0.00008	Ng	0.045	0.068	0.820
10. Cement	334	1963	0.727	0.0007	Ng	0.0007	Ng	0.002	0.070	0.199
		1966	0.579	0.0007	Ng	0.0002	Ng	0.012	0.182	0.225
		1969	0.643	0.001	Ng	0.00007	Ng	0.018	0.073	0.263
		1971	0.592	0.002	Ng	0.00007	Ng	0.015	0.088	0.299
11. Iron and steel	341	1963	0.613	0.090	0.005	0.003	0.011	0.005	0.077	0.192
		1966	0.492	0.083	0.007	0.001	0.009	0.047	0.086	0.270
		1969	0.457	0.081	0.008	0.002	0.007	0.040	0.095	0.308
		1971	0.402	0.094	0.009	0.002	0.006	0.041	0.091	0.350
12. Nonferrous metals	342	1963	0.161	0.065	0.0002	0.004	0.002	0.005	0.166	0.593
		1966	0.090	0.101	0.00001	0.001	0.001	0.020	0.191	0.603
		1969	0.102	0.002	0.0004	0.001	0.001	0.008	0.181	0.701
		1971	0.065	0.002	0.0001	0.0009	0.0009	0.010	0.164	0.754
13. Shipbuilding & repairing	381	1963	0.225	0.054	Ng	0.001	0.010	0.119	0.179	0.409
		1966	0.101	0.077	Ng	0.001	0.002	0.203	0.140	0.472
		1969	0.070	0.073	0.003	0.007	0.008	0.185	0.173	0.470
		1971	0.073	0.052	0.006	0.001	0.004	0.151	0.168	0.540
14. Railroad equipment	382	1963	0.161	0.102	0.012	0.004	0.001	0.017	0.287	0.413
		1966	0.130	0.085	0.012	0.011	0.0001	0.054	0.225	0.479
		1969	0.113	0.082	0.010	0.002	0.0002	0.067	0.158	0.564
		1971	0.076	0.093	0.012	0.002	0.003	0.055	0.164	0.591
15. Motor vehicle manufacture	383, 384	1963	0.010	0.019	0.00005	0.001	0.004	0.092	0.294	0.576
		1966	0.008	0.021	0.00003	0.001	0.002	0.185	0.246	0.534
		1969	0.009	0.022	0.0005	0.001	0.005	0.247	0.128	0.535
		1971	0.015	0.016	0.0002	0.0002	0.003	0.253	0.115	0.555
16. Aircraft manufacture	386	1963	NA	NA	NA	NA	NA	0.261	0.013	0.724
		1966	NA	NA	NA	NA	NA	0.255	0.006	0.736
		1969	NA	NA	NA	NA	NA	0.388	0.018	0.593
		1971	NA	NA	NA	NA	NA	0.399	0.018	0.582

Note: Ng denotes 'negligible' intensity.
NA denotes 'not applicable,' since that particular energy source was not being used in the process manufacture.

1. Data deficiences. These could be outright deficiencies in specific types of data or qualitative weaknesses that might result in unreliable estimates. Fortunately, industrial data in India are generally adequate and reliable (as discussed earlier), and barring the unjustifiably long lags in publication, analyses of the type presented in this report are quite feasible.

2. Constrained technology choices. There is evidence that choices of technology in a number of industries in LDCs are constrained by import restrictions and related problems, since indigenous research and development and innovative capabilities are not adequately developed. Consequently, technologies adopted for production are often not responsive to factor price differences. Typically, capital intensive technologies may be adopted under conditions of serious capital scarcity only because choices are limited by what is available from the exporting countries.

3. Deviations from the Production Possibility Frontier. Often production in many industries takes place far below the production possibility frontier, resulting from constraints in infrastructure, physical shortages or inputs such as power, or disequilibrium prices, particularly in the case of wages. In general, production decisions are made under a variety of constraints and economic distortions which result in suboptimal use of resources. In such instances, substitution between factors, the mix of inputs used, and their link with factor prices may deviate substantially from competitive and optimizing solutions. As a result, estimation of production relationships based on neoclassical production theory may not be truly meaningful.

Fully realizing the limitations mentioned above, we have estimated the diverse set of parameters presented in this report as an explanatory exercise. Wherever required, it is important to apply advanced estimation techniques in an attempt to explain the various adjustments which underlie developments in India's manufacturing industries, even though the constraints mentioned above may introduce problems in the estimation process and its outcome.

It should also be mentioned that the specification and estimation of translog production functions in particular is not without a plethora of problems even when dealing with more advanced economic systems. A particularly useful paper by Berndt (1976) analyzes the large differences in estimates from various studies dealing with capital/labor substitution in U.S. manufacturing. In essence, differences in estimated values can arise from a variety of reasons, including cyclical changes in the

utilization of factors, statistical biases, and adjustments toward constantly changing equilibrium values. Therefore, it is no surprise that estimates vary substantially from study to study in this field.

The primary objective of our study is to assess substitution possibilities between different factors of production explicitly including energy as an aggregated factor. At a disaggregated level we were interested in assessing price-induced interfuel substitution. We chose five sample industries--sugar, cotton textiles, inorganic fertilizers, cement, and iron and steel. The selected results of the estimation exercise are shown in tables 4-8 to 4-9 for the period 1965-1974.

Table 4-8. Allen Partial Elasticities for Specific Energy Forms for Selected Industry Groups

	σ_{13}	σ_{14}	σ_{15}	σ_{35}	Key
Sugar	0.1123	-0.0205	-0.0553	-0.2364	Coal - 1
Cotton textiles	0.0200	0.1039	-0.2454	-0.6369	Coke - 2
Inorganic fertilizers	-0.0158	-0.1434	0.2063	-0.7824	Petroleum products - 3
Cement	0.0035	-0.0070	0.0202	-0.0386	Fuel oil - 4
Iron and steel	-0.1164	2.1854	-1.3463	0.4241	Electricity - 5

We are limiting our discussion in this instance to only a few estimates of Allen partial elasticities which a priori appear to be interesting from the viewpoint of substitution possibilities or would be important for energy policy.

In general, the sugar industry shows limited substitution or complementarity between fuels. Weak substitutability (indicated by positive elasticities) exists between coal and petroleum products (kerosine), but there is some complementarity (indicated by negative elasticities) between coal and fuel oil, coal and electricity, and between petroleum products and electricity.

In the case of cotton textiles, coal and petroleum products, and coal and fuel oil, are weak substitutes. But coal and electricity, and

petroleum products and electricity, are complements, the partial elasticity for the latter being -0.636.

The inorganic fertilizers group shows low absolute values of partial elasticities except for petroleum products and electricity, which are complements. Fertilizer production, being process oriented, is power intensive, and undoubtedly the complementary relationships between petroleum products and electricity results from the use of naphtha as a feedstock and electricity as the major source of motive power.

The cement industry exhibits very weak substitution and complementary relationships among the different fuels. This could reflect the variation in technologies used and vintage of production plants. Quite naturally, the existing mix of wet and dry processes makes it difficult to obtain a clear aggregate picture for this group.

Partial elasticity estimates for iron and steel are useful not only because of the energy intensive nature of this industry, but also since the relatively small number of plants and extensive industrial concentration render this group amenable to policy descriptions. The low value for the partial elasticity between coal and petroleum products in this case can be conveniently ignored, but there is a high degree of substitution possible between coal and fuel oil (σ_{14} = 2.1854). On the other hand, coal and electricity are significant complements, but petroleum products and electricity are substitutes (σ_{35} = 0.4241), indicating the considerable among of diesel-fired captive power generated in steel plants.

Table 4-9. Allen Partial Elasticities for Aggregate Energy and Other Factors for Selected Industry Groups

	σ_{KL}	σ_{KE}	σ_{LE}	σ_{EM}	Key
Sugar	0.1205	-1.0242	-2.2679	0.4620	
Cotton textiles	0.5090	-2.1050	5.0346	-0.3345	K - capital
Inorganic fertilizers	0.2237	0.1900	-0.3995	0.1463	L - labor
Cement	0.3434	-0.2012	0.0116	-0.0756	E - energy
Iron and steel	-0.0920	-0.2068	0.0690	0.0537	M - materials

As shown in table 4-9, the sugar industry indicates strong complementary relationships between capital and energy, and labor and energy, respectively. There is also a somewhat weaker substitution linkage between energy and materials, which evidently arises from the use of bagasse as a fuel. The cotton textiles industry shows substitution between capital and labor (σ_{KL} = 0.0590), and a very substantial degree of substitution between labor and energy (σ_{LE} = 5.0364). But capital and energy, on the other hand, are strong complements, and energy and materials are weakly complementary.

In contrast, in the case of the inorganic fertilizer industry capital and labor, capital and energy, and energy and material, respectively, are weak substitutes, but labor and energy are complements. Partial elasticities in the cement industry also have low magnitudes, with the only estimate of any significance showing a weak substitution relationship between capital and labor. Similarly, the iron and steel industry is also characterized by low elasticities, including a weak complementary relationship between capital and energy.

Finally, in table 4-10, we have shown a sample of the estimates of price elasticities for capital, labor, aggregate energy, and materials. The elasticities in this table include some aberrations in the estimated values for own-price elasticities, namely n_{KK} for sugar, n_{EE} for cement, and n_{MM} for cotton textiles, all of which are positive even though small in magnitude. As for the cross-price elasticities, n_{KL} is positive for all

Table 4-10. Price Elasticities for Energy and Other Factors For Selected Industry Groups

	n_{KK}	n_{KL}	n_{KE}	n_{LL}	n_{LK}	n_{LE}	n_{EE}	n_{MM}
Sugar	0.2152	0.0121	-0.0163	-0.6104	-0.0099	-0.0362	-0.2294	-0.0661
Cotton textiles	-0.1428	0.0894	-0.0906	-0.3323	0.0321	0.2169	-0.4567	0.0076
Inorganic fertilizer	-0.0874	0.0271	0.0255	-0.0322	0.0227	-0.0473	-0.0671	-0.0336
Cement	-0.0103	0.0355	-0.0551	-0.0350	0.0483	0.0032	0.0635	-0.0076
Iron and steel	-0.0100	-0.0077	-0.0186	-0.0072	-0.0133	-0.0260	-0.0309	-0.0076

but the iron and steel group. The magnitudes are again low so that these results are in consonance with the partial elasticities presented earlier. On the other hand, n_{KE} shows a complementary relationship between capital and labor, except for the inorganic fertilizer group. Between labor and capital there is weak substitutability, except in the iron and steel group. The labor/energy relationship is somewhat more varied, with substitution in the case of cotton textiles, cement, and iron and steel, and complementarity in the case of the other two industries.

The own-price elasticity of labor in the sugar industry is significant but somewhat lower for cotton textiles. The own-price elasticities for capital as well as for materials are very low. This observation holds for the own-price elasticity of energy as well, except for the cotton textiles group, where it has a value of 0.4567. This appears consistent with the substitution possibilities (n_{LE} = 0.2169) between labor and energy.

Chapter 5

POLICY ANALYSIS AND CONCLUSIONS

It is difficult to analyze the implications of various policies in an industrializing economy, largely because desired objectives are difficult to articulate, and the time frame within which objectives should be evaluated is difficult to establish. Besides, a country may have to deviate from ideal solutions under a variety of constraints and compulsions. Choice of technology can be constrained by ideological preferences of aid givers as often as it is influenced by the lure of available credits, grants, and other favorable financing options.

It therefore serves no purpose to say that the industrial sector in India has been growing in capital intensity counter to the country's resource endowment and that as a policy this is undesirable. It is more meaningful to explore the structure of the manufacturing industries, pinpoint their rigidities and flexibilities, and analyze those influences which result in varying levels of utilization of different factors. Since the main focus of our study is on energy in the industrial sector, we will comment primarily on the implications of various policies and developments on industrial energy use, as revealed by the statistical analysis presented in this report.

Trend Analysis

The various ratios presented and discussed earlier provide useful insight into the trends that have characterized the evolution of manufacturing industries in India.

The increase in the capital intensity of the Indian economy in general is well known. At the macro level, capital/output ratios have shown a significant increase. While the industrial sector in particular has grown

in capital intensity over the past three decades, the increase has been uneven, for reasons described earlier. The most important factor appears to be the growth of heavy industry, despite the low levels of capacity utilization and industrial stagnation which have occurred from time to time. But within the limited time span covered in our analysis, we observe industry groups like cotton spinning and weaving, and other textiles, where capital intensity has remained steady or actually declined. The textiles group of industries, as it happens, is subject to wide swings, and trends change with variations in capacity utilization, which in turn are influenced overwhelmingly by world market conditions. But even in this group of industries, labor intensity has declined sharply during the period covered, and the capital/labor ratio has, consequently, been increasing.

Labor intensity in most industry groups shows a significant decrease over the time period studied. Even though circumstances behind this decrease varied over time as discussed earlier, there is a clear indication that changes in technology have been labor saving. This was not only true of industries which are relatively new, but it is true also of the more traditional ones which went through a process of modernization, such as the textiles group. Understandably, the scale of labor saving in the iron and steel, basic chemicals, and cement industries has been the most pronounced.

In the case of materials intensity, reductions in capacity utilization at the micro level are undoubtedly a major cause of increases in consumption of materials per unit of output. But it is difficult to quantify precisely the extent to which physical quantity increases in materials used per unit of output actually contributed to increases in the materials cost intensity in each industry group. Relative price changes were probably responsible for increases in this ratio in the rubber products, textiles, and iron and steel groups, but in the case of other industries--particularly those dominated by the public sector--low levels of performance largely resulted in greater materials consumption than warranted.

In the case of energy, if we first confine our discussion to energy intensity only, the trend in the sixties was overwhelmingly downward, except in the cement and nonferrous metals groups. But with increases in relative prices of energy, this did not result in a similar decline in energy cost intensity. International comparisons by other researchers have, however, established that despite these downward trends industrial

production in India has in general remained relatively energy intensive. Even the price increases of the seventies have not done much to change this picture.

These trends in factor intensity are by themselves useful, but for the purposes of our study a closer look at the linkages between different factors and their relative movements, particularly in relation to energy consumption, are of greater value. The ranking of different industries based on factor intensities has been reasonably stable over the period covered. But the measures of rank correlation presented earlier merit some further comment. The intensity of productive capital used showed a negative correlation with labor intensity but a positive correlation with energy cost intensity. Further, it showed a weak positive correlation with energy intensity and materials cost intensity. Significantly, the correlation between capital intensity and energy intensity has increased over time, indicating a growing complementarity between capital and energy. To some degree, this may very well have been in response to price changes for both these factors which brought about a substitution of other factors in technologies employed. Labor intensity, on the other hand, showed weak negative correlation with energy intensity, indicating the possibility of some substitution between these two factors.

Interindustry differences in rankings are quite substantial, and as would be expected, different industry groups are characterized by varying degrees of factor intensities. The changes in these values are brought out clearly by the graphical plots of factor intensities. But, understandably, there is no uniform pattern in the changes that have taken place between 1963 and 1971 as seen in these plots, although one could make generalizations of trends toward capital and energy cost intensification, but lower labor intensities. But these aspects can be examined further on the basis of the economic results from our estimation of industrial production functions.

Production Functions and Substitution Possibilities

The results presented and discussed earlier are quite extensive and could take up a great deal of space if they were to be discussed industry by industry, but since we are at this stage more concerned with general

policy implications, we will confine our discussion to questions that touch on the industrial sector as a whole.

Energy policy in India has to contend with the following realities:

1. The output of the industrial sector has grown with a greater than proportionate increase in capital inputs.

2. The cost intensity of energy in production has increased in most industry groups, even though in some cases the intensity of energy use has declined in the limited period covered in this study. But based on international comparisons by industry, India has highly energy intensive production techniques in operation.

The more important questions to consider in this context, therefore, are those relating to the linkage between capital and energy use and to the possibilities of substitution between different energy sources and between energy and other inputs. The use of the translog specification facilitates the derivation of various elasticities that provide indicative answers to these questions.

Elasticities were estimated using data for the periods 1965-1969, 1970-1974, 1965-1974, but we will comment on results from 1965-1975 only, since they naturally represent a longer run than the other two periods.

Significantly, the Allen partial elasticity σ_{KE} shows a complementary relationship for eleven out of the seventeen industry groups dealt with, albeit a weak relationship in most cases. The labor-energy partial elasticity in nine of the seventeen groups shows complementarity. It could be said, therefore, that capital and energy are complements in more cases than those in which they are substitutes. But more important than the nature of the relationship is its magnitude. The complementary relationships have values of σ_{KE} as high as -1.0242 for sugar, -2.1050 for cotton textiles, and -2.2819 for cotton ginning and pressing. In industry groups showing substitution effects, σ_{KE} is only as high as 1.0929 for tires and tubes, and 0.6895 for petroleum refineries. On the other hand, substitution effects for labor and energy as indicated by σ_{LE} are 1.1503 for cigarettes and tobacco manufacture, 5.0364 for cotton textiles, 14.9926 for cotton ginning and pressing, and 9.4878 for petroleum refineries. In those industries with labor and energy as complements, σ_{LE} is -2.2679 for sugar, -16.588 for woolen textiles, and -2.3958 for paperboards and strawboards.

We mentioned earlier some of the limitations inherent in the type of analysis attempted in this study, particularly when applied to a developing country. Hence, the observations listed above can at best be put forward cautiously as measures of real life production relationships. Within this cautious advocacy, however, we could say that, in general, capital and energy display greater complementarity than substitutability. But labor and energy are equally likely to be complements and substitutes. The most dominant values of all in the results obtained in this study are those of σ_{LE} for the two textile-based industry groups in the sample. Since textiles are a major industrial group in the country, policy prescriptions which can bring about substitution of energy by labor in these industries would be of particular interest. Technical studies in this area also appear to suggest a major potential for energy savings. Whereas initiative by the government in this direction would be welcome, much can be achieved in the long run by allowing market forces to act through pricing of energy on a rational basis.

It can also be concluded that the complementary link between capital and energy in a number of industry groups would result in greater energy intensity if current trends in capital deepening were to continue. This prospect requires that the energy implications of industrial expansion be carefully evaluated before specific investments are made in the future.

Interfuel Substitution

India is well endowed with coal resources. Fortunately, too, through a policy of restraint by the Government of India and the petroleum industry, consumption of petroleum products in the industrial sector has been kept at lower levels in comparison with many other countries, but there are possibilities for further reductions. From the viewpoint of national policy, therefore, any shifts away from consumption of petroleum to coal would be highly desirable. We would, accordingly, confine our present discussions principally to these energy sources, even though the econometric results presented and discussed earlier cover all five sources considered in this study.

If one studies the partial elasticities estimated in this study, σ_{13} for coal and petroleum products shows substitutability in nine of the

seventeen industry groups covered, but the values obtained indicate very weak linkages. In the case of σ_{14}, coal to fuel oil, a substitution relationship is estimated to exist in ten of the seventeen industries, with values as high as 1.6354 for organic heavy chemicals and 2.1854 for iron and steel. These indicate that there is at least some potential for substitution of coal for petroleum products or fuel oil in a fairly wide range of industries, with reasonably good prospects for this in at least two industry groups. It is likely, however, that even with post-1973 increases in oil prices and other mandatory measures restricting oil consumption, the estimated shift toward coal may not take place due to physical bottlenecks and uncertainties in the supply of coal.

Finally, it is also useful to assess the implications of partial elasticities for coal and electricity. We are at this stage not considering the link between fuel oil and electricity, since from the policy point of view there is little interest in this relationship, largely because the use of electricity for process heat is to be avoided on account of its high social cost and likewise the use of fuel oil for generating any form of power is not justified. σ_{51} for electricity and coal is positive in twelve of the seventeen industries studied, but these estimates are very low, indicating at best a weak substitution effect.

Quite apart from interfuel substitution possibilities, the estimated elasticities presented earlier also indicate a number of complementary relationships. These are not of any great consequence except in defining the energy profiles of production technologies in use. Also, they would be useful in determining priorities for interfuel substitution efforts, because wherever two fuels are complements, it may be reasonably expected that any substitution between them would not be possible without major changes in technology.

The research project on which this report is based can be regarded as exploratory in nature, but it does go well beyond work done in this field as applied to developing countries. Our work has been greatly facilitated by the availability of detailed data for estimating a wide range of ratios and production relationships. In this respect, India presents a good opportunity for research by virtue of the country's size, industrial development, and established data base, which despite being inordinately dated, is extensive and reliable enough to permit very comprehensive

research by social scientists. Undoubtedly, many studies of this type will be attempted in the future.

Policy Implications

The information presented in this report serves two purposes. First, a large amount of data has been collected, processed, and analyzed to provide useful information on the nature of industrial production in India. This information is in the form of a number of ratios showing changes in the intensity of various factors of production in sixteen different industry groups. This compilation of results would be directly useful in a number of studies both for making intercountry sectoral comparisons and intertemporal comparisons for India itself when data become available in the future. Secondly, we estimated a variety of production functions in major industry groups and derived elasticities both for four factor inputs as well as for major forms of energy used in the industrial sector in India. Fairly advanced techniques were employed for estimation based on the familiar translog specification.

Some well known economists with whom we discussed our approach for estimation of production functions expressed their reservations on using a methodology which is based on the assumption of price responsive choice of technology and factor combination. Their view was that these considerations, based on neoclassical assumptions, cannot be applied to modelling India's industrial sector. We fully realize the limitations of the econometric approach employing translog production functions, and these have been discussed earlier. But we are confident that the results obtained in this study can lead to useful indicative conclusions and are an essential step to perhaps introducing greater realism in subsequent research.

In general, it need hardly be repeated that the capital intensity of Indian industry has grown substantially. This has led to an increase in energy cost intensity, though there have been declines in physical intensity of energy use. However, the period covered in this analysis corresponds to a period of large industrial expansion and the establishment of long gestation manufacturing units. The energy intensity decline could very well have been a temporary effect brought about by an advance along

the learning curve representing a number of new industries. Whether these trends continued through the seventies is for subsequent research to discover.

Substitution possibilities between factors are quite widespread across industries, but barring some notable exceptions, are found to be weak. The most interesting cases of substitution potential is industries in the textiles group, and it appears the response to price changes in these would be significant. In the aggregate, of course, revisions in prices based on rational criteria would perhaps produce significant substitution responses for the country as a whole. This applies to possibilities of interfuel substitution as well which could bring about greater consumption of coal in preference to fuel oil and other petroleum products. In this respect, price changes by themselves would not be all important, but reliability of supply and the removal of physical constraints in the availability of electricity in particular would augment the price-related shift away from the consumption of petroleum products.

It is normal to end a research project by suggesting what further work needs to be done on the subject. We would not make an exception in this case, and in fact emphasize that global interest in the effect of industrial growth on energy use has now to shift from the developed to the developing countries. This is justified not only because of the little work done in this field in the less developed countries, but also because, in the aggregate, industrial growth in the Third World is expected to exceed that in the western countries in the next two decades.

Appendix A. Definition of Variables

No.	Items	Definition	Units used
1	2	3	4
1.	Fixed capital	Land, buildings (including those under construction), improvements to land and other construction, plant machinery and tools (including uninstalled), transport equipment, and other fixed assets such as furniture, fixtures, etc.	Million rupees
2.	Working capital	Stocks of materials, stores, fuels, semi-finished goods, including products and byproducts; cash on hand and at the bank, and the algebraic sum of sundry creditors.	Million rupees
3.	Productive capital	Fixed capital and working capital.	Million rupees
4.	Invested capital	The total of fixed capital and physical working capital, comprised of stocks of materials, stores, fuels, etc., semi-finished goods, including goods in process and finished products and byproducts as of the end of the year	Million rupees
5.	Number of persons employed	Sum total of persons engaged by each industry under various heads, such as workers, persons other than workers, etc.	Thousands (number)
6.	Manhours worked	Manhours worked during the year, calculated by multiplying the number of workers employed in each shift by the number of hours in the shift and aggregating products for all shifts and all working days of the year.	Million hours
7.	Wages and salaries	All payments made in cash to workers and persons other than workers as compensation for work done during the year.	Million rupees
8.	Materials consumed	All items of raw materials, chemicals, packing materials, and stores actually consumed during the year of manufacture. Materials consumed for repairs and maintenance are also included. It excludes the intermediate products, that is, goods produced within the factory and consumed for further manufacture.	Quantity in million tonnes
		The value of materials consumed is the cost at the factory.	Million rupees

Appendix A. (Cont.)

Sl. No.	Items	Definition	Units used
1	2	3	4
9.	Total input	All manufacturing costs of the industry. Included in it are the gross value of materials and fuels, etc., consumed, work done by the other concerns, products reported for sale last year but used for further manufacture, incidental expenditures on purchase of materials, etc., non-industrial services purchased (audit fees, legal expenses, etc.), depreciation and purchased value of goods sold in the same condition as purchased.	Million rupees
10.	Gross output	The aggregated value of products and byproducts manufactured for sale; work done for customers and sale of goods sold in the same condition as purchased; adjusted for the difference in stocks of semi-finished goods at the beginning and at the end of the year.	Million rupees
11.	Value added by manufacture	That part of the value of the product which is created in the factory, computed by deducting the gross value of input from the gross ex-factory value of output.	Million rupees
12.	Depreciation	The consumption of fixed capital during the year, estimated on the basis of cost of installation and working life of the fixed assets calculated in terms of the number of years.	Million rupees
13.	Fuels consumed	Energy input of manufacture, consisting of fuels such as coal, coke, coal gas, firewood, charcoal, petroleum products, fuel oil, and electricity. Details on electricity purchased and consumed have been separately collected.	Quantity in million tonnes or liters or million kWh and value in million rupees

Appendix Table B-1. Rank Correlation of Parameters of Production for the Year 1963

Variables	Productive capital intensity (K/V)	Labor intensity (L/V)	Productive capital/labor ratio (K/L)	Material cost intensity (M/V)	Energy cost intensity (F/V)	Energy intensity (E/V)	Unit energy cost intensity (U/V)	Composite index of energy (CIE)
Productive capital intensity (K/V)	1.00							
Labor intensity (L/V)	-0.250 (-.97)	1.00						
Productive capital/labor ratio (K/L)	0.809** (5.15)	-0.735** (4.06)	1.00					
Materials cost intensity (M/V)	0.15 (0.57)	0.00 (0.0)	0.047 (0.18)	1.00				
Energy cost intensity (F/V)	0.332 (1.32)	0.126 (0.48)	0.076 (0.29)	-0.188 0.72	1.00			
Energy intensity (E/V)	0.112 (0.42)	0.094 (0.35)	-0.071 (0.25)	0.1 0.38	0.932** 9.65	1.00		
Unit energy cost intensity (U/V)	0.388 (1.56)	-0.244 (-0.94)	0.438 (1.82)	-0.026 (-.10)	-0.182 (-.69)	-0.406 (-.166)	1.00	
Composite index of energy (CIE)	0.124 (0.47)	0.074 (0.28)	-0.044 (-0.14)	0.003 (0.01)	0.818** (5.31)	0.926* (9.21)	-0.482# (-2.06)	1.00

Note: Figures in parentheses indicate 't' test values: $H_0 : P = 0$.

**Correlation is significantly different from '0' with confidence of 95 percent and 99 percent (or) 5 percent and 1 percent level of significance.

#Correlation is significantly different from '0' with confidence of 95 percent or 5 percent level of significance.

*Correlation is significantly different from '0' with confidence of 99 percent of 1 percent level of significance.

Appendix Table B-2. Rank Correlation of Parameters of Production for the Year 1966

Variables	Productive capital intensity (K/V)	Labor intensity (L/V)	Productive capital/labor ratio (K/L)	Material cost intensity (M/V)	Energy cost intensity (F/V)	Energy intensity (E/V)	Unit energy cost intensity (U/V)	Composite index of energy (CIE)
Productive capital intensity (K/V)	1.00							
Labor intensity (L/V)	0.356 (-1.47)	1.00						
Productive capital/labor ratio (K/L)	0.871** (6.62)	-0.682** (-3.49)	1.00					
Materials cost intensity (M/V)	0.124 (0.47)	0.306 (1.2)	-0.024 (-0.09)	1.00				
Energy cost intensity (F/V)	0.509# (2.21)	-0.044 (-0.17)	0.344 (1.37)	-0.082 (-0.31)	1.00			
Energy intensity (E/V)	0.329 (1.31)	-0.085 (-0.32)	0.238 (0.92)	-0.129 (-0.49)	0.938** (10.13)	1.00		
Unit energy cost intensity (U/V)	0.194 (0.74)	-0.097 (-0.36)	0.297 (1.16)	-0.053 (-0.2)	-0.1 (-0.38)	-0.212 (-0.81)	1.00	
Composite index of energy (CIE)	0.144 (0.54)	-0.235 (-0.91)	0.135 (0.51)	-0.253 (-0.98)	0.812** (5.2)	0.912** (0.31)	-0.350 (-1.40)	1.00

Note: Figures in parentheses indicate 't' test values: $H_o : P = 0$.

**Correlation is significantly different from '0' with confidence of 95 percent and 99 percent (or) 5 percent and 1 percent level of significance.

#Correlation is significantly different from '0' with confidence of 95 percent or 5 percent level of significance.

*Correlation is significantly different from '0' with confidence of 99 percent of 1 percent level of significance.

Appendix Table B-3. Rank Correlation of Parameters of Production for the Year 1969

Variables	Productive capital intensity (K/V)	Labor intensity (L/V)	Productive capital/labor ratio (K/L)	Material cost intensity (M/V)	Energy cost intensity (F/V)	Energy intensity (E/V)	Unit energy cost intensity (U/V)	Composite index of energy (CIE)
Productive capital intensity (K/V)	1.00							
Labor intensity (L/V)	-0.350 (-1.4)	1.00						
Productive capital/labor ratio (K/L)	0.882** (7.02)	-0.703** (-3.7)	1.00					
Materials cost intensity (M/V)	0.112 (0.42)	0.109 (0.41)	0.062 (0.23)	1.00				
Energy cost intensity (F/V)	0.518* (2.26)	0.059 (0.22)	0.318 (1.25)	-0.024 (-0.09)	1.00			
Energy intensity (E/V)	0.444 (1.85)	-0.035 (-0.13)	0.315 (1.24)	-0.035 (-0.13)	0.956** (12.18)	1.00		
Unit energy cost intensity (U/V)	0.291 (1.14)	0.003 (0.01)	0.136 (0.52)	-0.103 (-0.39)	-0.056 (-0.21)	-0.185 (-0.71)	1.00	
Composite index of energy (CIE)	0.309 (1.21)	-0.124 (-0.47)	0.259 (1.00)	0.209 (-0.8)	0.900** (7.73)	0.938** (10.15)	-0.265 (-1.03)	1.00

Note: Figures in parentheses indicate 't' test values: $H_o : P = 0$.

**Correlation is significantly different from '0' with confidence of 95 percent and 99 percent (or) 5 percent and 1 percent level of significance.

*Correlation is significantly different from '0' with confidence of 95 percent or 5 percent level of significance.

*Correlation is significantly different from '0' with confidence of 99 percent of 1 percent level of significance.

Appendix Table B-4. Rank Correlation of Parameters of Production for the Year 1971

Variables	Productive capital intensity (K/V)	Labor intensity (L/V)	Productive capital/labor ratio (K/L)	Material cost intensity (M/V)	Energy cost intensity (F/V)	Energy intensity (E/V)	Unit energy cost intensity (U/V)	Composite index of energy (CIE)
Productive capital intensity (K/V)	1.00							
Labor intensity (L/V)	-0.379 (-1.531)	1.00						
Productive capital/labor ratio (K/L)	0.838** (5.87)	-0.762** (-4.2)	1.00					
Materials cost intensity (M/V)	0.315 (1.24)	0.250 (0.97)	0.142 (0.53)	1.00				
Energy cost intensity (F/V)	0.579** (2.62)	0.103 (0.39)	0.297 (1.16)	0.374 (1.51)	1.00			
Energy intensity (E/V)	0.453 (1.90)	-0.038 (-0.14)	0.215 (0.82)	0.203 (0.78)	0.865** (6.44)	1.00		
Unit energy cost intensity (U/V)	0.421 (1.73)	-0.094 (-0.35)	0.332 (1.32)	0.138 (0.52)	-0.112 (-0.42)	-0.203 (-0.79)	1.00	
Composite index of energy (CIE)	0.324 (1.28)	-0.2 (-0.76)	0.209 (0.80)	-0.032 (-0.12)	0.729** (3.99)	0.921** (8.82)	0.382 (-1.55)	1.00

Note: Figures in parentheses indicate 't' test values: $H_o : P = 0$.

**Correlation is significantly different from '0' with confidence of 95 percent and 99 percent (or) 5 percent and 1 percent level of significance.

#Correlation is significantly different from '0' with confidence of 95 percent or 5 percent level of significance.

*Correlation is significantly different from '0' with confidence of 99 percent of 1 percent level of significance.

Appendix Table C-1. Correlation Matrix of Capital Intensity with Respect to Other Parameters of Production

Industries	ASC code	Labor intensity (L/V)	Productive capital/labor ratio (K/L)	Materials cost intensity (M/V)	Energy cost intensity (F/V)	Energy intensity (E/V)	Unit energy cost intensity (U/V)	Composite index of energy (CIE)
1. Sugar and gur	207	0.545 (1.72)	0.085 (0.23)	0.356 (1.09)	0.615# (2.07)	0.765** (3.14)	0.701** (2.6)	0.543 (1.71)
2. Tobacco	220	0.702# (2.42)	-0.096 (-0.24)	0.301 (0.77)	0.664# (2.18)	0.737** (2.67)	0.698# (2.39)	0.619 (1.93)
3. Cotton textiles	231	0.902** (5.11)	-0.820** (-3.5)	-0.625# (-.196)	-0.214 (-0.54)	0.797 (3.23)**	-0.475 (-1.32)	0.779** (3.04)
4. Other textiles	232, 233, 239	0.685# (2.31)	-0.404 (-1.06)	0.436 (1.19)	0.767** (2.99)	0.910** (5.37)	0.251 (0.66)	0.796** (3.22)
5. Paper and paperboards	271	0.888** (4.67)	-0.699# (-2.4)	0.793** (3.19)	0.944** (7.04)	0.153 (0.38)	0.891** (4.82)	-0.587 (-1.78)
6. Rubber products	300	0.804** (3.32)	-0.363 (0.96)	0.445 (1.22)	0.387 (1.03)	0.844** (3.86)	0.717# (2.52)	0.417 (1.12)
7. Basic chemicals	321	0.030 (0.70)	0.145 (0.36)	0.891** (4.81)	0.798** (3.24)	0.188 (0.47)	0.061 (0.15)	-0.044 (-0.11)
8. Petroleum refineries	311	-0.700** (-2.6)	-0.345 (-0.97)	-0.100 (-0.27)	0.699** (2.59)	0.710** (2.67)	0.393 (1.13)	0.695# (2.56)
9. Miscellaneous products of coal and petroleum	329	0.949* (7.36)	0.628# (1.97)	0.765** (2.91)	0.743** (2.72)	0.561 (1.66)	0.958** (8.21)	0.150 (0.37)
10. Cement	334	0.018 (0.05)	0.764** (3.13)	0.924** (6.37)	0.877** (4.83)	-0.361 (-1.02)	0.479 (1.44)	-0.530 (-1.65)
11. Iron and steel	341	0.325 (0.84)	0.606 (1.86)	0.428 (1.16)	0.611 (1.89)	0.739** (2.61)	0.001 (0.00)	0.789** (3.15)
12. Nonferrous metals	342	0.125 (0.33)	0.847** (4.22)	0.878** (4.86)	0.827** (3.89)	0.689# (2.51)	0.372 (1.06)	0.530 (1.85)
13. Shipbuilding and repair	381	-0.47 (-1.43)	0.499 (1.53)	0.672# (2.4)	-0.527 (-1.64)	-0.200 (-0.54)	-0.077 (-0.2)	-0.120 (-0.32)
14. Railroad equipment	382	0.507 (1.44)	0.33 (0.86)	0.871** (4.35)	0.55 (0.13)	0.367 (0.97)	0.157 (0.39)	0.049 (0.12)
15. Motor vehicle manufacture	383, 384	-0.431 (-1.17)	0.600 (1.84)	0.746** (2.75)	0.891** (4.8)	0.368 (0.97)	-0.016 (-0.04)	-0.851** (-3.98)
16. Aircraft manufacture	386	0.720# (2.54)	0.660# (2.15)	-0.387 (-1.03)	-0.807** (-3.35)	-0.433 (-1.18)	0.610 (1.89)	-0.525 (-1.51)

Note: Figures in parentheses indicate t-test values, H : P = 0.

** Correlation is significantly different from 0 with confidence of 95 percent and 99 percent (OR) 5 percent and 1 percent level of significance.

Correlation is significantly different from 0 with confidence of 95 percent (OR) 5 percent level of significance.

* Correlation is significantly different from 0 with confidence of 99 percent (OR) 1 percent level of significance.

Appendix Table C-2. Correlation Matrix of Labor Intensity with Respect to Other Parameters

Industries	ASC code	Productive capital/labor ratio (K/L)	Materials cost intensity (M/V)	Energy cost intensity (F/V)	Energy intensity (E/V)	Unit energy cost intensity (U/V)	Composite index of energy (CIE)
1. Sugar and gur	207	-0.783** (3.38)	-0.545 (-1.72)	-0.215 (-0.58)	0.766** (3.15)	0.76** (3.1)	0.897** (5.37)
2. Tobacco	220	-0.707** (-2.76)	0.645# (2.07)	0.981** (12.26)	0.743** (2.72)	0.550 (1.61)	0.498 (1.41)
3. Cotton textiles	231	-0.984** (-13.49)	-0.655# (2.13)	-0.577 (-1.73)	0.819* (3.5)	-0.479 (-1.33)	0.794** (3.20)
4. Other textiles	232, 233, 239	-0.932** (-.631)	-0.041 (-0.17)	0.44 (1.2)	0.708# (2.46)	0.509 (1.45)	0.791** (3.17)
5. Paper and paperboards	271	-0.950** (-7.49)	0.616 (1.92)	0.899** (5.01)	0.465 (1.29)	0.810** (3.38)	-0.350 (-0.92)
6. Rubber products	300	-0.843** (-3.84)	0.112 (0.28)	-0.029 (-0.07)	0.746** (2.74)	0.982** (12.80)	0.031 (0.08)
7. Basic chemicals	311	-0.982** (-12.5)	0.093 (0.23)	0.359 (0.94)	0.299 (0.77)	0.936** (6.49)	-0.515 (-1.47)
8. Petroleum refineries	321	-0.480 (-1.45)	-0.138 (-0.37)	0.725** (2.78)	0.746** (2.97)	0.405 (1.17)	0.735** (2.87)
9. Miscellaneous products of coal and petroleum	329	0.364 (0.96)	0.678# (2.26)	0.635# (2.01)	0.540 (1.57)	0.984** (13.45)	0.209 (0.52)
10. Cement	334	-0.611# (-2.04)	0.116 (0.31)	0.344 (0.97)	0.523 (1.62)	0.364 (1.03)	0.370 (1.04)
11. Iron and steel	341	-0.552 (-1.62)	-0.408 (-1.10)	-0.138 (-0.34)	-0.208 (-0.52)	0.911** (5.4)	0.432 (1.17)
12. Nonferrrous metals	342	-0.410 (-1.19)	0.154 (0.41)	-0.086 (-0.23)	0.137 (0.37)	0.741** (2.92)	0.178 (0.48)
13. Shipbuilding and repair	381	-0.962** (-9.29)	-8.65** (-4.56)	0.317 (0.88)	-0.506 (-1.55)	0.661# (2.33)	-0.589 (-1.39)
14. Railroad equipment	382	-0.644# (-2.06)	0.652# (2.1)	-0.377 (-1.00)	0.724# (2.57)	0.58 (1.74)	0.691# (2.34)
15. Motor vehicle manufacture	383, 384	-0.943 (-6.94)	-0.301 (-0.77)	-0.690# (-2.34)	-0.06 (-0.15)	0.656# (2.13)	0.417 (1.12)
16. Aircraft manufacture	386	-0.029 (-0.07)	-0.25 (-0.63)	-0.893** (-4.87)	-0.636# (-2.02)	0.798** (3.25)	-0.681# (-2.28)

Note: Figures in parentheses indicate t-test values, H : P = 0.

** Correlation is significantly different from 0 with confidence of 95 percent and 99 percent (OR) 5 percent and 1 percent level of significance.

Correlation is signficiantly different from 0 with confidence of 95 percent (OR) 5 percent level of significance.

[illegible] confidence of 99 percent (OR) 1 percent level of significance.

Appendix Table C-3. Correlation Matrix of Capital/Labor Ratio with respect to Other Parameters of Production

Industries	ASC code	Materials cost intensity (M/V)	Energy cost intensity (F/V)	Energy intensity (E/V)	Unit energy cost intensity (U/V)	Composite index of energy (CIE)
1. Sugar and gur	207	0.899** (5.42)	0.713** (2.71)	-0.316 (-0.88)	0.375 (-1.07)	-0.828∅ (-2.13)
2. Tobacco	220	-0.794** (-3.2)	-0.753** (-2.8)	-0.229 (0.58)	0.025 (0.06)	0.037 (0.09)
3. Cotton textiles	231	0.683∅ (2.29)	0.690∅ (2.34)	-0.82** (-3.51)	0.496 (1.4)	-0.793** (-3.1)
4. Other textiles	232, 233, 239	0.308 (0.79)	-0.206 (-0.52)	-0.448* (-1.23)	-0.58 (-1.74)	-0.597 (-1.82)
5. Paper and paperboards	271	-0.417 (-1.12)	-0.764** (-2.9)	-0.638∅ (-2.43)	-0.64∅ (-2.04)	0.123 (0.3)
6. Rubber products	300	0.178 (0.44)	0.364 (0.96)	-0.419 (-1.13)	-0.89 (-4.79)	0.352 (0.92)
7. Basic chemicals	311	0.069 (0.17)	-0.205 (-0.51)	0.222 (0.56)	-0.929** (6.16)	0.544 (1.59)
8. Petroleum refineries	321	0.107 (0.29)	-0.284 (-0.78)	-0.379 (-1.09)	-0.257 (-0.7)	-0.357 (-1.01)
9. Miscellaneous products of coal and petroleum	329	0.632∅ (2.00)	0.670∅ (2.21)	0.336 (0.87)	0.439 (1.20)	-0.149 (-0.37)
10. Cement	334	0.59 (1.93)	0.417 (1.21)	-0.659∅ (-2.32)	-0.194 (0.52)	-0.708** (-2.64)
11. Iron and steel	341	0.727** (2.59)	0.686∅ (2.31)	0.837** (3.75)	-0.743** (-2.72)	0.363 (0.95)
12. Nonferrous metals	342	0.715** (2.71)	0.783** (3.33)	0.513** (0.58)	-0.011 (-0.03)	0.328 (0.92)
13. Shipbuilding and repair	381	0.890** (5.18)	-0.169 (-0.51)	0.627∅ (2.08)	-0.581 (-1.93)	0.702** (2.61)
14. Railroad equipment	382	0.057 (0.14)	0.444 (1.21)	-0.486 (-1.36)	-0.491 (-1.36)	-0.714∅ (-2.50)
15. Motor vehicle manufacture	383, 384	0.523 (1.5)	0.778** (3.03)	0.33 (0.86)	-0.462 (-1.28)	-0.442 (-1.21)
16. Aircraft manufacture	386	-0.219 (-0.55)	-0.221 (-0.56)	-0.033 (-0.08)	0.046 (0.11)	-0.090 (-0.227)

Note: Figures in parentheses indicate t-test values, H : P = 0.

** Correlation is significantly different from 0 with confidence of 95 percent and 99 percent (OR) 5 percent and 1 percent level of significance.

∅ Correlation is signficiantly different from 0 with confidence of 95 percent (OR) 5 percent level of significance.

* Correlation is significantly different from 0 with confidence of 99 percent (OR) 1 percent level of significance.

Appendix Table C-4. Correlation Matrix of Materials Cost Intensity with Respect to Other Parameters of Production

Industries	ASC code	Energy cost intensity (F/V)	Energy intensity (E/V)	Unit energy cost intensity (U/V)	Composite index of energy (CIE)
1. Sugar and gur	207	0.757** (3.06)	-0.112 (-0.30)	-0.17 (-0.46)	-0.435 (-1.28)
2. Tobacco	220	0.647** (2.08)	0.133 (0.35)	-0.090 (-0.22)	-0.104 (-0.26)
3. Cotton textiles	231	0.478 (1.33)	-0.810** (-3.39)	0.657# (2.13)	-0.733** (-2.64)
4. Other textiles	232, 233, 239	0.686# (2.31)	0.409 (1.1)	-0.165 (-0.41)	0.157 (0.39)
5. Paper and paperboards	271	0.815** (3.44)	-0.190 (-0.40)	0.782** (3.08)	-0.711# (-0.48)
6. Rubber products	300	0.894** (4.9)	0.677# (2.25)	-0.060 (-0.15)	0.676# (2.25)
7. Basic chemicals	311	0.942** (6.85)	0.341 (0.89)	0.049 (0.12)	0.100 (0.25)
8. Petroleum refineries	321	0.095 (0.25)	0.359 (1.02)	-0.855** (-4.01)	0.335 (0.94)
9. Miscellaneous products of coal and petroleum	329	0.986** (14.47)	0.901** (5.07)	0.655# (2.13)	0.497 (1.40)
10. Cement	334	0.962** (9.34)	-0.139 (-0.37)	0.351 (0.99)	-0.296 (-0.82)
11. Iron and steel	341	0.886** (4.68)	0.869** (4.31)	-0.585 (-1.177)	0.377 (1.00)
12. Nonferrrous metals	342	0.947** (7.77)	0.874** (4.76)	0.481 (1.45)	0.757** (3.06)
13. Shipbuilding and repair	381	-0.297 (-0.82)	0.338 (0.95)	-0.537 (-1.68)	0.411 (1.19)
14. Railroad equipment	382	0.262 (0.66)	0.386 (1.03)	0.513 (1.47)	-0.001 (0.00)
15. Motor vehicle manufacture	383, 384	-0.786** (3.11)	0.744** (2.73)	0.328 (0.85)	-0.390 (-1.04)
16. Aircraft manufacture	386	0.383 (1.02)	0.457 (1.26)	-0.561 (-1.66)	0.498 (1.41)

Note: Figures in parentheses indicate t-test values, H : P · 0.

** Correlation is significantly different from 0 with confidence of 95 percent and 99 percent (OR) 5 percent and 1 percent level of significance.

Correlation is significantly different from 0 with confidence of 95 percent (OR) 5 percent level of significance.

Appendix Table C-5. Correlation Matrix of Energy Cost Intensity with Respect to Other Parameters of Production

Industries	ASC code	Energy intensity (E/V)	Unit energy cost intensity (U/V)	Composite index of energy (CIE)
1. Sugar and gur	207	0.365 (1.04)	0.137 (0.37)	-0.041 (-0.11)
2. Tobacco	220	-0.761** (2.87)	0.581 (1.75)	0.541 (1.57)
3. Cotton textiles	231	-0.518 (-1.48)	0.389 (1.04)	-0.516 (-1.48)
4. Other textiles	232, 233, 239	0.546 (1.6)	0.532 (1.54)	0.310 (0.8)
5. Paper and paperboards	271	0.216 (0.54)	0.867** (4.26)	-0.510 (-1.45)
6. Rubber products	300	0.614 (1.9)	-0.201 (-0.5)	0.715# (2.51)
7. Basic chemicals	311	0.368 (0.97)	0.304 (0.78)	-0.047 (-0.11)
8. Petroleum refineries	321	0.806** (3.6)	0.173 (0.47)	0.739** (2.90)
9. Miscellaneous products of coal and petroleum	329	0.839** (3.78)	0.632# (2.00)	0.405 (1.09)
10. Cement	334	-0.009 (-0.02)	0.397 (1.15)	-0.206 (-0.56)
11. Iron and steel	341	0.955** (7.90)	-0.277 (0.71)	0.705# (2.43)
12. Nonferrrous metals	342	0.920** (6.22)	0.311 (0.87)	0.806** (3.61)
13. Shipbuilding and repair	381	0.525 (1.63)	-0.239 (-0.65)	0.389 (1.19)
14. Railroad equipment	382	-0.518 (-1.48)	0.233 (0.59)	0.888** (-4.73)
15. Motor vehicle manufacture	383, 384	0.355 (0.393)	-0.125 (-0.31)	-0.751** (-2.79)
16. Aircraft manufacture	386	0.727** (2.59)	-0.603# (-2.29)	0.848** (3.91)

Note: Figures in parentheses indicate t-test values, H : P = 0.

** Correlation is significantly different from 0 with confidence of 95 percent and 99 percent (OR) 5 percent and 1 percent level of significance.

Correlation is signficiantly different from 0 with confidence of 95 percent (OR) 5 percent level of significance.

* Correlation is significantly different from 0 with confidence of 99 percent (OR) 1 percent level of significance.

Appendix Table C-6. Correlation Matrix of Energy Intensity with Respect to Other Parameters of Production

Industries	ASC code	Unit energy cost intensity (U/V)	Composite index of energy (CIE)
1. Sugar and gur	207	0.653# (2.28)	0.912** (5.90)
2. Tobacco	220	0.947** (7.19)	0.949** (7.39)
3. Cotton textiles	231	-0.864** (-4.2)	0.979** (11.75)
4. Other textiles	232, 233, 239	-0.026 (-0.06)	0.935** (6.44)
5. Paper and paperboards	271	-0.121 (-0.30)	0.643# (2.06)
6. Rubber products	300	0.610 (1.88)	0.566 (1.68)
7. Basic chemicals	311	-0.043 (-0.11)	0.631# (1.99)
8. Petroleum refineries	321	-0.181 (-0.49)	0.986** (15.83)
9. Miscellaneous products of coal and petroleum	329	0.458 (1.26)	0.811** (3.39)
10. Cement	334	-0.586 (-1.96)	0.966** (9.93)
11. Iron and steel	341	-0.413 (-1.11)	0.724# (2.57)
12. Nonferrous metals	342	0.335 (1.01)	0.967** (10.03)
13. Shipbuilding and repair	381	-0.604# (-2.01)	0.985** (15.09)
14. Railroad equipment	382	-0.031 (-0.08)	0.739** (2.69)
15. Motor vehicle manufacture	383, 384	0.525 (1.51)	(0.129) (0.32)
16. Aircraft manufacture	386	-0.736** (-2.66)	0.955** (6.60)

Note: Figures in parentheses indicate t-test values, H : P = 0.

** Correlation is significantly different from 0 with confidence of 95 percent and 99 percent (OR) 5 percent and 1 percent level of significance.

Correlation is signficiantly different from 0 with confidence of 95 percent (OR) 5 percent level of significance.

* Correlation is significantly different from 0 with confidence of 99 percent (OR) 1 percent level of significance.

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