ECONOMICS OF FUEL SUBSTITUTION WITH SPECIAL REFERENCE TO INDIAN COMPANIES

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By

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DECLARATION

I hereby declare that the work embodied in this dissertation entitled, "Economics of Fuel Substitution with Special Reference to Indian Companies" has been carried out by me under the supervision of Prof. B. Kamaiah in the Department of Economics, University of Hyderabad. The dissertation or part thereof has not been submitted for any other degree or diploma or any other University.

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I hereby affirm that Ms. Sai Sailaja Bharatam has carried out the research work embodied in the present thesis under my supervision and guidance. I recommend her thesis entitled, "Economics of Fuel Substitution with Special Reference to Indian Companies" for submission for the Degree of Doctor of Philosophy in Economics.

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Chapter 1

Introductory Background and Objectives of the Study

1.0. Introduction

Energy is consumed in the industrial sector by a diverse group of industries including manufacturing, mining, and construction and for a wide range of activities, such as process and assembling uses, space conditioning, and lighting. Industrial sector energy demand varies across regions and countries of the world, based on the level and mix of economic activity, technological development, and population growth, among other factors.

According to the International Energy Agency (IEA) industrial sector is the largest of all sectors, consuming about 50 percent of delivered energy worldwide in 2003. Compared to other end use sectors industrial energy use is projected to grow more rapidly. Worldwide, energy consumption in the industrial sector is expected to increase on an average of 2.4 percent per year by 2030, as compared to the present ratio of 1 percent average annual growth in the world's population. Industrial energy consumption is increasing in all countries and regions. One way of looking at the future of world energy markets is to consider trends in energy consumption at the end-use sectoral level.

Fossil fuels play a vital role in meeting the energy demand of many industrial processes. For example manufacturing industries rely on a variety of fuels for meeting their energy needs. Using two or more fuels for production is not new and is possible if the machinery supports. For instance, industrial boilers are designed to burn coal, natural gas, distillate fuel oil, or residual fuel oil. Also there are boilers that are capable of switching to two or more fuels for making an un-disrupting production. The system of switching one to other fuel in the energy literature is known as inter-fuel substitution. Fuel substitution till the date is possible only with fossil fuels or with fuels which share homogenous combustion properties. The process of switching fuels in a firm is determined by two important factors a) availability of the fuel and b) prices of these available fuels. The purview of the present work is to measure the price responses of the fuels that are available for production process.

1.1. Research Problem Defined

Measuring inter-fuel substitution in the industrial sector would help the policy makers and industry to explore many dimensions of their expansion through cost minimization. The empirical work on fuel substitution and the impact of fuel substitution in deciding the future of fuels individually for economic development was given a minimal importance. Also the literature on the issue of fuel substitution in developing countries like India is relatively thin in the area of energy economics. The economics of fuel substitution has its roots in micro economic production theory.

There are alternative approaches to examining the issue of inter-fuel substitution. In recent times however, the one approach for the estimation of substitution relationships that has captured the attention of researchers is the transcendental logarithmic (translog) cost approach. While studies exist on the translog energy cost applications in developed countries, very few of its applications are explored in developing countries.

The focus of the present study is to examine the nature of fuel substitution for major fuel consuming sectors of the Indian economy. The study covers major segments of fuel consumers at industry and firm level. At the industry level three major energy intensive industries namely-- power, fertilizer and textile are studied. For understanding the fuel substitution pattern at a firm level a set of companies using two fuels for production process are considered. The companies are categorized into five fuel groups namely, (since electricity is a secondary form of energy and power industry is also studied at the industry level it is not considered in the fuel groups). i) coal-natural gas, ii) coal-light diesel oil, iii) coal-high-speed diesel oil, iv) high speed diesel oil – light diesel oil and v) natural gas-high speed diesel oil.

The present work aims to understand the possibilities of inter-fuel substitution from all segments of industrial energy end-users. In India while studying the inter-fuel substitution possibilities many available studies have considered major industrial groups like fertilizer, cement, textile and electricity generation. However studies covering industrial energy demand from industries and firms together are not available in the literature. The present study positions itself in this context and examines the inter-fuel substitution possibilities both at industry and firm levels, in substitution possibilities as it has been felt important.

1.2. Objectives

Accordingly the present study has the following four objectives.

I. To explain the theoretical linkages between energy and economy, and review the evidences relevant to the context.
II. To undertake a comprehensive review of previous works concerning fuel substitution possibilities with special reference to the Indian context.
III. To estimate the cost shares, elasticities of substitution between fuels and own-cross price elasticities at industry level with aggregated data, for the fuels: coal, oil, light diesel oil,

high speed diesel oil and natural gas in the power, textile and fertilizer industries of India during 1981-2004.

IV. To estimate cost shares and own as well as cross price elasticities with firm level disaggregated data for firms using two fuels in the production process by grouping them during the period 1991-2004

1.3. Rationale for the Study

Electricity is one of the most vital infrastructure inputs for the economic development of a country. With the growing industrialization the demand-supply gap for power increased multifold in India. Since independence, the Indian electricity sector has grown manifold in size and capacity. All these years coal remained as major input or source of fuel for the electricity generation. But with the growing environmental concerns globally, the focus of researchers has of late shifted to various renewable forms of energy like solar, wind, tidal etc. However, the cost-effective breakthroughs of utilizing the renewable forms of energy for heavy industrial purposes are still a question mark.

Hence the present era of fossil fuels need to be continued for a few more decades. In this context, given the growing demand for fuels, fuel substitution possibilities and more so its measurement assumes importance. An econometric investigation towards the elasticities of substitution of fuels would help in understanding the future of fuels individually, in the forth-coming years. Keeping the above facts in view the present study seeks to throw light on the substitution possibilities of coal with other fossil fuels.

Manufacturing sector ranks first among the other major consumers of commercial energy in India. In the recent years, the intensity of energy use has also been raising in this sector. The current study attempts to cover the two major energy intensive manufacturing industries namely-- textile and fertilizer of Indian economy and estimate the fuel shares for the selected period. The study also focuses on selected Indian companies that use two fuels as inputs in the production process.

1.4. Methodology

The study employs the translog approach as introduced by Christensen, Jorgenson and Lau (1973). The approach provides a flexible functional form and constitutes an important development in the theory of production. The underlying theory of the function has been fully expounded in subsequent studies, and techniques for estimating the Allen partial elasticities of substitution, which have been widely used to investigate the empirical nature of derived demands for factors.

The present study adopts translog cost functions specifically for estimating own-cross price elasticities of fuels. Translog cost functions are estimated with aggregate and disaggregate data sets for understanding the substitution possibilities of fuels at the industry and firm levels. For the present study the translog cost functions are estimated using aggregate data sets relating to the power, fertilizer and textiles sectors of India. Similarly, with disaggregate data, a set of 25 Indian companies using two fuels for the production processes are selected.

To make the best fit of translog cost functions, due care is taken regarding the utilization of fuels, which has been ignored by the earlier works. For example fuels are used for various purposes in the production processes. Hence it is not just irrelevant to study all the fuels used in the industry or firm for estimating inter-fuel substitution but it may be void theoretically. Therefore, fuel substitution is possible only and when two or more fuels are used for producing a homogeneous product. In other words, many fertilizer plants use both coal and natural gas as fuel input for producing ammonia. But at the same time they also use other fuels like light diesel oil or high speed diesel oil for machinery. In such a case only coal and natural gas are considered while estimating the fuel substitution possibilities in fertilizer industries.

The selected 25 companies are drawn from 5 fuel-groups. The fuel groups are coal-natural gas, high speed diesel oil–light diesel oil, natural gas-high speed diesel oil, coal-light diesel oil, coal-high speed diesel oil. From these fuel groups 7, 3, 3, 2 and 10 companies respectively are chosen for analysis.

1.5. Data Sources

The Center for Monitoring Indian Economy (CMIE) brings out yearly an energy data edition, which is a compilation of secondary data for all the sectors and for different forms of energy. And also the wholesale price indices of the fuels are provided by the CMIE publications. Data for the present study are drawn from CMIE 2005.

Off take of different forms of fuels like coal, naphtha, natural gas, light diesel oil (ldo) and high sulphur diesel oil (hdo), and fuel oil by various sectors of the economy are provided in the publications which are used for this study. The data collected for the present study relate to fertilizer, power and textile for the period of 1981 to 2004.

CMIE *Prowess* provides data on the total energy consumption and fuel consumption of companies across the economy, which is collected for the period of 1991-2004 for a set of 25 companies. Companies using two fuels for one and the same purpose be it fuel or feedstock, are selected on the basis of a thorough understanding of the company and its product range. For example, in fertilizer production natural gas and coal are used as feedstock and some other fuels are used as fuels for running the machinery. In such a case, only coal and gas used as feed stock are considered for the study.

Like wise, the other companies using two fuels for combustion or say for fuel purposes are cement, glass, textile and breweries, which are also selected in the same fashion. However, this selection problem does not arise with the sectoral analysis since the off-take of the fuels across the sectors is selected for the study.

For estimating a translog cost function and deriving the demand for fuels of fertilizer and power industries, data collected on the selected fuels namely, coal, oil (naphtha), and natural gas are used. Wholesale Price Indices (WPI) of the fuels coal, oil and gas considered as proxy for prices at economy level. Also the previous studies (for instance, Murty, 86) considered WPI of the specified fuels as proxy for prices. In case of textile industry, coal, fuel, oil high sulphur diesel oil, and light diesel oil are used as inputs in the production process. Hence a separate estimation is carried for this industry with respective WPIs

1.6. Organization of the Study

The present work is schematized into seven chapters. The first chapter provides the background of the study and introduces the research problem duly explaining objectives of the study. The second chapter presents details on energy economy linkages. The third chapter presents a brief review of the relevant literature available till date. Chapter four describes the methodology adopted for the study. Chapter five presents a brief profile of the industries and companies selected for the study. Chapter six presents the estimated equations and the results that are generated from the translog cost functions, elasticities of fuel substitution and the own and cross price elasticities of fuels. Chapter seven provides the major findings of the study and their policy implications.

Chapter 2

Energy- Fossil Fuels and Economic Development

2.0. Introduction

Energy resources are often considered as basic wealth to a society. Many a time's economists favor markets and private ownership for the allocation of goods and services to make the economy grow faster through competition in the factor markets. The emergence of energy markets brought many issues in the area of energy economics. Experts categorize the various models as first and second-generation models. These concepts and arguments are presented in this chapter. It is believed that this background paves the way for identifying the research gaps that are explained in chapter one of the thesis. An introduction to the developing countries energy demand analysis and relevant information on the Indian fuels is presented in this chapter.

2.1. Energy-Economy Interactions

Energy has *played* a vital role in taking mankind from an early basic existence to the present supersonic era. In the early stages of economic development, most economies were agricultural and depended mainly on human labor. During industrialization energy was used intensively to raise productivity, output and living standards. The urbanization phase, which combined with human labor, raised productivity, output and living standards. This urbanization phase, which closely corresponded with the industrialization process, intensified energy consumption. The history of economic development shows a parallel development in energy consumption, in increasingly more convenient forms.

The fact that expanded provision and use of energy services is strongly associated with economic development leaves the fact open that how important energy is as a causal factor in economic development. Development involves a number of other steps besides those associated with energy, notably including the evolution of education and labor markets, financial institutions to support capital investment, modernization of agriculture, and provision of infrastructure for water, sanitation, and communications. However if a keen observation is made on these developmental aspects, it can be seen that they are not exceptional from energy use. Hence it is an accepted fact that direct or indirect use of energy paves the way soon for an economy to grow faster.

2.2. Energy and Economic Development

The linkages among energy, other inputs, and economic activity change as an economy moves through different stages of development. Barnes(1992) described this phenomenon as *energy ladder*, though himself recognizes that the ladder concept does not imply a monotonic transition from one type of energy to another, but also has a relationship with income levels of households and in turn economies. At the lowest levels of income and social development, energy tends to come from harvested or scavenged biological sources (wood, dung, sunshine for drying) and human effort (also biologically powered). Initially processed biofuels (charcoal), animal power, were used as a source of energy and later commercial fossil energy became prominent.

Energy resources of different levels of development may be used concurrently at any given stage of economic development: electric lighting may be used concurrently with biomass cooking fires. Changes in relative opportunity costs as well as incomes can move households and other energy users up and down the ladder for different energy-related services.

Despite substantial differences in energy forms and economic activities across different stages of development, some common elements can be seen. Energy acquisition is a costly activity requiring a variety of inputs, whether that cost is denominated in terms of household labor allocated to biomass gathering or expenditures for commercial fuels and the inputs needed to provide them. Energy utilization also does not occur in a vacuum but depends on the opportunity costs of other inputs, notably various types of capital goods (be they cook stoves or electricity grids).

The literature makes clear that observed patterns of energy production and utilization reflect a great deal of subtle optimizing behavior, given the constraints faced by the economic actors [Barnes 1992]. Those constraints can impede better outcomes, and much of the work to date on energy development has concerned how lower-cost and more effective energy services can be delivered by alleviating or working around financing and informational barriers as well as regulatory distortions. It should be noted that energy-development nexus varies with stage of development. Before going to the energy use and energy intensive sectors of the economy, a brief note on the resource classification of energy forms is given below.

2.2.1. Resource Classification

Energy can be extracted from various sources like bio energy, human energy, mechanical energy, kinetic energy and animal energy. Energy classifications may base on its nature, quality, marketability and storing capacity. Some of such classifications are discussed here.

NATURE CLASSIFICATION

Conventional and non –conventional resources: conventional energy is used conventionally and can be stored for example oil and gas. The non-conventional sources are rarely used. Moreover these cannot be stored easily. Their storing as well as conversion involves heavy costs, e.g., wind, biogas etc.

QUALITY CLASSIFICATION

Renewable and non-renewable energy resources: Energy resources like firewood, agricultural waste, solar energy and wind energy are inexhaustible in character and can be renewed depending upon the changes in demand. But energy resources like oil and natural gas coal, and other fossil fuels, resources that stored beneath the earth are limited in character and would be exhausted within a prescribed period of time. Greater usage of such fuels would result in energy crisis and the supply cannot be adjusted according to the changing demand.

MARKETABILITY CLASSIFICATION

Commercial and non-commercial energy: Some of the energy resources fetch a price and can be marketed while others are freely available, e.g., solar energy, fuel wood and animal wastes. Commercial energy resources are oil, gas, coal, hydroelectric and nuclear fuels.

DIRECT AND INDIRECT ENERGY CLASSIFICATION

Primary and secondary resources of energy: Some of the energy sources can be used directly, e.g. coal, oil, solar energy, and fuel wood. But these energy sources may be used to generate energy indirectly. For instance, electricity, petroleum lubricants, liquefied petroleum gas.

2.2.2. Resource Use and Energy Efficiency

The choice of a resource depends basically on the thermodynamic efficiency and economic efficiency of the resource. The optimal point of the above two can be quoted as the energy efficiency of the resource. Energy efficiency can be improved by the technological innovations. The energy intensity of an economy will be high in the early stages of development process. As an economy grows, its energy intensity levels will decrease. This phenomenon is due to the increased urbanization and technological betterment in the industry, energy is consumed at a high rate. In brief more and more energy is needed in convenient forms when the economic development takes place.

Improving energy efficiency involves efficient utilization of scarce resources, which is essential from energy security perspective. Improving energy efficiency of an economy increases productivity, which in turn significantly reduces the green house gas (GHG) emissions and reduces solid waste production.

2.3. Energy and Environment

Most of the literature in the area of energy aims in bringing out environmental hazards that are being generated in the modern days, with the extensive use of fossil fuels. But a stream of scholars like Gordon (1993), believe that unless there is a definite proof or need the present era of fossil fuels need to be continued till alternative energy forms turn to be economically viable options for heavy industrial use. At the same time it is difficult to expect developing countries industrial structures to change overnight their production technologies, hence a better form of fossil energy like natural gas need to be focused for few more years. The present chapter tries to bring out the relations of energy and environment with economic rationality.

2.3.1. Economics of Environment

In economics the environment is viewed as a composite asset that provides a variety of services. It is a very special asset, to be sure, because it provides the life-support systems that sustain our very existence. The environment provides the economy with both raw materials, which are transformed into consumer products by the production process, and energy, which fuels this transformation. Ultimately those raw materials and energy return to the environment as waste products. The environment also provides services directly to consumers. The air we breathe, the nourishment we receive from food and drink, the protection we derive from shelter and clothing are all benefits we receive either directly or indirectly from the environment.

If the environment is defined broadly enough, the relationship between the environment and the economic system can be considered as a “closed system”. A closed system is one in which the system imports or exports matter or energy. By ‘the economy’ we refer to the population of economic agents, the institutions they form, which include firms and governments and the inter linkages between agents and institutions, such as markets. By ‘environment’, we mean the biosphere, the thin skin on the earth’s surface on which life exists. As an example, consider the generation of electricity. In extracting fossil fuels to use as an energy source, in burning these fuels to release their energy, we also release carbon dioxide, (CO_2) and sulphur dioxide (SO_2), both of which may produce undesirable environmental impacts that reduce human well-being.

2.3.2. Understanding Environmentalism

According to Gordon (1993) the literature on energy technology provides ample evidence that further advances will occur and new reserves and efficient technologies will be explored. The work also argues that definitive proof of anything is never possible and economic policies commitments to the environmental future should be limited especially in the developing countries. The study suggests that countries should delay response until the dangers of alleged problems of their nations are clear. And also it is quite possible that much ahead industrial nations are contributing more to the global warming than the developing nations.

The record since 1974 provides chastening examples of incorrect pessimistic forecasts and premature investment in response to certain environmental predictions. We see endless updating by resource pessimists of their perpetually incorrect forecasts of impending shrinkages of energy supplies, shortages of investment funds, and thus inevitably rising oil prices. With this focus it is clear that a sudden shift in the attention of researchers and literature towards energy caused environmental hazards, hindered the economic focus of energy and markets.

2.3.3. Resource Exhaustion-*Is Really a Problem?*

Another point to be noted is that energy supply and availability difficulties were there in the yester years and will remain hence they must be managed. Even if supply limits dominate the market, superior planning could be a solution for avoiding such supply shocks. The literature on exhaustible resources clearly establishes that resource exhaustibility creates no special market failures. It has been argued that monopoly generally will retard depletion. The predominant monopolistic and oligopolistic situation of energy markets might not allow resource exhaustion until it finds new resources or avenues of energy supply. Economists correctly define environmentalism as *efficiently internalizing externalities*. Policies have strayed from this goal. Gordon (1993) also argues that those who call themselves as environmentalists are simply well intentioned respondents of warnings of environmental damages.

The study strongly criticizes that these environmentalists are more like our neighbors who are exposed to the warnings about world ruin and contribute their piece of understanding about environmental hazards to literature as threats. The prime example is the attack on nuclear power. The critics disagreed whether the concern was routine radiation releases, reactor accident, or danger of nuclear terrorism. As each problem proved manageable, the case turned to complaints about the absence, for which the critics were responsible of a definitive waste storage program. Hence many nations now adopt the nuclear power.

2.3.4. Environmental Concerns in Indian Context

India, the world's second most populous nation, has seen its population explode from 300 million in 1947 to more than one billion today. This rapidly growing population has placed a strain not only on India's infrastructure, but also on its environment. According to the World Health Organization, New Delhi is one of the top ten most polluted cities in the world. Two primary sources of air pollution in India are vehicular emissions and untreated industrial smoke.

Coal is a major commercial energy source in India. Increased coal consumption over the past four decades has led to a nine-fold increase in energy-related carbon emissions. Environmental effects due to the relatively high use of coal in the energy mix are exacerbated by the low energy efficiency of coal-based electricity generating plants. Inefficient plants are one of the contributing factors to steadily increasing energy consumption per unit of output (i.e. energy intensity). With the high costs associated with replacing existing coal-based plants, it is realistic to assume that these plants will continue running for the next couple of decades.

Though the fact is known that the present coal scenario cannot be changed in the near future, the present study aims to understand how much of the coal use is substituted in the recent past. It is clear that technology cannot be changed in the short span of a decade but it is quite possible to estimate the market driven forces like prices of alternatives (oil and gas) affecting the coal use in India. Pachauri (1989) viewed that it is necessary to understand why and how energy consumption and demand vary over time and across sectors, regions, industrial units and households.

An in-depth analysis of factors affecting energy consumption would indicate what policy measures are needed to adjust energy demand in the context of macro objectives. Such analysis may be done at macro level relating energy consumption with population, level of economic activity that is gross output, gross domestic output, structure of economic activity, patterns of industrialization, urbanization, energy prices, technological changes etc.

Coming back to India's per capita energy use and carbon emissions (while lower than the world average), result in a substantial percentage of world energy use and carbon emissions, because of the country's large population and heavy reliance on coal. India faces great challenges in energy and environment as it enters the 21st Century. A rapidly growing population will continue to increase demands for electricity generation and will place greater pressures on the environment to absorb increasing industrial and vehicular emissions.

2.3.5. Reduced Environmental Concerns from Fossil Fuels in Modern Days

It is an accepted fact that fossil fuels are more pollutants than renewable forms of energy. However increased concerns about environment from all over the globe is pressurizing fossil fuel users to remove the hazardous properties of these fossil fuels in the process of utilization. A brief look on these fuel usage in the modern days is presented below in support of the above placed views of Gordon (1993).

2.3.5.1. Coal and Environment in the Modern Days

Environmental laws and modern technologies have greatly reduced coal's impact on the environment. Without proper care, mining can destroy land and pollute water. Today, restoring the land damaged by surface mining is an important part of the mining process. Because mining activities often come into contact with water resources, coal producers must also go to great efforts to prevent damage to ground and surface waters.

When coal is burned as fuel, it gives off carbon dioxide, the main greenhouse gas that is linked with global warming. Burning coal also produces emissions, such as sulfur, nitrogen oxide (NOx), and mercury, that can pollute the air and water. Sulfur mixes with oxygen to form sulfur dioxide (SO2), a chemical that can affect trees and water when it combines with moisture to produce acid rain. Emissions of nitrogen oxide help create smog, and also contribute to acid rain. Mercury that is released into the air eventually settles in water. The mercury in the water can build up in fish and shellfish, and can be harmful to animals and people who eat them.

The coal industry has found several ways to reduce sulfur, nitrogen oxides, and other impurities from coal. They have found more effective ways of cleaning coal before it leaves the mine, and coal companies look for low-sulfur coal to mine. Power plants use "scrubbers" to clean sulfur from the smoke before it leaves their smokestacks. In addition, industry and government have been cooperating to develop "clean coal technologies" that either remove sulfur and nitrogen oxides from coal, or convert coal to a gas or liquid fuel. The scrubbers and NOx removal equipment are also able to reduce mercury emissions from some types of coal. Scientists are working on new ways to reduce mercury emissions from coal-burning power plants.

2.3.5.2. Oil and Environmental Concerns

Products from oil (petroleum products) help us do many things. Over the years, new technologies and laws have helped to reduce problems related to petroleum products. As with any industry, the government monitors how oil is produced, refined, stored, and sent to market to reduce the impact on the environment. Since late 90's in India, fuels like diesel fuel have also been improved so that they produce less pollution when we use them.

2.3.5.3. Natural Gas and Environment

Natural gas burns more cleanly than other fossil fuels. It has fewer emissions of sulfur, carbon, and nitrogen than coal or oil, and it has almost no ash particles left after burning. Being a clean fuel is one reason that the use of natural gas, especially for electricity generation, has grown so much and is expected to grow even more in the future.

2.3.6. Sub-Section Summary

This sub-section provides certain popular arguments towards the extension of fossil fuel era. And the economics of fuel usage is supported along with the environmental concerns. The fossil fuel related emissions though are of concern India is not yet in a position to effort the capital intensive renewable energy. Hence, it is possible to make the existing scenario more efficient in environmental terms by imposing certain restriction on the exploration, production and mining of these fuels, rather talking of changes to be mooted overnight in heavy industries.

2.4. Energy and Production Chain

One could explore the linkage between economic development and energy with the help of macroeconomic data on income or production, energy utilization, capital investment, human knowledge acquisition, and other factors. That is, one could examine across countries and perhaps across time how Gross Domestic Product (GDP) per capita changes with energy availability per capita.

The literature on energy development contains evidence of an inverse relationship explaining, how energy usage is strongly driven by economic development, as indicated by per capita income. However, while drawing conclusions about the process of development it is pertinent to recognize that there are many interactions between energy and economic development.

As an economy develops, continued economic growth will be possible with less energy per unit of additional growth. The proportionate change in the energy consumption is associated with a proportionate change in economic activity which is called the energy elasticity.

As development proceeds, there is a major shift in the structure of energy demand from household uses to transport and industrial uses, including electricity generation. At low levels of income, the household sector is the predominant energy user often accounting for the highest of the total energy consumption. At higher levels of GNP per head, the share of household sector falls and the share of industry and transport rises. This structural change is more noticeable in the move from low-to middle-income countries. There is less variation noticed between middle and high-income countries.

2.5. Energy and Fuel Eras

History reveals three primary energy eras: Coal, Oil and Gas, and Renewable energy. There is no sharp distinction among these eras since one grows contemporary to the other and leads the era by taking the place of the previous. For example the dominant fuel at the phase of industrial revolution was coal; later oil consumption took a front seat though coal remains as the primary commercial fuel in many developing countries. Presently the focus has been shifted to natural gas in many developed countries after the oil shocks.

However, developing countries are yet to look and explore at the natural gas way of industrialization. Renewable energy like wind, solar and tidal is the buzz for the developed countries where as it remains still a luxury effort for heavy industrial usage in developing countries. Due to the heavy capital investments, in spite of the well known fact that renewable forms of energy are eco-friendly, developing countries are yet to come to a situation where large scale industry needs are met by these forms of energy.

2.5.1. Fuel use in Energy and Non-Energy Industries

Energy in the form of fuels is also used to produce another form of energy or say electricity. Apart from this, fuel use is often associated with industrial sector. As the machinery used in industrial processes are the principle users of the fuels, the linkage between industrial development and energy is supposed as the best indicator of economic development. Fertilizer and Textile industry are one among such energy intrinsic industries. In energy producing plants coal, naphtha (oil), and natural gas based electricity generation is prominent.

2.6. Measuring Industrial Energy Demand-Issues in Modeling

The demand for energy is a derived demand; energy is not consumed directly. It is only used in conjunction with some form of energy using equipment. The three main types of decisions that energy consumers confront are: first whether to purchase or replace energy using durable goods providing certain services like heating, lighting, industrial processing, etc. Second, is the choice between equipment of differing technical and energy using characteristics providing the desired services. Given purchase and installation of the equipment, the third decision refers to choosing the intensity of use i.e. capital utilization. These decisions span the short run when the stocks of energy using goods are fixed and in the long run when the stock can be changed, have implications for appropriate model specification.

2.6.1. Classification of Models

The various models may be classed as follows:

1. Market models;
2. Process models ;(the present study is a case of these models)
3. Demand models
4. Programming models on location;
5. Optimization models;
6. Systems dynamic engineering models;
7. Energy balance models.

Econometric **market models** rely on the pricing mechanism to clear the market all the time. Most energy demand modeling is not grounded in this framework, except where energy markets are linked with a macro-model. Here, economic activity variables are endogenized and price determination includes endogenous energy price variables. The attraction of such general equilibrium models is the complete description provided by the economy consistent with economic theory. In this framework the problem however is the extensive data requirements and the difficulty of characterizing dynamic adjustments.

Process models focus on the transformation of commodity inputs into finished products. Demand is often exogenous; the prices are not market clearing prices. The production and cost function analysis (to be discussed later in detail) can be viewed as a form of process modeling. The present study is also based on such a process model where output and cost functions are estimated.

Demand models are strictly confined to demand side behavior and would be away from incorporating a supply side approach that might introduce production theory.

Programming models focus on inter-regional efficiency in production, distribution and utilization.

The underlying theory of econometric models is often based on optimizing revenue, demand etc. Hence **optimization models** can be said as a set of modeling procedures with ‘throw-in-all-the-variables style. These models were primarily developed at the time of oil shocks during early 70’s in order to understand the circumstances and consequences of oil shocks.

System dynamic models are based on attributes of commodities that lend themselves to engineering or systems analysis.

Energy balance models are basically accounting models, and can involve the assessment of energy costs; but normally they do not involve behavioral equations. They may be useful in organizing input data in the process of energy aggregation.

2.6.1. Analytical framework

In the industrial sector, organizations are seen as producing output Q via inputs of capital(K), labor(L), energy(E) and materials(M) (K, L, E and M). The firm maximizes output π = output ($P_Q Q$) minus costs ($C=P_k K+P_L L+P_M M+P_E E$): that is

$$\text{Max } \pi = P_Q Q - C \qquad 2.1$$

$$\text{Subject to } Q = Q(K,L,E,M,t) \qquad 2.2$$

where the time variable, *t*, represents technological change. The maximization problem in (2.1) and (2.2) has a dual representation in terms of cost minimization for any given output level Q:

$$\text{Minimize } C= (Q, P_i) \qquad 2.3$$

Subject to (2.3) where P_i is the input price of input i. the solution to this minimization problem is a set of factor demand equations:

$$I_i = I\ (P_{i,}\ Q) \qquad 2.4$$

where I_i is the demand for factor i.

The demand for any input in the production of goods and services as in (2.4) is then a function of all input prices, the level of output. A set of constraints on input demand functions is implied by the assumption of cost minimization and by the general characteristics attributed to the cost function. These constraints are

a) Homogeneity: factor demand functions are homogeneous of degree zero in all (input) prices;
b) Symmetry: the elasticity of substitution matrix is symmetric;

c) The law of demand: the demand of input ‘i’ decrease when its price increases, or at least does not rise (the own price elasticity of demand is negative).

2.7. First Generation Static Energy Models

Energy prices remained the most popular culprit of productivity slowdown in the 1970’s. Reductions in energy prices in the 1980s raised the question of whether overall productivity would be favorably affected. And now that the decline in energy prices has been arrested, fears loom that productivity and hence economic growth may once again deteriorate.

Accounting analysis can detail the component breakdown of historical trends in multifactor energy and labor productivity, but provides little insight into the reasons why such changes have taken place. It is here that estimation of econometric cost functions focusing on the effects of technology and shifts in input prices especially energy prices on both total and individual factor productivity can shed some light. But too much attention on energy productivity per se can obscure assessment of the efficiency of industry responses to economic change.

Many industries indicate significant implicit energy savings even though their recorded energy productivity performance of individual inputs necessarily connotes inefficiency. This paved way for looking at energy-output coefficients at firm level and in cases sector level.

2.8. Second-Generation Energy Models and Energy-Output Coefficients

Trends in the ratio of energy consumption to the level of output—known as energy-output coefficients are popular in examining energy demand across sectors and economies. The proposition is that when energy prices are increasing, a rise in the energy coefficients is perverse, whereas a fall in the energy coefficient is seen as evidence of the efficiency of the price mechanism.

The burden of much of the work employing the economic theory of production and cost function is to cast doubt on this simplistic picture. Rather, it is important to look beyond the energy-output coefficient to discern what is happening. This is especially important for individual industries.

2.9. Energy-Output Coefficients Indicate Energy Intensity

The energy intensity of a nation's economy, which measures the total primary energy use per unit of gross domestic product, is used broadly as a convenient, aggregated indicator of energy use efficiency. The ratio is affected by numerous factors, such as geography, culture, wealth, natural endowments and economic structure. Its change over time thus reflects, besides efficiency developments other factors, such as structural change and fuel substitution.

2.10. Energy Demand Analysis in Developing Countries- Some Issues

Energy demand analysis plays a vital role in energy planning and policy making in developing countries. Planners and policy makers need to have a good understanding of the factors affecting demand projection for the future. Given the capital intensity and long gestation periods of energy investments, supply bottlenecks, and adverse effects of energy shortages, detailed demand studies need to be undertaken at the sectoral levels along with the aggregate studies.

Energy demand analysis involves (a) assembling and presenting a consistent set of data on consumption of various forms of energy (b) estimating the level of shortage or unfulfilled demand at relevant price ranges and (c) quantifying the relationship of energy demand with relevant economic variables such as income, prices of different energy sources and their substitutes. In the context of developing countries, energy demand analysis becomes complex on account of the following factors.

In the first place, in normal course, a major share of the consumption of commercial fuels and electricity is accounted for by a few industrial enterprises, from manufacturing sector or energy sector itself for generating thermal electricity. This means that individual investment decisions by one or a few of these large scale users can have significant impacts on energy availability and total consumption.

Secondly, it is difficult to assess the response to changes in fuel prices because user choices are limited to large industrial segments due to technical constraints. Hence obtaining theoretically developed results while estimating price elasticities in developing countries may not be possible. For instance in many cases, the law of demand explains that when prices go up demand falls. Which proves to be a likely phenomenon for any other goods excepting goods that are scarce.

Thirdly, commercial energy used in industrial sector is scarce in nature and many times has a single or a set of users as said above. So there is every possibility of arising with positive own and negative cross price elasticity situations when certain energy forms dominate the industry. In other words, when two fuels say coal and diesel oil are used in a production process and coal is a major fuel input when prices of coal increase firms tend to reduce the consumption of diesel oil and vest the share on coal.

Thus, unlike the industrialized countries, analysis of energy demand in developing countries not only requires the assembling of a set of consistent data but also gets complicated by the set of factors outlined above. In view of this, it becomes even more necessary for developing economies than industrial counties to study variations at a more disaggregated level for example-- selected energy intensive industries major end-users (electricity generation and manufacturing). The present work is an attempt in the direction of understanding price elasticity of demand at sectoral as well as at firm level simultaneously.

2.11. Issues in Estimating Demand for Energy in Developing Countries

Data on commercial sources of energy such as coal, oil, natural gas, and electricity are generally available in every country. A lot of effort is required to assess the quality of information and prepare a consistent set of data showing production, and final consumption. Usually, new data are available only in aggregate terms, and the pattern of uses does not distinguish between different sets of energy or fuels. For example, evaluating data on the use of Furnace Oil (FO), Low Sulphur Heavy Stock

(LSHS) and Natural Gas (NG) may only be available by region or by producing company rather than by end-use. Further, disaggregated data on consumption by sector or end-use may not be available since suppliers keep records in a particular way. Sometimes, there may be incentives to substitute one oil product for another due to price differentials, and it may be necessary to estimate the level of such substitution. Hence, detailed and carefully designed surveys are needed to ascertain the shares of different forms of energy going to different sector.

In addition to the data availability issues, there are also various problems in the process of estimation that one should consider. One has to be careful in aggregating different forms of energy by using conversion factors, because it may distort the picture regarding relative contribution of alternative sources. Generally, various fuels are aggregated in terms of their gross energy content, and totals are presented in terms of million tones of oil equivalent or million tones of coal equivalent or joules. Such aggregation will help to account the differences in quality of fuels. In other words oil is a more convenient fuel and has a higher efficiency than say coal hence bringing them to a uniform format will avoid aggregation mistakes.

2.12. Energy Demand Analysis at the Sectoral Level

In view of the problems associated with energy demand analysis at the macro level, it is necessary to quantify determinants of demand at the sector level for example--agriculture, industry, transport, household etc. The techniques applied to each sector can be adapted depending on the availability of data and the causative mechanisms involved; for instance, it is possible to use different models for different sectors.

Energy use in industry gained importance since it is the major consumer of commercial forms of energy. And also the industrial sector energy use can be analysed at the sub sector or enterprise level. To explain the aggregate and product wise energy consumption in the industrial sector, a few studies have been undertaken in developing countries which estimated the elasticities of substitution between energy and non-energy inputs as well as the elasticity of substitution among different fuels. This approach has been widely used in the developed countries.

As said earlier energy demand is a derived demand. The objective of the previous studies has been to estimate elasticities of substitution between one energy type and another. The present work also adds as a contribution to this literature. Chapter three builds a detailed review of literature on the elasticity of substitution aspects.

In brief the above scripted are the theoretical interactions of energy and economy and certain issues in relation to these interactions. In the following lines a factual look at the status of the global and Indian energy sector is presented.

2.13 Global Energy Consumption Trends

In the International Energy Outlook-2007(IEO-2007) projections, the world marketed energy consumption is expected to grow by 57 percent over the 2004 to 2030 period. Total world energy use has raised from 447 quadrillion British thermal units (Btu) in 2004 to 559 quadrillion Btu in 2015 and then to 702 quadrillion Btu in 2030. Global energy demand grew despite the relatively high world oil and natural gas prices that are projected to persist into the mid-term outlook. A rapid growth in energy demand from 2004 to 2030 is projected for nations outside the Organization for Economic Cooperation and Development (non-OECD nations).

Total non-OECD energy demand increases by 95 percent in the IEO-2007 reference case projection, as compared with an increase of 24 percent in OECD energy use. The robust growth in demand among the non-OECD nations has largely been the result of strong projected economic growth. In all the non-OECD regions combined, economic activity—as measured by GDP in purchasing power parity terms—increases by 5.3 percent per year on average, as compared with an average of 2.5 percent per year for the OECD economies.

Trends in end-use sector energy consumption can vary widely, according to the level and pace of economic development in a given region. In the OECD region, where energy markets generally are well established, demand for delivered energy in each of the end-use sectors grows more slowly than in the non-OECD nations. For the industrial sector, energy-intensive industries continue to expand more rapidly in the non-OECD countries, where investors are attracted by lower costs and fewer environmental constraints, than in the OECD countries.

In 1980, the OECD accounted for 52 percent of the world's industrial sector energy use. In 2004 the OECD share had fallen to 44 percent, and it is projected to decline to 33 percent in 2030, as non-OECD industrial energy use outpaces that in the OECD. For the OECD countries, industrial sector energy use is projected to grow at an average rate of 0.6 percent per year from 2004 to 2030; for the non-OECD countries, the projected increase averages 2.5 percent per year.

According to the IEO-2007, energy use in the construction and transportation sectors is projected to grow more slowly in the OECD countries than in the non-OECD countries. With slow or declining population growth in many OECD nations, generally slow growth in energy use in the buildings sectors is projected, averaging 0.6 percent per year in the residential sector and 1.1 percent per year in the commercial sector from 2004 to 2030.

For the non-OECD region as a whole, strong growth in demand for energy is projected in the construction industry, averaging 2.4 percent per year in the residential sector and 3.7 percent per year in the commercial sector. Historically, growth in transportation activity has been closely linked to income growth, indicating a strong relationship between per-capita GDP and passenger car travel per capita, especially in countries with developing economies.

In the OECD countries, where extensive infrastructure is in place already and GDP is projected to grow much more slowly, demand for transportation fuels increases by 0.9 percent per year. The IEO-2007 reference case projects increased world consumption of marketed energy from all sources over the 2004 to 2030 projection period. Fossil fuels (petroleum and other liquid fuels, natural gas, and coal) are expected to continue supplying much of the energy used worldwide.

Liquids supply the largest share of world energy consumption over the projection period, but their share falls from 38 percent in 2004 to 34 percent in 2030, largely in response to a reference case scenario in which real world oil prices remain near the current level through 2030. Liquids remain the dominant energy source, given their importance in the transportation and industrial end-use sectors. However, their share of the world energy market in this year's outlook is lessened in the projection, as other fuels replace liquids where possible outside those sectors. Fossil fuel prices in the reference case also support renewed interest in expanding the use of nuclear power and renewable energy sources to generate electricity.

World use of petroleum and other liquids might grow from 83 million barrels oil equivalent per day in 2004 to 97 million barrels per day by 2015 and could be 118 million barrels per day by 2030 in most regions of the world. However outside the transportation sector, liquid fuels continue to erode. Liquids remain the most important fuels for transportation, because there are few alternatives that can compete widely with petroleum- based liquid fuels. On a global basis, the transportation sector accounts for 68 percent of the total projected increase in liquids use from 2004 to 2030, followed by the industrial sector, which accounts for another 27 percent of the increase.

To meet the increase in world liquids demand, the total supply in 2030 is projected to be 35 million barrels per day higher than the 2004 level of 83 million barrels per day. Conventional liquids production by members of the Organization of the Petroleum Exporting Countries (OPEC) contributes about 21 million barrels per day to the total increase, and conventional liquids production in non-OPEC countries adds another 6 million barrels per day. Unconventional resources (including biofuels, coal-to-liquids, and gas-to-liquids) from both OPEC and non-OPEC sources are expected to become increasingly competitive.

World production of unconventional resources, which totalled only 2.6 million barrels per day in 2004, is projected to increase to 10.5 million barrels per day and account for 9 percent of total world liquids supply in 2030, on an oil equivalent basis, according to the IEO-2007. Natural gas consumption might increase on average by 1.9 percent per year, from a world total of 99.6 trillion cubic feet in 2004 to 129.0 trillion cubic feet in 2015 and could go up to 163.2 trillion cubic feet in 2030.

Rising world oil prices after 2015 increase the demand for natural gas, as it is used to displace the use of liquids in the industrial and electric power sectors. Although natural gas prices vary by region, they tend to rise as demand increases.

Among the end-use sectors, the industrial sector remains the largest consumer of natural gas worldwide, accounting for 43 percent of the world's total projected natural gas consumption in 2030. Coal is the fastest-growing energy source worldwide according to IEO-2007 projections. World coal consumption is projected to increase from 114.5 quadrillion Btu in 2004 to 199.1 quadrillion Btu in 2030, at an average annual growth rate of 2.2 percent. World coal consumption increased sharply from 2003 to 2004, largely because of a 17-percent increase on a Btu basis in non-OECD Asia (mainly, China and India).

Coal's share of total world energy use is projected to increase from 26 percent in 2004 to 28 percent in 2030. The electric power sector accounts for about two-thirds of the world's coal consumption throughout the projection period, and the industrial sector accounts for most of the remainder. China's industrial sector is projected to account for about 78 percent of the total net increase in industrial coal use worldwide.

China has abundant coal resources, limited reserves of oil and natural gas, and a leading position in world steel production. World net electricity generation would go up by 85 percent according to the projections of IEO-2007, i.e. from 16,424 billion kilowatt-hours in 2004 to 22,289 billion kilowatt-hours in 2015 and 30,364 billion kilowatt-hours in 2030. Most of the projected increase in electricity demand is in the non-OECD nations, where electricity generation increases on average by 3.5 percent per year from 2004 to 2030, as compared with 1.3 percent per year in the OECD nations. Coal and natural gas remain the most important fuels for electricity generation throughout the projection period, together accounting for 80 percent of the total increment in world electric power generation from 2004 to 2030.

Electricity generation from nuclear power is projected to increase from 2,619 billion kilowatt-hours in 2004 to 3,619 billion kilowatt-hours in 2030. Higher fossil fuel prices, energy security concerns, improved reactor designs, and environmental considerations are expected to improve the prospects for new nuclear power capacity in many parts of the world, and a number of countries are expected to build new nuclear power plant. It is also projected in IEO-2007 that the world's installed nuclear capacity will grow from 368 giga-watts in 2004 to 481 giga-watts in 2030.

Declines in nuclear capacity are projected only in OECD Europe, where several countries (including Germany and Belgium) have either plans or mandates to phase out nuclear power, and where some older reactors are expected to be retired and not replaced. Nuclear power generation in the non-OECD countries is projected to increase by 4.0 percent per year from 2004 to 2030.

The largest increase in installed nuclear generating capacity is expected in non-OECD Asia, where annual increases in nuclear capacity average 6.3 percent and account for 68 percent of the total projected increase in nuclear power capacity for the non-OECD region as a whole. Of the 58 gigawatts of additional installed nuclear generating capacity projected for non-OECD Asia between 2004 and 2030, 36 gigawatts is projected for China and 17 gigawatts for India. Russia also is expected to add substantial nuclear generating capacity over the mid-term projection, increasing capacity by 20 gigawatts.

2.14 Global End-Use Fuel Consumption Scenario

According to IEO-2007 in recent years, atmospheric concentrations of carbon dioxide have been increasing at a rate of about 0.5 percent annually. Because anthropogenic (human caused) emissions of carbon dioxide result primarily from the combustion of fossil fuels for energy, energy use has emerged at the center of the climate change debate. World carbon dioxide emissions continue to increase steadily, from 26.9 billion metric tons in 2004 to 33.9 billion metric tons in 2015 and 42.9 billion metric tons in 2030, an increase of 59 percent over the projection period.

From 2003 to 2004, carbon dioxide emissions from the non-OECD countries grew by almost 10 percent, largely because of a 17-percent increase in coal use in non- OECD Asia, while emissions from the OECD countries grew by less than 2 percent. The result of the large increase in non-OECD emissions was that 2004 marked the first time in history that energy-related carbon dioxide emissions from the non-OECD countries exceeded those from the OECD countries—although by only about 8 million metric tons. Further, because the projected average annual increase in emissions from 2004 to 2030 in the non-OECD countries (2.6 percent) is more than three times the increase projected for the OECD countries (0.8 percent), carbon dioxide emissions from the non-OECD countries in 2030, at 26.2 billion metric tons, are projected to exceed those from the OECD countries by 57 percent.

One way of looking at the future of world energy markets is to consider trends in energy consumption at the end-use sector level. With the exception of the transportation sector, which is dominated by petroleum-based liquids products at present, the mix of energy use in the residential, commercial, and industrial sectors varies widely by region, depending on a combination of regional factors, such as the availability of energy resources, the level of economic development, and political, social, and demographic factors. The next section outlines IEO-2007 reference case projections for delivered energy consumption by end-use sector in the OECD and non-OECD regions.

2.14.1. Industrial Sector

Energy is consumed in the industrial sector by a diverse group of industries—including manufacturing, agriculture, mining, and construction—and for a wide range of activities, such as process and assembly uses, space conditioning, and lighting. Inputs that typically are considered energy products are included in industrial sector energy use. For example, natural gas and petroleum products used as feed stocks to produce non-energy products, such as plastics, where as they are also used for fueling in the industrial sector.

Increasing international trade is fostering a shift towards a less energy-intensive mix of industrial activity. For example, many of Japan’s heavy industries are reducing their output as demand for energy intensive materials increasingly is met by imports from China and other Asian countries. In Germany, a decline in industrial energy intensity in the early 1990s was largely the result of closures of heavy industries in the former East Germany after reunification.

Much of the inefficient, energy-intensive capacity in the eastern part of Germany has already been shut down, but further improvements are projected as capital stock is replaced and modernized. Electricity accounted for about 16 percent of OECD industrial energy use in 2004, and its share increases slightly over the projection period. Oil and natural gas were the most heavily used fuels in the OECD countries’ industrial sectors in 2004, together accounting for two-thirds of the energy consumed in the sector. The two energy sources are projected to maintain their overall share in 2030, but consumption of natural gas is projected to grow almost five times as rapidly as that of liquids (table 2.1).

Electricity and coal make up the bulk of the remaining projected energy consumption, while renewables remain a minor energy source for the sector. Non-OECD

Countries Industrial sector energy consumption is projected to increase by 2.5 percent per year in the non-OECD countries between 2004 and 2030. The non-OECD economies generally have higher industrial sector energy consumption relative to GDP than do the OECD countries. On average, the ratio is almost 40 percent higher in the non-OECD countries.

This is particularly true of Russia and the Eastern European countries which still have energy-inefficient capital industrial base retained from the days of central planning. Per dollar of GDP, Russia's industrial sector consumed almost 8,000 Btu of delivered energy in 2004, and the non-OECD European and other Eurasian countries averaged 5,500 Btu, as compared with the overall non-OECD average of 3,500 Btu per dollar of GDP and the overall OECD average of around 2,500 Btu per dollar of GDP. As inefficient facilities in non-OECD Europe and Eurasia are replaced with modern capacity, industrial energy intensities in the region are expected to decline more rapidly than in most of the rest of the world.

Of the non-OECD economies, China, India, and the other Asian nations are expected to have rapid increases in industrial sector energy consumption between 2004 and 2030. Whereas the economies of the OECD countries have largely moved away from heavy, energy-intensive industries (such as steel and cement) towards light manufacturing and service activities, the economies of many of the non- OECD countries and regions are still dependent on energy intensive, heavy manufacturing sectors. Although electricity is expected to become an increasingly important component of industrial sector delivered energy demand in the non-OECD economies, oil, coal, and natural gas were the most heavily used fuels in 2004, and they are projected to remain so in 2030.

Liquids use in the non-OECD industrial sector increases at a slower rate than natural gas or coal use (table 2.1). The continued importance of coal in the non-OECD industrial sector is largely attributable to China, which accounts for 70 percent of industrial coal use in the non-OECD economies in 2030.

Table.2.1

Projected Growth in Industrial Sector Delivered Energy Consumption by Fuel, 2004-2030 (Average Annual Percent Change)

	OECD	**Non-OECD**
Liquids(oil)	0.2	1.9
Natural Gas	1.0	2.5
Coal	0.3	2.7
Electricity	0.9	3.0
Total Delivered Energy	0.6	2.5

Source: Energy Information Administration (EIA)

web site www.eia.doe.gov/iea/.

2.14.2. Commercial Sector

The commercial sector—often referred to as the services sector or the services and institutional sector—consists of businesses, institutions, and organizations that provide services. The sector encompasses many different types of buildings and a wide range of activities and energy-related services. Examples of commercial sector facilities include schools, stores, restaurants, hotels, hospitals, museums, office buildings, banks, and even stadiums that hold sporting events.

Most commercial energy use occurs in buildings or structures, supplying services such as space heating, water heating, lighting, cooking, and cooling. Energy consumed for services not associated with buildings, such as for traffic lights and city water and sewer services, is also categorized as commercial sector energy use. Economic and population growth trends drive commercial sector activity and the resulting energy use. The need for services (health, education, financial, government) increases as populations increase. The degree to which these additional needs are met depends in large measure on economic resources—whether from domestic or foreign sources—and economic growth.

Economic growth also determines the degree to which additional commercial sector activities are offered and utilized. Higher levels of economic activity and disposable income lead to increased demand for hotels and restaurants to meet business and leisure requirements; to house-holds and services new and expanding businesses; and for cultural and leisure space such as theaters, galleries. Construction of all these activities requires more energy in different forms.

A faster population growth is also expected in the non-OECD countries relative to that in the OECD countries. Education, health care, and social services etc again requires different forms of energy to meet the needs of this growing population of countries. Under these circumstances, commercial delivered energy use in non-OECD countries is projected to double between 2004 and 2030, to 12.5 quadrillion Btu, and to continue growing to 16.1 quadrillion Btu in 2030. Over the 2004 to 2030 period, commercial energy use in the non-OECD region increases at an average annual rate of 3.7 percent.

Electricity demand for commercial applications is projected to grow rapidly in the non-OECD nations as more clinics, schools, and businesses gain access to electricity. Annual growth in commercially delivered electricity use averages 4.9 percent through

2030, with projected consumption of 6.1 quadrillion Btu in 2015 and 10.5 quadrillion Btu in 2030. The largest increases in commercial electricity demand are projected for nations with rapidly growing economies, particularly China and India, as their burgeoning economies foster increase in demand for services also increases.

According to IEO-2007 projections, commercial demand for natural gas grows by 3.6 percent per year from 2004 to 2015 and by 2.7 percent from 2004 to 2030, as several countries focus on expanding the infrastructure necessary for delivery of the fuel. Commercial sector liquids consumption is projected to increase from 1.6 quadrillion Btu in 2004 to 2.2 quadrillion Btu in 2015 and 2.5 quadrillion Btu in 2030 in the non-OECD region, increasing more rapidly in areas where the availability of natural gas is limited.

Commercial sector coal use in the non- OECD countries increases from 0.5 quadrillion Btu in 2004 to 0.8 quadrillion Btu in 2030, with most of the growth occurring between 2004 and 2015. Coal remains an economically attractive choice for commercial water heating, space heating, and cooking in non-OECD countries in the projections, especially in China and India, which together account for around 80 percent of non-OECD commercial coal use from 2004 through 2030. Table 2.2. depicts the projections made for OECD and Non-OECD countries fuel wise annual average percentage change. This shows that by 2030 Non-OECD countries are still going to be dependent on fossil fuels.

Table 2.2

Growth in OECD and Non-OECD Commercial Sector Delivered Energy Consumption by Fuel, 2004-2030(Average Annual Percent Change)

	OECD	**Non-OECD**
Liquids	0.0	1.8
Natural Gas	0.9	2.7
Coal	-0.6	1.7
Electricity	1.7	4.9
Total Delivered Energy	1.1	3.7

Source: EIA

2.15 Fuel Substitution Possibilities in Developing Countries

Before bringing out any policy related to industry, energy or environmental issues, it is needed to estimate the fuel substitution that took place for last two to one decade in the economy as a whole and also at the company level. Price of the fuel is one of the major determining factors along with the availability of the fuel which decides the substitution of a fuel over a period of time. Keeping this in focus the present work intends to bring out an estimate of price elasticity of substitution that took place in the economy and at the company level for last two decades. As a background to the present study, the present section broadly brings out the global literature on the fuel substitution.

Power generation and several industrial processes can use alternative fuels. Since the pollution characteristics of fuels vary very widely, an effective fuel switching program could often make a substantial contribution to the reduction of pollution in a region and in a country as a whole.

Two important and inter-related issues are involved in this process. The first is purely technical and engineering approach and the second is that of the size of incentives or say cross and own price elasticities of fuels which can be estimated through an econometric analysis backed by economics. In order to assess the economic viability of pursuing a fuel switching program it is necessary to have some assurance that it is possible to change the proportions of different fuels used as inputs to different processes.

The evidence presented in the fuel substitution studies till date is mostly towards the developed countries of the world economy. Countries largely dependent on coal as a primary source of energy show that there is clearly potential for fuel substitution. The tendency to rely on one fuel may be due to strong economies of scale in the energy generation in certain developing economies. There has been relatively little systematic study of fuel switching in developing countries for the power and industrial sectors.

From an economic analysis view this is largely due to lack of research in these countries. And this research gap persists since the analysis of this nature on fuel substitution possibilities needs a lengthy time series of data which is generally not available in developing countries.

2.16. Indian Energy Scenario

According to Energy Information Administration (EIA) estimates India was the fifth largest consumer of oil in the world during 2006. However coal continues to remain in the mainstay in the commercial energy consumption of India. A brief note on the status of reserves, consumption and growing demand for coal, oil and natural gas are presented here.

2.16.1. Coal

Coal is the most abundantly available domestic source of energy in India. With India having just 0.8% of world's known oil and natural gas resources, but abundant coal reserve, coal plays a pivotal role in Indian energy scenario. India's coal deposit is fourth largest in the World contributing10.2% of the total world's reserves. The United States have the largest coal reserves with share of almost 30%, while Russia and China are second and third largest with the share of 20% and 14% respectively.

In terms of production, India is the third largest coal producer in the world and India's Coal India Ltd, the largest coal producer in the world makes up around 85% of the country's coal production. 84% of the total production comes from open cast mines. Indian coal reserve is around 253.3 bn tonnes, out of which 95.8 bn tonnes is proven reserve. The Indian coal deposits have limited reserve of coking coal (32.1 bn tonnes), out of which only 5.31 bn tonnes is of primary coking coal.

The presence of high ash (up to 40%), low calorific value (average of 4000 Kcal/Kg compared to 6000 Kcal/Kg in imported coal), high transportation cost, mismatch in deposit location are some of the distinct characteristics of Indian coal. Around 70% of India's reserves are concentrated in 4 states, namely Jharkhand, Orissa, Chattisgarh and West Bengal. Jharkhand has 29% of total coal reserve, Orissa accounts for 24%, and Chhattishgarh accounts for 16% while the West Bengal makes up 11% of the total reserve in the country.

India’s total coal consumption in 2005 was around 433 mn tones but the production stood at 397 mn tonnes and hence around 35 mn tonnes of coal was imported into the country. According to, Planning Commission India coal consumption is expected to reach to 1125 mn tonnes by 2016-17, driven by the huge demand coming from Power, steel and cement sectors. Consumption from Power sector is expected to grow to around 750 mn tonnes by 2016-17, contributing almost 67% of the total coal consumption in India.

Indian coal market is in deficit as against the surplus in international market and imports almost 25-30 mn tonnes of coal. India’s coal import will continue as demand in the country will outpace the supply and the deficit in India continues. According to Planning Commission, the Demand will outpace production by around 70 mn tonnes.

India has a long history of commercial coal mining covering nearly 220 years starting from 1774 by M/s Sumner and Heatly of East India Company in the Raniganj Coalfield along the Western bank of river Damodar. However, for about a century the growth of Indian coal mining remained sluggish for want of demand but the introduction of steam locomotives in 1853 gave a fillip to it.

Within a short span, production rose to an annual average of 1 million tonne (mt) and India could produce 6.12 mts. per year by 1900 and 18 mts per year by 1920. The production got a sudden boost from the First World War but went through a slump in the early thirties. The production reached a level of 29 mts. by 1942 and 30 mts. by 1946.

With the advent of Independence, the country embarked upon the 5-year development plans. At the beginning of the 1st Plan, annual production went upto 33 mts.

During the 1st Plan period itself, the need for increasing coal production efficiently by systematic and scientific development of the coal industry was being felt. Setting up of the National Coal Development Corporation (NCDC), a Government of India Undertaking in 1956 with the collieries owned by the railways as its nucleus was the first major step towards planned development of Indian Coal Industry.

Along with the Singareni Collieries Company Ltd. (SCCL) which was already in operation since 1945 and which became a government owned company under the control of Government of Andhra Pradesh in 1956, India thus had two Government coal companies in the fifties. SCCL is now a joint undertaking of Government of Andhra Pradesh and Government of India sharing its equity in 51:49 ratios.

Coal mining: Right from its genesis, the commercial coal mining in modern times in India has been dictated by the needs of the domestic consumption. On account of the growing needs of the steel industry, a thrust had to be given on systematic exploitation of coking coal reserves in Jharia Coalfield. Adequate capital investment to meet the burgeoning energy needs of the country was not forthcoming from the private coal mine owners. Unscientific mining practices adopted by some of them and poor working conditions of labor in some of the private coal mines became matters of concern for the Government. On account of these reasons, the Central Government took a decision to nationalize the private coal mines.

Nationalization was done in two phases. In the first phase, the coking coal mines were taken up in 1971-72 and later the non-coking coal mines in 1973. In October, 1971, the Coking Coal Mines (Emergency Provisions) Act, 1971 provided for taking over in public interest of the management of coking coal mines and coke oven plants pending nationalization. This was followed by the Coking Coal Mines (Nationalization) Act, 1972 under which the coking coal mines and the coke oven plants other than those with the

Tata Iron & Steel Company Limited and Indian Iron & Steel Company Limited, were nationalized on 1.5.1972 and brought under the Bharat Coking Coal Limited (BCCL), a new Central Government Undertaking.

Another enactment, namely the Coal Mines (Taking over of Management) Act, 1973, extended the right of the Government of India to take over the management of the coking and non –coking coal mines in seven states including the coking coal mines taken over in 1971. This was followed by the nationalization of all these mines on 1.5.1973 with the enactment of the Coal Mines (Nationalization) Act, 1973, which now is the piece of Central legislation determining the eligibility of coal mining in India.

The Coal Mines Authority Ltd. (CMAL) was set up in 1973 to operate the nationalized non-coking coal mines. NCDC was brought under CMAL. In September 1975, the nationalized coal industry was restructured with the establishment of Coal India Limited (CIL), a holding company with its headquarters at Calcutta. CIL has now eight subsidiary companies. While seven of the subsidiaries of Coal India Limited viz. Eastern Coalfields Limited (ECL), Bharat Coking Coal Limited (BCCL), Central Coalfields Limited (CCL), Northern Coalfields Limited (NCL), Western Coalfields Limited (WCL), South Eastern Coalfields Limited (SECL) and Mahanadi Coalfields Limited (MCL) are coal producing companies directly engaged in raising and distribution of coal, the Central Mine Planning and Design Institute Limited (CMPDIL), the eighth subsidiary of CIL is engaged in mine planning and designing in the coal sector and is also rendering mining and engineering consultancy services. CIL, the holding company is responsible for lying down.

Corporate objectives, approving and monitoring performance of subsidiary companies in the fields of long-term planning, conservation, research and development, production, sales, finances, recruitment, training, safety, industrial relations, wages, material management, etc. CIL also owns and manages the North Eastern coalfields at Assam, which contributes approximately 0.5% to CIL's consolidated turnover. At present, CIL and its subsidiaries control all the coal mines in the country except the ones under the public sector, namely, Singareni Collieries Company Limited (SCCL), the TI SCO/IISCO collieries and a few captive coal mines managed by agencies such as the Damodar Valley Corporation.

Currently, CIL has a monopolistic position in the Indian coal industry and accounts for 86% of coal production. SCCL follows with a 10% production share. The balance is accounted by mainly the captive producers. Coal India Limited with its present annual production level of approximately 306 million tonnes is the largest coal company in the world. As compared to many other sectors, Coal has relatively higher importance to the economy. It is the key source of energy and accounts for around 56% of Primary Energy Consumption in India.

The workforce strength is also relatively higher at 0.6 mn. The industry reports a turnover of Rs. 260 bn, which is around 1.2% of GDP. The contribution to the government through various duties and taxes is over Rs.35 bn or 0.2% of GDP. The Indian coal industry has a diversified user base. However, power sector accounts for the bulk of the consumption at 74%. Other prominent users include Steel, Cement and Fertilizers units.

The coal resources of India are available in sedimentary rocks of older Gondwana formations of peninsular India and younger Tertiary formations of Northern/North - Eastern hilly region. Based on the results of regional/promotional exploration, where the boreholes are placed 1-2 Km.apart, the resources are classified into Indicated or Inferred category. Subsequent detailed exploration in selected blocks, where boreholes are less than 400meter apart, upgrades the resources into more reliable proved category.

2.16.2. Oil and Natural Gas

After coal oil and gas, remain as major forms of commercial energy in India. A brief note on the reserves, production and consumption of oil and gas is presented below.

The Basins

There are 26 sedimentary basins in India, covering a total area of approximately 1.78 million sq. km. Of this, the offshore area (up to 200-metre isobaths water depth) accounts for 0.39 million sq. km, while the onshore area takes up the balance 1.39 million sq. km. The sedimentary basins in India have been classified into four categories, based on: the geological knowledge of the basin; presence and/or indication of hydrocarbons; and the current status of exploration.

Category I is proven petroliferous basins with commercial production. There are seven basins in this category. Category II Basins with known occurrences of hydrocarbons, but from which no commercial production has yet been obtained. Two basins fall under this category. Category III Basins in which significant shows of hydrocarbons have not yet been found, but which on general geological considerations are considered prospective. Seven basins fall under this category. Category IV Basins, which on analogy with similar hydrocarbon producing basins in the world, are deemed to be prospective. Ten basins fall under this category.

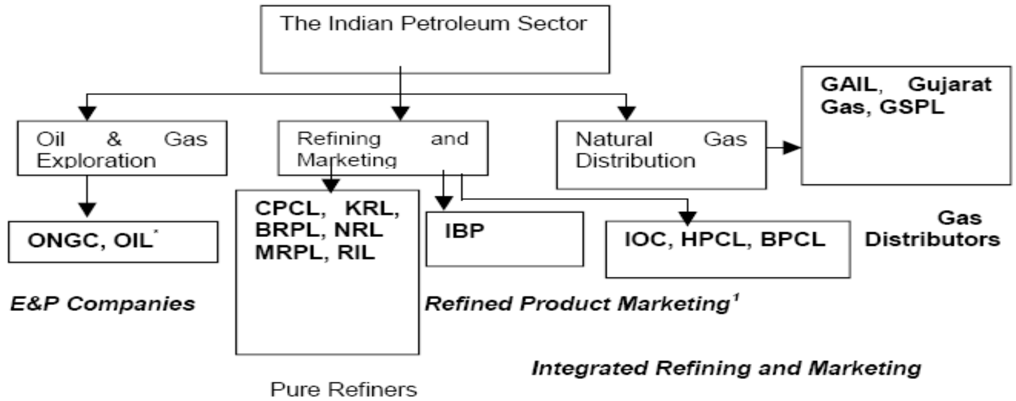
India’s hydrocarbon resource base, according to the Ministry of Petroleum and Natural Gas, is 29 billion metric tones. So far, oil has been commercially produced in only seven of the 26 sedimentary basins, while the oil reserve established through exploration is only 6.8 billion metric tones, which approximately translates to 23% of the total oil and oil equivalent suspected to exist. Exploratory drilling, so far, has been confined mainly to on land areas and up to water depths of 200 meters.

Exploratory drilling has recently been initiated in some segments of the deep-water areas, which have an estimated basin area of 1.35 million sq. km and are believed to hold a significant resource base. Of the total sedimentary basin area of 3.14 million sq. km (including deep waters), only 16% falls under the moderate to well explored category. Of the balance, while exploratory activity has been initiated in approximately 27% of the area, over 57% of the area continues to fall under unexplored (41%) or poorly explored (16%) category.

The Indian oil sector has historically been a regulated one dominated by Government undertakings. However, with the Government loosening its control, new private sector players are now gaining presence. Unlike the international oil majors which have integrated operations along the energy value chain, the Indian oil sector has companies operating in three distinct sub-segments: Oil & Gas Exploration and Production (E&P), Oil Refining and marketing of refined products (R&M) and, Distribution of Natural Gas. The major players in each of these sub-sectors are listed in the figure below.

Figure 2.1

Indian Petroleum Sector



Source: ICRA

ONGC (Oil and Natural Gas Corporation Ltd.) is the major player in the Indian E&P sector. Other players include OIL (Oil India Ltd.), Reliance Industries Ltd. (RIL), Indian Oil Corporation Ltd. (IOC), Gas Authority of India Ltd. (GAIL), British Gas, Essar Oil, Videocon, Cairn Energy, Hindustan Oil Exploration Company, Niko Resources, Gazprom, Energy Equity, Geoenpro Petrol Ltd., Geopetrol International, Enpro India Ltd., Hardy Oil, Tata Petrodyne, Gujarat StatePetroleum Corporation, Selan Exploration Technologies Ltd., L&T, Joshi Tech., Interlink Petroleum, Mosbacher, Tullow Oil, Phoenix, Okland International, Premier Oil and Geo Global Resources Government Controlled Companies: ONGC, OIL, IOC, Hindustan Petroleum Corporation Ltd. (HPCL), Bharat Petroleum Corporation Ltd. (BPCL), GAIL and Gujarat State Petronet Ltd. GSPL). Chennai Petroleum Corporation Ltd. (CPCL), Bongaigaon Refineries & Petrochemicals Ltd. (BRPL) and IBP Co. Ltd. (IBP) have now become subsidiaries of IOC. On 23/12/2004, the boards of IOC and IBP decided to merge IOC with IOC with a swap ratio of 1:1.25. Kochi Refineries Ltd. (KRL) and Numaligarh Refineries Ltd. (NRL) are now subsidiaries of BPCL.

Joint Sector Companies: Mangalore Refinery and Petrochemicals Ltd. (MRPL) used to be a joint sector company with equal stake of HPCL and Aditya Birla Group. However, ONGC has bought the majority stake of the Aditya Birla Group in MRPL making it a public sector company. Private Sector Companies: Reliance Petroleum Ltd. (RPL) - which has now been merged with parent Reliance Industries Ltd. (RIL), Gujarat Gas

The preceding chart includes the names of players whose activities in their respective areas were operational as on March 31, 2004. Thus, it is evident that Government companies have dominated in each of the areas of the oil sector. However, with the Government now loosening its control, the future is likely to see the entry of private players in almost all areas of the oil sector. The segment of oil and gas exploration and production has players such as ONGC and OIL, both public sector undertakings (PSUs). Until recently, almost the entire exploration and production work was carried out by these two national oil companies.

Of late, the Government has been awarding oil exploration/development blocks to private companies also. The New Exploration Licensing Policy (NELP) of the Government is a step in this direction. Under the NELP the Government offers attractive fiscal terms such as: level playing field for national oil companies; international oil price to contractors; zero cess liability; and 50% rebate on royalty payments for seven years for deep offshore areas. Oil exploration and production has also been given infrastructure status, which, inter alia, provides for a seven-year tax holiday. So far, the Government has awarded 90 blocks in the first four rounds of NELP.

In the Upstream Oil Exploration and Production Sector, ONGC, which is an Indian Company, is the major player accounting for the largest share in Oil and Gas production. Other players in the upstream sector include both Indian and foreign companies. As far as LNG (Liquefied Natural Gas) projects are concerned, Petronet LNG, an Indian Company, has set up an LNG terminal at Dahej (Gujarat). Shell, a multinational, is in the process of setting up an LNG terminal at Hazira (Gujarat).

Distribution and marketing of gas is done mainly by GAIL, a public sector undertaking. The other players in the natural gas distribution industry are small and regional players, such as Gujarat Gas (a subsidiary of British Gas), Mahanagar Gas Ltd. (a 50% joint venture between GAIL and British Gas and operational in Mumbai), Indraprastha Gas Ltd. (promoted by GAIL and BPCL and operational in Delhi), and the two State Government undertakings in the North-Eastern States (Assam Gas Company Ltd. and Tripura Natural Gas Company Ltd.). OIL, a public sector undertaking also has a marginal share of the natural gas distribution business.

2.17. Fuel Intensive Industries of India- A Case of Textile and Fertilizer

The overall growth in demand for all forms of fuel is dependent on the industries that use them in large proportions. A brief note on two such fuel intensive Indian industries that are textile and fertilizer is presented below.

2.17.1. Textile Industry

The Indian textile industry accounts for about 4% of India's GDP and 14% of the total industrial production. The domestic textile industry plays a vital role in the economy as it contributes to over 27% of country's total export earnings and 8% of the total import bill. The textile industry can be classified into (i) organized sector and (ii) decentralized or rural sector. The organized segment of the textile industry produces 4%

of total fabrics produced in the country, with most of it being manufactured in power looms. The total yarn required by both the organized and the decentralized sector is produced entirely within the organized segment. The cotton-textile/manmade fiber industry is the single largest organized industry in the country. The decentralized segment comprises mainly the small power looms and the handloom units.

Energy Consumption in Textile Industry

The domestic textile industry is one of the most energy-intensive industries. Coal and furnace oil are used for process head requirements. All textile mills, except those around Mumbai, use coal in their boilers. An estimated 80%-90% of the electricity used is motive power for driving pumps, motors, drives, etc.

The thermal energy requirement in a textile unit varies according to various factors like type of cloth to be processed, type and number of processing operation, type and number of machines, quality of cloth, and production capacity. Their thermal energy requirement for one meter of cloth processing varies in the range of 4500-5500kcal whereas 0.45-0.55 kwh of electrical energy goes into its processing (TERI 2004). The textile research associations in India have established energy consumption norms by machine and unit/mill, which are linked with productivity. Electricity consumption by a mill per kg of production and the heat utilization efficiency of a mill was evolved by Ahmadabad Textile Industries Research Association (ATIRA) in the early 1970's.

2.17.2. Fertilizer Industry

India has predominantly been an agricultural economy, with agriculture contribution to over a quarter of India's GDP. A sizeable proportion of the population is dependent on agriculture for their livelihood. The economy achieved self-sufficiency and self-reliance in the production of food grains following the Green Revolution, thereby providing an impetus to the overall economic development. The significance of fertilizers in the chapter of India's agricultural and all-round development of the nation as a whole cannot be ignored.

India ranks third in the world in terms of the production and consumption of fertilizers. The most widely used fertilizers include nitrogenous, phosphatic, potassic, and complex fertilizers. The demand for potassic fertilizers is met entirely through its imports, as there are not produced domestically. The total all India consumption of fertilizers in terms of nutrients, that is, N (nitrogen), P_2O_5 (phosphorous oxide), and K_2O (potassium oxide) taken together has increased marginally from 16.09 mt in 2003/04. The break up of N,P_2O_5, and K_2O consumption during 2004/05 was 11.08 mt, 4.12mt, and 1.60 mt, respectively, as against 10.47 MT, 4.01 MT, and 1.60MT, respectively, in the previous year.

Energy Consumption in Indian Fertilizer Industry

Of the four types of fertilizers-nitrogen, phosphate, potash, and complex the production of nitrogenous fertilizers is highly energy-intensive. The basic chemical that is used to produce nitrogenous fertilizer is ammonia. Natural gas, naphtha, fuel oil, and coal are used as feedstock for ammonia production. Thus, production of ammonia itself involves almost 80% of the energy consumption in the manufacturing processes of a variety of final fertilizer products. The specific energy consumption of ammonia is given in table 2.3.

Table 2.3

Specific Energy Consumption of Ammonia

(Giga-calories per tones)

year	Natural Gas	Naphtha	Fuel oil	Coal
1988-89	10	12.23	14.32	33.84
1989-90	9.6	12.35	14.36	38.85
1990-91	9.6	11.92	15.08	39.13
1991-92	9.6	11.74	13.53	39.65
1992-93	9.5	11.73	13.9	42.69
1993-94	9.41	11.7	na	na
1997-98	8.86	10.95	13.31	48.13
2002-03	8.65	9.4	12.78	na

Source: Teddy 2004/05

The average energy consumption in ammonia production exhibits a declining trend over the year that is also depicted in table 2. This is mainly due to increased share of natural gas, which is the most efficient route in the manufacture of ammonia. Similarly, the average energy consumption in urea production was recorded as 6.49 Gcal/tonne during the same period. This is equivalent to 5 million tones of oil equivalent (mtoe), of total urea production in the country.

Natural gas being the preferred feedstock accounted for 56% of the Urea capacity as on November 1, 2006. There has not been much conversion of plants using other feedstocks to natural gas. Shriram Fertilizers and Chemical unit at Kota, Rajasthan has also recently converted to natural gas. Naphtha is used for less than 30% of urea production and the balance capacity is based on fuel oil and low sulphur heavy stock

(LSHS) as feedstock. The two coal-based plants at Ramagundam and Talcher were closed down due to technological obsolescence and non-viability. The total off-take of natural gas in fertilizer industry as feedstock declined from 7.95 billion cubic meters (bcm), in 2002/03 to 7.89 bcm in 2003/04. This is explained by the unavailability of natural gas and rise in gas prices.

The consumption of naphtha in the manufacture of fertilizer industry rose from 3.03 mt in 2002/03 to 3.23 mt in 2003/04. There was a corresponding increase in the consumption of furnace oil/LSHS from 1.87 mt in 2002/03 to 1.89 mt in 2003/04. Further more, most of the energy input goes into the manufacturing of ammonia. Based on the available technology and economy of use, natural gas is the most appropriate source of feedstock for ammonia production.

2.18. Fuel Demand in Indian Power Sector

Electricity is one of the most vital infrastructure inputs for the economic development of a country. Since independence, the Indian electricity sector has grown manifold in size and capacity. The total installed generation capacity is depicted in table 2.4.

Table2.4

Installed capacity as of February 2007

(Million Watts)

	Thermal (coal)	Thermal (gas)	Thermal (oil)	Thermal (total)	Nuclear	Hydro	Wind
State	38,870	3,500	605	42,975	Nil	25,728	2,568
Private	4,241	4,183	597	9,021	Nil	1,306	3,623
Central	26,510	5,899	Nil	32,409	3,900	7,052	Nil
Total	69,621	13,582	1,202	84,405	3,900	34,086	6,191

Source: SSKI

The above table depicts that with 84,405 MW thermal electricity generation stands as the primary source of electricity generation. Coal stands as the dominant fuel in the thermal energy mix.

2.19. Is Fuel Availability a Hurdle? - No

Coal- based power plants are unlikely to face any fuel shortage given India's estimated 1001 billion tonnes of mineable coal reserves and the option to import high quality coal mainly from Indonesia and Australia. The plants using gas or liquid fuels would continue to face fuel shortages and the grim choice of running plants with higher costs or shutting down.

But there exists a demand-supply gap. The country is currently deficit in power both at meeting its energy requirement as well as the peak load demand. The problem becomes acute during peak hours and thus, necessitates planned load shedding by many utilities to maintain the grid in a healthy state. The all India average shortages during

2001-2002 were 7.8% in terms of energy and 13% in terms of peak load. There were considerable regional, local, rural-urban and seasonal variations. Many parts of the country are unable to meet their unconstrained demand and resort to load shedding.

2.20. Summary

To sum up this chapter deals with energy-economy interactions, hurdles involved in estimating the energy demand for developing countries and sums up presenting current status of fuels namely coal, oil, gas and fuel intensive industries namely--textile, fertilizer and power in the Indian context. Also a brief description of the major players and the organization of the fuels and the fuel intensive industries are presented in the chapter. As explained at the end of the chapter there is no nearing shortage of fuels for the economy from the resource point of view. However, there exists a huge demand-supply gap. Hence there is every need to understand the factors that lead to this demand-supply gap. The present chapter serves to understand the background and the need for studying the elasticity of substitution of the fossil fuels in detail.

Chapter 3

Review of Literature

3.0. Introduction

The present chapter reviews the literature till the date on interfuel substitution. A brief review of the factor or input substitution is also presented to draw the difference between the two. The dearth of recent studies in the area of interfuel substitution in the Indian context is clearly brought out though this review. And a brief note on the works undertaken on the discussions of conceptual framework and the studies of energy substitution are also discussed towards the end of the chapter.

Energy prices in India, basically of commercial energy, went up five fold in recent years. A trend analysis of different energy products and their prices in India has been done by **Sarkar and Kadekodi (1987)**. The study has shown that the petroleum products as a singular group have shown a price increase at a trend rate of 15.19% between 1970-71 and 1985-86. Much of this increase has been contributed by an increase in crude oil prices. Meeting the future energy demand is going to be a major concern for India, not only for sustaining but also accelerating the future growth of the economy.

In recent years, the short and medium term policy objectives of most countries have been framed in terms of reducing the overall energy intensity of their economies, as well as the dependence on commercial sources of energy, like coal, oil, gas, and electricity. In order to achieve these objectives, besides taking steps for conservation of available energy, most countries have also focused on investigating the possibilities for both inter-input i.e. involving energy and other non-energy inputs like capital, labor and materials and inter-fuel like coal, oil, gas and electricity substitution.

The extent of impact and energy shortage on economic activity depends crucially on the elasticity of substitution among energy inputs. By analyzing the substitution possibilities among the alternative fuels like coal, oil, gas, researchers guide the policy makers in planning the future of fuels individually. It might also help in framing policies for extraction, imports, pricing etc.

In India, while a number of studies providing estimates of demand functions for final consumption goods are available, only a few studies on energy input demand functions have become available, **[Jha et al, 1991].** Most of the studies seem to have focused mainly on the substitution possibilities between capital and labor inputs. Knowledge of the role of fuels and the extent to which substitution is possible in the energy intensive sectors of the economy, are especially needed. Most of the earlier studies have focused on the factor substitution effects in the manufacturing sector. This is because, the industrial sector in any country has been the major energy consumer.

As mentioned earlier, a review of the earlier studies which focused on both factor and fuel substitution becomes relevant and the same is attempted in the chapter. Broadly, the studies may be categorized as inter-input substitution studies, and inter-fuel substitution studies. But many a times both input and fuel substitution are studies together to bring out a comprehensive understanding on the energy substitution. Also a study by **Thompson (2006)** briefing the theory of energy substitution brings out the importance of energy substation estimation in understanding the development of an economy. Studies falling under all the above categories are reviewed in the following sections of the present chapter.

3.1. Studies on Input Substitution

Evidence on the possibilities for substitution between energy and non-energy inputs in the manufacturing sector of the United States (for the period 1947-1971) has been provided by **Berndt and Wood (1975).** Based on four inputs 'KLEM' (capital, labour, energy and materials) model of cost function, the study assumed perfect competition in the factor markets, input prices as fixed, and production characterized by constant returns to scale. The study chose to employ the translog cost function for the four inputs KLEM model. The study utilized the annual inter industry flow tables presented by **Faucett (1973)**. These tables measured flows of goods and services from 25 producing sectors to 10 consuming sectors and five categories of final demand in both current and constant dollars. Finally they concluded that energy demand is responsive to a change in its own price. Energy and labor are slightly substitutable, energy and capital display substantial complementarities. Since the study covers only the United States the conclusions cannot be generalized to all the countries.

Extending the work of **Berndt and Wood (1975)** to inter country data **Griffin and Gregory (1976)**, estimated translog cost function from pooled international data for the manufacturing sector of nine industrialized countries. The model is constructed from pooled international data for four benchmark years namely 1955, 1960, 1965, and 1969. The data collected from various national level statistical sources of respective countries consisted of manufacturing sectors energy, labor and capital cost shares values at factor cost. In an early study of **Berndt (1975)** it was found that energy is a substitute for labor and a complement to capital. But the study of **Griffin and Gregory**, found that the elasticity of substitution between energy and other inputs is non-zero. the study has not come out with findings significantly different from those of **Berndt (1975)**.

Laumas and Laumas (1981) studied the substitution possibilities among energy inputs and other non-energy factors of production in response to price changes in the Indian manufacturing industries for the years 1960-70. The study estimates the cross price elaticities of demand of pairs of factor inputs and the own price elasticity of demand for each of the four factors. In order to estimate these elasticities, maximum likelihood estimates of a four input translog cost function for different product groups were obtained. The study presents three conclusions. First, for most industries factors other than labor appear to be fairly good substitutes for energy. Thus it concludes that the lack of energy alone cannot be a severe bottleneck to the continued growth of India's manufacturing sector. Second, tests of separability employed in this study, indicate that the traditional functional forms such as the Cobb-Douglas cannot adequately describe the technology of India's manufacturing sector and energy must be treated as an input in the production process. Third, the own price elasticity of energy is generally higher than the own price elasticity of other inputs which indicates that energy input can allow a fair amount of adjustment in a firm's productive response to factor price changes. However the work is based on a cross section data and it insists that the conclusions drawn may not be applicable in the short-run.

Input substitution possibilities in the Indian energy intensive industries has been studied by **Jha et al (1991)**. An aggregate time series data covering the period of 1960-61 ti 1982-83 is collected from Annual Survey of Industries for estimating the three input translog cost function for each industry. They confined the study to iron and steel, gas and electricity, cement and cotton textiles industries in India. The study distinguished the production as a function of Labor (L), Capital (K), and energy clubbed with materials. The major finding of the study are: i) all factors of production are good substitutes for each other in the cement industry, ii) labor and capital are good substitutes for each other in the iron and steel industry but they are complementary inputs in cotton textiles, iii) labor and energy materials are substitutes in all the four industries. The work is a detailed piece of study focusing on four major manufacturing industrial segments of India.

Morrison (1993) attempted to analyze some interactions between energy and capital that affect firm's productive performance through indirect effects of energy price charges. Based on a flexible cost function framework with capital, labor, energy and materials inputs, the role of the substitutability of energy and capital, as well as capacity utilization in productive performance of U.S. manufacturing firms is evaluated in this study. The data selected for this study is similar to that of **Berndt and Wood** for two digit U.S. manufacturing for period 1949-76. The disaggregation of industries into seven important two-digit manufacturing industries and decomposition of capital into three components with a focus on high-tech capital equipment has provided implications which are contrary to the past studies. According to this study, energy and capital in U.S. manufacturing appear to have because increasingly substitutable over time in most industries excepting high technology industries.

Roy et al (1999) analysed productivity growth and input trends in six energy intensive sectors of the Indian economy using a translog production model. Relevant data for the six industries, aggregate manufacturing and total industry were collected from various editions of the Indian Annual Survey of Industries, on value shares for the four input factors for each industry, for the period 1973-93. The study found that inter-input substitution possibilities are relatively weak.

Frondel et al (2002) reviewed a series of empirical studies of factor substitutability, which used the transog approach for estimation. The paper made an attempt to explain the reasons for the divergent results of the static translog studies of the capital-energy debate. They conclude that using a tranlog approach reduces the issue of factor substitutability to a question of cost shares, which leads to divergent results of the studies. Hence, the study suggests a better approach via a restricted cost function that allows a distinction between the short and long run changes of factor substitution.

The forgoing review has been confined to studies which have focused on the inter-input substitution, and based on select important studies. In the forthcoming section a review of studies concerning inter-fuel substitution is presented.

3.2. Studies on Inter-Fuel Substitution

An early but important study in fuel substitution possibilities has been made by **Atkinson and Halvorsen (1976)**, which examined the demand for fossil fuels by electric utilities, that accounted for 66 per cent of coal, 8 per cent of oil and 19 per cent of natural gas consumed as fuel in the U.S in the year 1971. The study also investigated aspects of the production process, including separability of fuels from other inputs, homotheticity, returns to scale and technical change. The literature existed prior to this study addressed all the fuels as a single fuel input for production. And also the methodology used for these studies comprised restrictive functional forms, imposing severe a priori constraints on elasticities of substitution. The study of **Atkinson and Halvorson (1976)** however addressed all these issues by treating coal, oil and gas as different inputs, and by using transcendental logarithmic function, which avoids many a priori restrictions. The model estimated assumes electric energy produced by a plant to be a function of variable and fixed inputs. They also assumed capital and labor are fixed inputs in existing plants. They assume that a restricted profit function provides a convenient model for analyzing the effect of price changes on fuels choice. The own and cross price eleasticities for fuels are derived from the demand functions.

Most of the earlier studies assumed that the production technology could be specified in terms of capital, labor and a fuel aggregate. **Atkinson and Halvorsen** argue that this is a valid assumption if fuels are weakly separable from capital and labor. The model estimated by them makes it possible to test the separability assumption explicitly.

The model is estimated for individual plants using Federal Power Commission data for 1972. The prices of fuels are calculated by dividing expenditures on each type of fuel by quality purchased. Therefore plants, which used only one type of fuel in 1972, could not be included in the sample. The number of plants using all the three fuels is to small for estimation of the system of profit and demand equations. Therefore separate sets of equations estimated for each pair of fuels; coal-gas, coal-oil and oil-gas.

Major findings of the study indicate that steam electric power generation is characterized by substantial ex-post inter-fuel substitution, homotheticity, absence of strong scale economies, and little embodied technical change. The data on the price of output are not available at the plant level. Hence the work needed further extension with a modified set of data.

Griffin (1977) estimated the inter-fuel substitution relationships among fossil fuels namely coal, gas and residential fuel oil in the generation of electricity. This study extends the application of the tranlsog model to an international sample consisting of pooled, cross section, and time series observations. The study estimated two models for analysing the fuel substitution behavior of electric utilities. Model-one concentrates on inter country long-run effects of fuel substitution and model two on the estimates within the countries. The study assumes that coal, gas and fuel oil make up a separable and homogenous energy aggregate. There are two sub models; one in which capital, labor, and aggregate energy inputs are determined. The sample selection is based on empirical considerations, inter-country pooled data to reflect more on the long-run equilibrium and to provide a much robust sample of relative fuel price variations than conventional time series data.

The study made use of a pooled multi-country sample, consisting of observations for 20 OECD countries for five intervals during the period 1955-1970. The estimated model investigates inter-fuel substitution among countries the selected countries. A major finding of the study is that higher oil prices creating a fairly high stimulus to both coal and gas tends to be particularly weak. With this study the extension of the translog cost function to a pooled international sample offers a potentially fruitful new avenue of research for 80's and 90's.

Harloversen (1977) estimated energy demand equations for two digit manufacturing industry of the U.S for the year 1971. The study aims at examining the shifts in composition of energy consumption in manufacturing as a result of changes in relative energy prices. There exists a difference in energy consumption across industries, due to their energy intensity levels or due to the output. The study explains that apparent differences in energy consumption across industries indicate that the inter relationships between the demand for each type of energy should be examined on an industry-by-industry basis. The translog cost share equations are estimated with the help of data on the quantity consumed and total cost of each type of energy provided by the U.S. Bureau of census for the year 1971. The price of each type of energy is calculated by dividing cost by quantity consumed. The study found that the estimated fuel elasticities of demand vary both across industries and across types of energy. Aggregate manufacturing demand for each type of energy appears to be highly price-responsive. The results also indicate significant cross price responsiveness, particularly with respect to the demand for fuel oil.

But the elasticities do not measure the net effects of price changes on consumption of fuel oil, natural gas and coal. Because these fuels are inputs in the production of electric energy, the net effects of price changes will include changes in the demand for fuels in electric power generation. The propriety of study for a policy recommendation is questionable since the data period is only one year.

The study which was first of its kind in the Indian context about energy demand and inter-fuel substitution has been attempted by **Uri (1978).** He applied a translog price possibility frontier to a pooled sample in order to measure the extent of energy substitution effects in the commercial sector in India. The study estimated the translog price possibility frontier. The share equations are estimated with pooled annual data compiled for 1960 through 1971 by five commercial sub sectors namely i) mining and manufacturing ii) transportation iii) domestic iv) agriculture and v) commercial, government etc.

The study concludes that coal, oil and electrical energy are all in competition with each other as an energy source in most sub sectors and every indication points to the fact that elements within the commercial sector are responsive to relative price changes when making their energy choice. The results indicated in this study show that changes in energy prices have significant effects on energy consumption.

Kar and Chakraborty (1986), attempted to verify the degree of inter-fuel substitution possibilities through the elasticity estimates for manufacturing sector. The study examines whether or not the energy demanded shifts in the energy mix are due to changes in relative energy prices. The study analyses elasticities of inter-fuel substitution in eleven relatively energy intensive industries. The study assumes that in all the eleven industries there exists a homothetic and linear homogenous production function which is weakly separable in energy and other input aggregates. The study selected transcendental logarithmic cost function for the purpose of estimation. For the estimation of the translog model in the eleven energy intensive Indian manufacturing industries, data on prices of energy types like coal, oil and electricity and their cost share of each fuel type in total energy consumption are necessary.

Annual Survey of Industries, reports the consumption of each fuel type in both quality and value terms for sub-groups of industries categorized under each three-digit level industries for the periods of 1959-1971, 1973-74. The study uses this data information available over the period 1959-71 for the estimation of the model. Price for each type of fuel has been obtained by dividing the total value of consumption of each fuel type by the coal replacement amount of each type. The study concludes that coal and oil are better substitutes for the industries compared to coal-electricity or oil-electricity, as the magnitudes for latter co-efficients are comparatively smaller. There is a discrepancy in the study due to the break sample data i.e. year 1971-1973.

Vlachou and Samouilidis (1986) studied inter-fuel substitution in various sectors of the Greek economy. In this study fuels are aggregated to solid fuels, liquid fuels and electricity. The model is estimated using time series data over the period 1960-80. The results indicate substitutability between liquid fuels and electricity and complementarity between liquid and solid fuels and substitutability between electricity and solid fuels.

Ali (1986) studied south Australian residential sector fuel substitution possibilities. He estimated a cost function for the period of 1960-82 to find the elasticity of substitution among the fuels for South Australia. The work assumes that there are two points of view to look at the consumer behavior in the residential energy sector. One view point postulates that each consumer wants to maximize utility subject to a budget constraint and that utility is a function of goods and services consumed. And the other view is consumption is an activity in which goods, singly or in combination, are inputs and in which the output is a collection of characteristics. The second view can also considers the households as producers who determine the optimal uses of inputs by minimizing costs for a given level of output, the level of output being determined by the budget constraint.

The estimated own-price elasticities for gas and oil in the study are larger than that of electricity. The major finding of the work is that if all energy prices and per capita income increase by the same percentage, household energy consumption will decline despite the increase in income. The work is one of its kind since there are not many studies which modeled the household or residential energy elasticity of demand.

Magnus and Woodland (1987) studied substitution of coal, oil, gas and electricity in the Dutch Manufacturing for the period 1958-1976. The six industries of Dutch manufacturing sector are (i) food, beverages and tobacco products (ii) textiles (iii) paper and paper products (iv) chemical industry (v) building materials, earthenware, glass and glass products and (vi) fabricated metal products, transport equipment and mechanical and electrical engineering. All these industries together account for roughly 75% of Dutch manufacturing output. This study assumes that the energy inputs are weakly separable from all other inputs and outputs, and focuses upon the estimation of the substitution possibilities between energy types (fuels).

An additional feature of the study is that the stochastic specification employs a multivariate error components model involving serial correlation. This model specifies that the vector of random disturbances in the system of share equations comprises of a vector which is different for each industry, and a common vector which reflects macro-economic disturbances affecting all industries in the same manner. As a result the disturbances for the different industries are coreelated with each other, requiring joint estimation of the share equations for all industries on efficiency grounds. Both components of the disturbance vectors are assumed to follow first-order autoregressive processes.

Thus, the model involves both contemporaneous and inter-temporal correlations between disturbances, and is estimated by the method of maximum likelihood. The results indicate that, at the sectoral level, the conditional demands for fuels are inelastic with respect their own prices. They also show that coal and oil are substitutes for gas that is, the demand for these fuels increases when the price of gas increases. Gas is found in the study as substitutable for coal, oil and electricity. While elasticities at the industry level vary in size and sign, the results show that gas is a substitute for both coal and oil in five out of the six manufacturing industries.

Andrew and Marshall (1991) present an econometric study of the demand for energy in the UK economy using quarterly time series data for the period 1971-1986. The study considers four economic sectors: other industry, domestic, other final users and transport; and the four most important fuels: gas, electricity, oil and coal. The work aims to construct an econometric model to explain the substitution possibilities among the four fuels in each economic sector, and to obtain forecasts of the individual demands. A model based on a translog cost function is formulated. The work is different from the earlier studies since the technical progress is modeled by means of stochastic, as opposed to deterministic, trend components. The model is estimated using quarterly UK data for four economic sectors, and forecasts of the future level of demand are made. The findings show significant price effects in the system of shares, although the resulting short-term demand elasticities are, in general, quite small.

Gas, electricity and oil are substitutes in all the sectors except in the other final users sector where electricity and oil were found to be complements. The stochastic trend incorporated in the model indicate that technical progress for the four sectors, shows that at constant prices, the technology biases the use of fuels towards gas and against coal in all the sectors. The biases for electricity are positive in the other industry and other final users sectors and negative in the other two. For oil, the biases are positive only in the transport sector, however the work predicts only for the five year period fuel substitution possibilities between and among fuels and is not aimed at predicting longer substitution possibilities.

Bacon (1992) through his study for World Bank brings out the distinction between the econometric analysis and engineering analysis of fuel substitution. Many econometric studies of fuel switching and fuel use have been published and these form a natural starting point for an analysis of methods of measuring fuel substitutability. Interest in the use of fuels began with a series of studies in the 1970's which investigated the impacts of the rise in the real energy prices following the first oil shock. A crucial point for such studies was the extent to which energy was a substitute or complement to the other inputs. The methodology developed in these studies was later extended to disaggregating between the different fuels so that it became possible to estimate the degree to which one fuel was switched for another as well as the degree to which fuels were substituted in total against other factors of production.

All econometric studies have made certain assumption about the nature of the use of energy which are central to the models developed but which are quite different in spirit from the approach of engineering studies. The central assumption is that there is a continuous degree of substitutability between the various inputs. Small changes in external forces, such as relative prices, will then produce small changes in the patterns of energy use and fuel choice. The principle defense for the econometric approach is that for an aggregate defined over many plants a small change in price will produce a response at some, but not necessarily all, sites, so that there is always an aggregate response to price changes.

The second distinctive feature of the econometric studies of fuel substitution is that typically the link between capital and energy is not formally specified. They are usually viewed as two factors which may or may not be complements or substitutes. If one fuel is to be substituted for another the prices of the fuels are used as explanatory factors. Where as in an engineering analysis of fuel substitution is a mere statement of choice between fuels, and doesnot attempt to consider the market forces like prices which are mostly dependent on the policy changes in a developing economy.

Jones (1995) studied inter-fuel substitution for industrial demand in the U.S. The study has primarily two objectives. First, using annual data on U.S. industrial fuel consumption from 1960 to 1992, to estimate a dynamic and extended version of linear logit model that satisfies global symmetry, thereby gaining important new insights about the rate of dynamic adjustment in industry energy demand that Pindyck (1995) sought unsuccessfully to obtain. Secondly, to provide new evidence on the impact of excluding the consumption of fuels used for non-energy purposes on estimates of price elasticities and the rate of dynamic adjustment.

The study used fuel-specific consumption data for the industrial sector published by state energy data report for the period 1960 to 1991. And annual fuel prices were taken from State Energy Price and Expenditure Report for 1970-1991. The study concludes that aggregate data does not seem to impart any significant bias to estimation of the rate of dynamic linear logit model. The results of the study are compared to that of previous studies and the study concludes that the dynamic linear logit model should be used extensively for the studies of energy demand in future.

Soderholm (2001) analysed the short-run inter-fuel substitution between fossil fuels in West European power generation. The problem is studied within a restricted translog cost model, which is estimated by pooling time series data across eight countries in West Europe. The countries are Austria, Belgium, Germany, Ireland, Italy, Netherlands, Spain and the UK. For these countries annual time-series data between 1978 and 1995 have been used except in the cases of Austria and Ireland for which data for the periods 1978-1994 and 1981-1995 respectively, due to the availability are used. The total sample used was 140 observations.

The estimated model includes fossil fueled electricity production, installed thermal power capacity, fossil fuel use in electricity production and the prices for three fossil fuels. The study presents framework for inter-fuel substitution in existing thermal plants. The study concludes that short-fuel substitution is significant in the West European power sector.

Bjorner and Jensen (2002) studied the inter-fuel substitution between electricity, district heating and other fuels for most Danish industrial companies during the period between 1983 and 1997. In this study they estimated two models of interfuel substitution namely (i) translog model and (ii) cost share linear logit model for estimating the cost shares of the selected fuels. The data selected is micro level panel data, collected from energy surveys carried out by Department of Energy Statistics, Denmark for the years 1983, 1985, 1988, 1990, 1993, 1995, 1996 and 1997. All the industrial companies with more than 20 employees are chosen for most of the period. The panel is unbalanced.

In the estimates presented, companies that are present in only one year (in each energy pattern) and industrial companies with their own local production of electricity or district heating are excluded. A total of 3636 different companies are included in the estimations. These companies cover the majority of all industrial companies and the value added of the Danish industrial sector in the period analyzed.

The study found that the two models give the same qualitative answers with respect to inter-fuel substitution. Thus for both models, inter-fuel substititution is higher for companies using electricity and fuels. The study brings out that the increase in use of electricity by the industrial companies which has taken place in Denmark as well as in most other developed countries cannot be attributed to changes in the price of electricity relative to other types of energy. Rather the increase is related to technological change.

Ko and Dahl (2001) studied inter-fuel substitution in US electricity generation for the year 1993. Due to the restructuring and increased competition changes in the US electricity market, the fuel choice in generation is expected to become more flexible and responsive to the changes. To investigate this hypothesis, studies on US electricity fuel choices for three decades are reviewed and an analysis is provided on the US electricity market which is quite different form the one on which earlier studies are presented in this study. A dataset including 185 utilities on monthly basis for the year 1993 were studied. The study sums that fuel choice is showing a considerable amount of price responsiveness to the restructuring of industry. And the amount of responsiveness seems to have increased for oil and natural gas when compared to coal.

Kratena (2003) studied inter-fuel substitution for coal, oil, gas and electricity at a level of 12 activities. The fuel input demand is estimated at an aggregate level for the selected activities by using time series approach. The impact of prices and of technical progress in each activity is decomposed into two effects that is changes in the share of appliance technologies and (b) fuel switch within appliance technologies. The study concludes that technical change taken place endogenously leads to inter-fuel substititution.

While these are the studies done on interfuel substitution possibilities and elasticities of substitution of fossil energy the following section discusses the studies undertaken combining both input and fuel substitution possibilities.

3.3. Studies on Input and Fuel Substitution

Pindyck (1978) compared the inter-fuel substitution and the industrial demand for energy in ten countries. The objective of the study was to provide some new evidence on the extent of capital, labor and energy substitutability, the long-run own and cross price elasticities of energy and individual fuels, the impart of growth in individual activity on the demands for energy and individual fuels, and the effects, for ten different countries, of increased energy costs on the cost of output. The study made some restrictive assumptions about the structure of production.

The study assumed that capital, labor and energy inputs are as a group weakly separable from the fourth input materials. Secondly the production function is weakly separable in the major categories of capital, labor and energy. Thirdly, that the capital, labor and energy aggregates are homothetic in their components in particular, that the energy aggregate is homothetic in its oil, gas coal, and electricity inputs. The model is estimated using pooled time-series data for a cross-section of ten countries: Canada, France, Italy, Japan the Netherlands, Norway, Sweden, the UK, the US and West Germany.

The share equations for the energy cost function are estimated using data over the period 1959-1973. The share equations for the total cost function are estimated using data for 1963-1973. The major finding of the study is that elasticity of substitution for energy and capital is positive, so that these inputs are substitutes and not complements as earlier studies had indicated. And the elasticity of substitution is smaller in case of the U.S. and Canada for labor and energy.

The study found through its estimated factor substitution model that for Europe and Japan labor and energy are substitutes and capital and labor are substitutes. And the in the estimated sub model of inter-fuel substitution the fuel price elasticities are as follows. The coals own price elasticities are large for all countries. For Europe and Japan own price elasticities for natural gas are large, while those for oil are small. For Netherlands and West Germany as oil and gas prices fell, there was a large increase in the share of natural gas as supplies became available for the first time. To conclude the study could not come to any consensus on any substitution possibilities of factor and fuel substitutions. Exact explanation for this could probably require further work.

Vashist (1984) studies the price sensitivity of energy demand and substitution possibilities among energy components as well as between energy and non-energy inputs. The study is carried out at the level of total manufacturing sector. The demand for oil is, to a large extent, met through imports, which account for a major proportion of country's export earnings. Hence an investigation into the characteristics of energy demand assumes importance. The objective of the study is to acquire knowledge of price and substitution elasticities of energy inputs for the manufacturing sector. The prescription and assessment of energy conservation measures, the evaluation of effects of energy price rises or the question of reducing dependence on imported oil require knowledge of price and substitution elasticities.

Estimation of energy model from its derived share equations required cost shares and prices of energy components that is coal, oil and electricity while estimation of the aggregate sub model requires cost shares and prices of aggregate inputs that is capital, labor and energy. The basic data for the study has been drawn from Annual Survey of Industries for the period 1960-71, published by the Central Statistical Organization of the Government of India. The study concludes that the interfuel relationship is that of substitution within energy sub model but is of a complementary when all the net cross-price elasticities are negative.

The study concludes that at least in the short-run, there do not exist substantial substitution possibilities among energy components in the Indian manufacturing sector. The net own price elasticieites for coal, oil and electricity when calculated at the means of exogenous variables shown that the three energy components are responsive to their prices and a target of say 10 per cent conservation of any energy component can be achieved by raising its relative price by 23 per cent approximately. Coming to the aggregate energy model framed in the study the cross price elasticity between energy and capital tends to be complements in the short-run.

Murty (1986) estimated the demand for energy and non-energy inputs in the Indian manufacturing sector relating to substitution possibilities between renewable that is electricity and non-renewable that is oil and coal energy sources in view of the increasing supply price of non-renewable energy. The study provides evidence on substitution possibilities among various energy inputs and their substitution/ complementarity relationships between energy and non-energy inputs and between various non-energy inputs (labor, capital and intermediates).

The study proposes two models for the Indian manufacturing Sector. One is the aggregate energy model and the other is the energy-sub model. Both the models are estimated using time series data. The energy sub-model is estimated for the period 1953-1977 while the aggregate model is estimated for the period 1960-1977. The estimation of energy sub-model requires the data on shares of energy components in the total annual energy cost of manufacturing sector and the price-index number of energy inputs, namely, coal, electricity and oil.

The Report of the Working Group(1979) on framing an integrated energy policy, Government of India, provided data on annual consumption of commercial energy in the industrial sector by items in million tons of coal replacement (MTCR) for the years 1953-1954 to 1978-79. Using this data the study estimate the share of coal, electricity and oil in the total annual energy cost of manufacturing sector during the 25 years period. The data required for estimating the aggregate model on shares of labor, capital, energy, annual cost of the manufacturing sector and the index numbers of input prices are collected from Annual Survey of Industries reports for factory sector.

The production structure for Indian manufacturing sector estimated with the specification of translog cost function does not impose any restrictions on elasticity of substitution between inputs. The study concludes that the elasticities of substitution between inputs in Indian manufacturing sector are high. And the elasticity of substitution between aggregate energy and other intermediary inputs is low while there are high elasticities of substitution between capital and energy inputs. The own price elasticites for energy inputs as well as for aggregate energy and non-energy inputs are highly price responsive. Finally the study concludes that there are strong substitution possibilities between capital and labor.

From the above review it is clear that on exclusive study based on fuel substitution among all the major energy-consuming sectors has not been attempted till date. Existing studies either focus on input or fuel substitution for manufacturing sector or for electricity sector individually. However, to understand and access the future of the fuels individually in the short and long run, a study combining fuel substitution possibilities in both energy and non-energy industries is needed.

3.4. Study on Applied Theory of Energy Substitution

Thompson (2006) studied the applied theory of energy substitution in production. The study reviews the applied theory of energy cross price partial elasticities of substitution, and presents it in a transparent fashion. It uses log linear and translog production and cost functions due to their economic properties and convenient estimating forms, however the work emphasizes on using other innovative functional forms keeping the underlying theory unchanged. The objective of the work is to encourage increased empirical research that would deepen understanding on the application of energy substitution.

The accuracy of the translog cost functions is reviewed one again for the modern days and was proved as the best fit model for estimating price elasticities by Stern (1994). The work also points out that certain previous studies questioned the accuracy of the translog function, since the results contradict the underlying theory of production function. But Stern (1994) proved that the results in these earlier works contradict the underlying theory due to the unrealistic assumptions and not due to the functional inaccuracy.

3.5. Concluding Remarks

To sum up, the chapter reviews a set of studies aimed at inter factor/input substitution and energy substitution. The review covers selected important studies till date undertaken on interfuel substitution. The conclusions varied from time to time and from region to region. Though a large part of the work concerns the United States economy, a few studies are available for the developing countries. Even in India, there are a few studies undertaken in the recent times on estimating the elasticity of substitution among the fossil fuels.

Chapter 4

Methodology

4.0 Introduction

Over the last several years an extensive amount of literature has been developed centering on the theory of production and cost. Earlier research work in this area concentrated largely on a few specific functional forms for the production relationship, the most popular being the Cobb-Douglas and Constant Elasticity of Substitution (CES), models. But these forms appear to be highly restrictive in case of more than one product or more than two factors of production. For instance in the context of several inputs, it implies pair of inputs are equal and the possibility of complementarity between any pair of factors is ruled out. Recently, several functional forms have been proposed which avoid these restrictions and are flexible. Transcendental logarithemic functional form is one such orm. The present chapter discusses the translog function and its application in general and describes the methodology adopoted for the present study.

4.1 Transcendental Logarithmic (Translog) Function

The literature on production and cost, and on utility and demand has evolved in several directions. In the area of producer behavior modeling, the classic paper by Arrow et al(1961) called into question the inherent restriction of the Cobb-Douglas model that all elasticties of factor substitution are equal to one. Researchers since then developed numerous flexible functions that allow substitution to be unrestricted, and not constant. Similar strands of literature have appeared in the analysis of energy demand.

4.1.1. A Brief History of the Functional Form

The tranlog function introduced by Christensen, Jorgenson and Lau (1973), being one such flexible functional form constitutes an important development in the theory of production and its applications. The underlying theory of the function has been fully expounded in subsequent studies, and techniques for estimating the Allen partial elasticities of substitution have been widely used to investigate the empirical nature of derived demands for factors.

4.1.2. Translog Application in the Earlier Studies

The translog function can be studied from input function or cost function due to duality principles. However in most studies cost function approach has been adopted. **Griffin (1976),** and **Pindyck(1979),** have developed translog model to study inter input and interfuel substitution. **Uri (1979),** following **Berndt (1973)** and **Jorgensen (1973),** in the Indian context estimated inter fuel substitution possibilities in the commercial sector. Later Murthy (1986) adopted translog cost functions for estimating both inter-input and inter-fuel substitution possibilities in India. In a contemporary study done by **Kar and Debesh(1986),** also chose Tranlog cost function for the purpose of estimating the shifts in the energy mixes in relation to the changes in relative energy prices. In all the above studies there exists either three or more than three fuels for estimating the translog cost function. But in case of a developing economy there are many such instances where companies use fuel switching system with two fossil fuels with similar combustion properties. Hence the present study adopts a methodology for company level estimates that was initiated by **Ko and Dahl (2001).** The study uses two fuel input case for estimating the inter-fuel substitution in US electricity generation industry. In the case of two fuels for Indian companies the present study follows Ko and Dahl (2001), and in case of three and four fuels the study follows the classic model of **Pindyck(1979).**

4.1.3. Functional Form of Translog Cost Function

A brief note on the properties of the Translog function are presented here. The Translog functional form represents the cost or output by functions that are quadratic in the logarithms of inputs and outputs. It provides a second order local approximation to an arbitrary underlying function about a point. In this form, the magnitude of the error of approximation can be assessed by measuring the discrepancy between the point of evaluation and the point of expansion. For a given set of parameters, the Translog form will be well behaved, thus meeting the minimum requirements of a production or cost function in a region of input space. The Translog production and cost functions are neither additive nor homogeneous and can easily include multiple products and multiple inputs.

Suppose that a firm produced 'Y' level of output using 'n' energy and 'm' non-energy inputs. Assuming the absence of technical progress, the production structure may be given by

$$Y = f\left(x_1, x_2 \ldots. x_n ; \overline{x_1}, \overline{x_2}, \overline{x_m} \ldots \right) \qquad \ldots. (4.1)$$

where $x_1, x_2 \ldots\ x_n$ are 'n' energy inputs and

$\overline{x_1}, \overline{x_2} \ldots\ \overline{x_m}$ are 'm' non-energy inputs

If the input prices $p_{1,} p_2, \ldots p_n, \overline{p}_1, \overline{p}_2, \ldots \overline{p}_m$ are exogenous to the firm, then under cost minimizing behavior, the production function given in (4.1) may be represented by a cost function C^* of the form

$$C^* = c^* \left(p_1, p_2 \ldots p_n ; \overline{p}_1, \overline{p}_2 \ldots p_m ; y \right) \qquad \ldots. (4.2)$$

if the production function is homothetic weak separable (HWS) in energy inputs, then following Shepherd (1953) it is possible to write equation **(4.2)** as:

$$C^{*} = C^{*}\left(p_e; \overline{p}_1, \overline{p}_2 ... p_m; y \right) \qquad \text{.... (4.3)}$$

where, $p_e = C(p_1, p_2 ... p_n)$ .... (4.4)

HWS is a standard assumption when the interest is to analyse the substitution possibilities of a sub-set of inputs. It has been shown that HWS is a necessary and sufficient condition for a two stage allocation. In the first stage, an optimal sum of energy inputs is chosen by minimizing the cost per unit of energy given by p_e in equation (4.4). In the second stage, the mix of energy as an aggregate, and non-energy inputs is chosen from the minimization of total cost in equation (4.2).

The present study concentrates on substitution possibilities of the energy inputs only. The translog second order approximate of the cost given in equation (4.4) is given by

$$\ln p_e = \ln C = \beta_o + \sum_i \beta_i \ln p_i + \frac{1}{2} \sum_i \sum_j \beta_{ij} \ln p_i \ln p_j \qquad \text{... (4.5)}$$

where $\beta_o, \{\beta_i, i = 1,2,.........n\}, \{\beta_{ij}, i, j = 1,2,...n\}$ are fixed parameters.

Differentiating equation (4.5) with respect to logarithm of prices, we get a system of share equations of the form:

$$S_i = \beta_i + \sum_j \beta_{ij} \ln p_j \qquad i = 1,2,....n \qquad \text{.... (4.6)}$$

where S_i is the share of the energy input ,$'i'$ is the total energy cost.

Parametric Restrictions:

If the production function associated with the cost function given in equation (4.4) is to be well behaved, then the following restrictions need to be imposed on the parameters of equation (4.6).

i) $\sum \beta_i = 1$ (cost exhaustion)

ii) $\sum_i \beta_{ij} = 0$ for all j

$\sum_j \beta_{ij} = 0$ for all i (homogeneity)

$\beta_{ij} = \beta_{ji}$ for all i, j (symmetry)

iii) The cost (price) function given in equation (4.4) should be concave in input prices.

4.1.4. Measures of Price Responsiveness

Two commonly used measures of price responsiveness are the Allen-Uzawa partial elasticity of substitution, σ_{ij} and the price elasticity of demand e_{ij} . For the translog cost functioin given in equation (4.6), the measures are given by Berndt and Wood (1975) which are as follows:

$$\sigma_{ij} = \frac{\left(\beta_{ij} + S_i S_j\right)}{S_i S_j} \quad \text{if } i \neq j \qquad \text{....(4.7a)}$$

$$\sigma_{ij} = \frac{\left(\beta_{ii} + S_i^2 - S_i\right)}{S_i^2} \qquad \text{... (4.7b)}$$

$$e_{ij} = \sigma_{ij} S_j \qquad \text{if } i \neq j \qquad \text{….(4.7c)}$$

$$e_{ij} = \sigma_{ii} S_i \qquad \text{…. (4.7d)}$$

If $\sigma_{ij} < 0$, the factors i and j are complements

$\sigma_{ij} > 0$, the two factors are substitutes

$\sigma_{ij} = 0$, they are independent

The elasticities in the equations are measured at mean value of cost share for input i.

4.2. Data Sources

The Center for Monitoring Indian Economy (CMIE) brings out yearly an energy data edition, which is a compilation of secondary data for all the sectors and for different forms of energy. And also the wholesale price indices of the fuels are provided by the CMIE publications. Data collected for the present study are drawn from CMIE 2005.

Off take of different forms of fuels like coal, naphtha, natural gas, light diesel oil (ldo) and high sulphur diesel oil (hdo), and fuel oil by various sectors of the economy are provided in the publications which are used for this study. CMIE prowess provides data on the total energy consumption and fuel consumption of companies across the economy, which is collected for the period of 1991-2004 for a set of 25 companies. Companies using two fuels for one and the same purpose be it fuel or feedstock, are selected on the basis of a thorough understanding of the company and its product range. For example, in fertilizer production natural gas and coal are used as feedstock and some other fuels are used as fuels for running the machinery. In such a case, only coal and gas used as feed stock are considered for the study. However there are no studies that are available till the date that estimated within company inter-fuel substitution possibilities. The early possible data that is from 1991 is collected to estimate the translog cost functions in the present study.

Like wise, the other companies using two fuels for combustion or say for fuel purposes are cement, glass, textile and breweries, which are also selected in the same fashion. However, this selection problem does not arise with the sectoral analysis since the off-take of the fuels across the sectors is selected for the study.

For estimating a translog cost function and deriving the demand for fuels of fertilizer and power industries, data collected on the selected fuels namely, coal, oil (naphtha), and natural gas are used. Wholesale prices indices of the fuels coal, oil and gas considered as proxy for prices at economy level. Also the previous studies (for instance, Murty, 86) considered WPI of the specified fuels as proxy for prices. In case of textile industry, coal, fuel, oil high sulphur diesel oil, and light diesel oil are used as inputs in the production process. Hence a separate estimation is carried for this industry with respective WPIs.

4.3. Estimated Equations-Sectors

4.3.1. Fertilizer and Power

Translog cost equation for the fertilizer and power sectors with three fuels namely coal(c), oil(o), and gas(g) is as follows.

$$\ln C = \beta_0 + \beta_c \ln p_c + \beta_o \ln p_o + \beta_g \ln p_g + \beta_{cc}\left(\frac{1}{2}\ln^2 p_c\right) + \beta_{co}\ln p_c \ln p_o + \beta_{cg}\ln p_c \ln p_g$$
$$+ \beta_{oo}\left(\frac{1}{2}\ln^2 p_o\right) + \beta_{og}\ln p_o \ln p_g + \beta_{gg}\left(\frac{1}{2}\ln^2 p_g\right) + \varepsilon$$

… (4.8)

Taking the derivatives of equation 4.8 with respect to the logarithms of the fuel prices and dividing the prices by p_g, we obtained the following translog fuel cost share equations

$$S_c = \frac{\partial \ln c}{\partial \ln p_c} = \beta_c + \beta_{cc} \ln\left(\frac{p_c}{p_g}\right) + \beta_{co} \ln\left(\frac{p_o}{p_g}\right) \qquad \text{… (4.8a)}$$

$$S_o = \frac{\partial \ln c}{\partial \ln p_o} = \beta_o + \beta_{co} \ln\left(\frac{p_c}{p_g}\right) + \beta_{oo} \ln\left(\frac{p_o}{p_g}\right) \qquad \text{… (4.8b)}$$

The Allen-Uzawa elasticities of substitution for a pair of fuels i.e. coal-oil and coal-gas and oil-gas are estimated as follows for the fertilizer and power sectors.

$$\left.\begin{aligned} \sigma_{cg} &= \frac{\beta_{cg} + S_c S_g}{S_c S_g} \\ \sigma_{og} &= \frac{\beta_{og} + S_o S_g}{S_o S_g} \end{aligned}\right\} \qquad \text{… (4.8c)}$$

The Allen-Uzawa own elasticities of substitution for each fuel in fertilizer and power sector are given by

$$\left.\begin{aligned} \sigma_{cc} &= \frac{\beta_{cc} + S_c^2 - S_c}{S_c^2} \\ \sigma_{oo} &= \frac{\beta_{oo} + S_o^2 - S_o}{s_o^2} \\ \sigma_{gg} &= \frac{\beta_{gg} + S_g^2 - S_g}{S_g^2} \end{aligned}\right\} \qquad \ldots (4.8d)$$

The cross price elasticities of demand for coal-oil, coal-gas, oil-gas equations in fertilizer and power sector are as follows:

$$\left.\begin{aligned} e_{co} &= S_c \sigma_{co} \\ e_{cg} &= S_c \sigma_{cg} \\ e_{og} &= S_o \sigma_{og} \end{aligned}\right\} \qquad \ldots (4.8.e)$$

The own price elasticities of demand for coal-coal, oil-oil, and gas-gas in fertilizer and power sectors are

$$\left.\begin{aligned} e_{cc} &= S_c \sigma_{cc} \\ e_{oo} &= S_o \sigma_{oo} \\ e_{gg} &= S_g \sigma_{gg} \end{aligned}\right\} \quad \dots (4.8.f)$$

4.3.2. Textile Industry

The translog cost equation for the textile industry with four fuels namely, coal(c), oil (o), high speed diesel oil (hdo), and light diesel oil (ldo) is as follows:

$$\ln C = \beta_0 + \beta_c \ln p_c + \beta_o \ln p_o + \beta_h \ln p_h + \beta_l \ln p_l + \beta_{cc}\left(\frac{1}{2}\ln^2 p_c\right) + \beta_{co} \ln p_c \ln p_o + \beta_{ch} \ln p_c \ln p_h +$$
$$\beta_{cl} \ln p_c \ln p_l + \beta_{oo}\left(\frac{1}{2}\ln^2 p_o\right) + \beta_{oh} \ln p_o \ln p_h + \beta_{ol} \log p_o \ln p_l + \beta_{hh}\left(\frac{1}{2}\ln^2 p_h\right) + \beta_{hl} \ln p_h \ln p_l$$
$$+ \beta_{ll}\left(\frac{1}{2}\ln^2 p_l\right) + \varepsilon$$

$$\dots (4.9)$$

The estimated share equations based on the above equation are as follows:

$$S_c = \frac{\partial \ln c}{\partial \ln p_c} = \beta_c + \beta_{cc} \ln\left(\frac{p_c}{p_l}\right) + \beta_{co} \ln\left(\frac{p_o}{p_l}\right) + \beta_{ch} \ln\left(\frac{p_h}{p_l}\right) \quad \dots (4.9a)$$

$$S_o = \frac{\partial \ln c}{\partial \ln p_o} = \beta_o + \beta_{co} \ln\left(\frac{p_c}{p_g}\right) + \beta_{oo} \ln\left(\frac{p_o}{p_g}\right) + \beta_{oh} \ln\left(\frac{p_h}{p_l}\right) \qquad \dots (4.9b)$$

$$S_h = \frac{\partial \ln c}{\partial \ln p_c} = \beta_h + \beta_{ch} \ln\left(\frac{p_c}{p_l}\right) + \beta_{oh} \ln\left(\frac{p_o}{p_l}\right) + \beta_{hh} \ln\left(\frac{p_h}{p_l}\right) \qquad \dots (4.9c)$$

Through the following equations the Allen-Uzawa cross elasticities of substitution are estimated for the textile industry for the fuel pairs, coal-oil, coal-hsdo, coal-ldo, oil-hsdo, oil-ldo, and hsdo-ldo.

$$\left.\begin{aligned}
\sigma_{co} &= \frac{\beta_{co} + S_c S_o}{S_c S_o} \\
\sigma_{ch} &= \frac{\beta_{ch} + S_c S_h}{S_c S_h} \\
\sigma_{cl} &= \frac{\beta_{cl} + S_c S_l}{S_c S_l} \\
\sigma_{oh} &= \frac{\beta_{oh} + S_o S_h}{S_o S_h} \\
\sigma_{ol} &= \frac{\beta_{ol} + S_o S_l}{S_o S_l} \\
\sigma_{hl} &= \frac{\beta_{hl} + S_h S_l}{S_h S_l}
\end{aligned}\right\} \qquad \dots (4.9d)$$

The estimated all Allen-Uzawa own elasticities of substitution for each fuel are

$$\left.\begin{aligned} \sigma_{cc} &= \frac{\beta_{cc} + S_c^2 - S_c}{S_c^2} \\ \sigma_{oo} &= \frac{\beta_{oo} + S_o^2 - S_o}{S_o^2} \\ \sigma_{hh} &= \frac{\beta_{hh} + S_h^2 - S_h}{S_h^2} \\ \sigma_{ll} &= \frac{\beta_{ll} + S_l^2 - S_l}{S_l^2} \end{aligned}\right\} \qquad \ldots (4.9e)$$

The estimated cross price elasticities of demand for coal-oil, coal-hsdo, coal-ldo,oil-hsdo oil-ldo, hsdo-ldo are as follows:

$$\left.\begin{aligned} e_{co} &= S_c \sigma_{co} \\ e_{ch} &= S_c \sigma_{ch} \\ e_{cl} &= S_c \sigma_{cl} \\ e_{oh} &= S_o \sigma_{oh} \\ e_{ol} &= S_o \sigma_{ol} \\ e_{hl} &= S_h \sigma_{hl} \end{aligned}\right\} \qquad \ldots (4.9f)$$

The estimated own price elasticities of demand for coal-coal, oil-oil, and gas-gas are

$$\left.\begin{aligned} e_{cc} &= S_c \sigma_{cc} \\ e_{oo} &= S_o \sigma_{oo} \\ e_{hh} &= S_h \sigma_{hh} \\ e_{ll} &= S_l \sigma_{ll} \end{aligned}\right\} \quad \dots (4.9g)$$

4.4. Estimated Equations -Firm Level Data with Five Fuel Groups

4.4.1. Coal-High Sulpher Diesel Oil Group

Ten firms using Coal-Hsdo are identified and have the following translog cost equation:

$$\ln C = \beta_0 + \beta_c \ln p_c + \beta_h \ln p_h + \beta_{cc}\left(\frac{1}{2}\ln^2 p_c\right) + \beta_{ch} \ln p_c \ln p_h + \beta_{hh}\left(\frac{1}{2}\log^2 p_h\right) + \varepsilon$$

… (4.10)

And the derived cost share equation for coal after dropping the hsdo is

$$S_c = \frac{\partial \ln c}{\partial \ln p_c} = \beta_c + \beta_{cc} \ln\left(\frac{p_c}{p_h}\right) \quad \dots (4.10a)$$

The Allen-Uzawa cross elasticity of substitution for coal-hsdo is given by:

$$\sigma_{ch} = \frac{\beta_{ch} + S_c S_h}{S_c S_h} \qquad \ldots (4.10b)$$

The Allen-Uzawa own elasticity of substitution for coal-hsdo using firms is given by

$$\left.\begin{aligned} \sigma_{cc} &= \frac{\beta_{cc} + S_c^2 - S_c}{S_c^2} \\ \sigma_{hh} &= \frac{\beta_{hh} + S_h^2 - S_h}{S_h^2} \end{aligned}\right\} \qquad \ldots (4.10c)$$

The cross-own price elasticities of demand for firms using coal-hsdo as energy inputs are computed through the following equation

$$\left.\begin{aligned} e_{ch} &= S_c \sigma_{ch} \\ e_{cc} &= S_c \sigma_{cc} \\ e_{hh} &= S_h \sigma_{hh} \\ e_{ll} &= S_l \sigma_{ll} \end{aligned}\right\} \qquad \ldots (4.10d)$$

4.4.2. Coal-Light Diesel Oil Group

There are only two firms that are using coal and light diesel oil as energy inputs for an output. The estimated equation set for this group is as follows

$$\ln C = \beta_0 + \beta_c \ln p_c + \beta_l \ln p_l + \beta_{cc}\left(\frac{1}{2}\ln^2 p_c\right) + \beta_{cl} \ln p_c \ln p_l + \beta_{ll}\left(\frac{1}{2}\ln^2 p_l\right) + \varepsilon$$

… (4.11)

The cost share equation for coal and light diesel oil group is given by:

$$S_c = \frac{\partial \ln c}{\partial \ln p_c} = \beta_c + \beta_{cc} \ln\left(\frac{p_c}{p_l}\right) \qquad \text{… (4.11a)}$$

The Allen-Uzawa cross elasticity of substitution for coal and light diesel oil is given by:

$$\sigma_{cl} = \frac{\beta_{cl} + S_c S_l}{s_c s_l} \qquad \text{… (4.11b)}$$

The Allen-Uzawa own elasticity of substitution for coal and light diesel oil are given by:

$$\left.\begin{aligned} \sigma_{cc} &= \frac{\beta_{cc} + s_c^2 - s_c}{s_c^2} \\ \sigma_{ll} &= \frac{\beta_{ll} + s_l^2 - s_l}{s_l^2} \end{aligned}\right\} \qquad \text{... (4.11c)}$$

The cross-own price elasticities of demand for the two firms using coal and light diesel oil are:

$$\left.\begin{aligned} e_{cl} &= S_c \sigma_{cl} \\ e_{cc} &= S_c \sigma_{cc} \end{aligned}\right\} \qquad \text{… (4.11d)}$$

4.4.3. Coal-Natural Gas Fuel group

Seven firms use coal and natural gas as a energy input in the production process. Their translog cost function is given by

$$\ln C = \beta_0 + \beta_c \ln p_c + \beta_g \ln p_g + \beta_{cc}\left(\frac{1}{2}\log^2 p_c\right) + \beta_{cg} \log p_c \log p_g + \beta_{gg}\left(\frac{1}{2}\log^2 p_g\right) + \varepsilon$$

… (4.12)

Derived cost share equation for the above is as follows … (4.12a)

$$S_c = \frac{\partial \ln c}{\partial \ln p_c} = \beta_c + \beta_{cc} \ln\left(\frac{p_c}{p_g}\right)$$

The Allen-Uzawa cross elasticity of substitution for coal and natural gas using firms are as follows:

$$\sigma_{cg} = \frac{\beta_{cg} + S_c S_g}{S_c S_g} \qquad \text{… (4.12b)}$$

The Allen-Uzawa own elasticity of substitution for coal and natural gas is given by:

$$\left.\begin{aligned} \sigma_{cc} &= \frac{\beta_{cc} + S_c^2 - S_c}{S_c^2} \\ \sigma_{gg} &= \frac{\beta_{gg} + S_g^2 - S_g}{S_g^2} \end{aligned}\right\} \qquad \text{… (4.12c)}$$

The cross-own price elasticities of demand for the two firms using coal and natural gas firms are as follows:

$$\left.\begin{aligned} e_{cg} &= S_c \sigma_{cg} \\ e_{cc} &= S_c \sigma_{cc} \\ e_{gg} &= S_g \sigma_{gg} \end{aligned}\right\} \qquad \text{… (4.12d)}$$

4.4.4. Natural gas – High Sulphur Diesel Oil

Three firms using natural gas and high sulphur diesel oil. Their estimated translog cost function is as follows

$$\ln C = \beta_0 + \beta_g \ln p_g + \beta_h \ln p_h + \beta_{gg}\left(\frac{1}{2}\ln^2 p_c\right) + \beta_{gh} \ln p_g \ln p_h + \beta_{hh}\left(\frac{1}{2}\ln^2 p_h\right) + \varepsilon$$

… (4.13)

The derived cost share equation based on the above

$$S_g = \frac{\partial \ln c}{\partial \ln p_g} = \beta_c + \beta_{gg} \ln\left(\frac{p_g}{p_h}\right)$$ … (4.13a)

The Allen-Uzawa cross elasticity of substitution for the three firms using natural gas and high sulphur diesel oil as fuel inputs is as follows:

$$\sigma_{gh} = \frac{\beta_{gh} + S_g S_h}{S_g S_h}$$ … (4.13b)

The Allen-Uzawa own elasticities of substitution for the above are:

$$\left.\begin{aligned}\sigma_{gg} &= \frac{\beta_{gg} + S_g^2 - S_g}{S_g^2} \\ \sigma_{hh} &= \frac{\beta_{hh} + S_h^2 - S_h}{S_h^2}\end{aligned}\right\} \quad \dots (4.13c)$$

The estimated cross-own price elasticities of demand for natural gas and high sulphur diesel oil are:

$$\left.\begin{aligned}e_{gh} &= S_g \sigma_{gh} \\ e_{gg} &= S_g \sigma_{gg} \\ e_{hh} &= S_h \sigma_{hh}\end{aligned}\right\} \quad \dots (4.13d)$$

4.4.5. High Sulphur Diesel Oil-Light Diesel Oil

There are three firms that are using high sulphur diesel oil and light diesel oil for one and the same process and their estimated translog cost function is as follows:

$$\ln C = \beta_0 + \beta_h \ln p_h + \beta_l \ln p_l + \beta_{hh}\left(\frac{1}{2}\ln^2 p_h\right) + \beta_{hl} \ln p_h \ln p_l + \beta_{ll}\left(\frac{1}{2}\ln^2 p_l\right) + \varepsilon \quad \dots (4.14)$$

The derived cost share equation of hsdo and ldo is as follows

$$S_h = \frac{\partial \ln c}{\partial \ln p_h} = \beta_h + \beta_{hh} \ln\left(\frac{p_h}{p_l}\right) \qquad \text{… (4.14a)}$$

The Allen-Uzawa cross elasticities of substitution for the high sulphur diesel oil and light diesel oil

$$\sigma_{hl} = \frac{\beta_{hl} + S_h S_l}{S_h S_l} \qquad \text{… (4.14b)}$$

The Allen-Uzawa own elasticity of substitution for the above are:

$$\left.\begin{aligned} \sigma_{hh} &= \frac{\beta_{hh} + S_h^2 - S_h}{S_h^2} \\ \sigma_{ll} &= \frac{\beta_{ll} + S_l^2 - S_l}{S_l^2} \end{aligned}\right\} \qquad \text{... (4.14c)}$$

The cross-own price elasticities of demand for the above are as follows:

$$\left.\begin{aligned} e_{hl} &= S_h \sigma_{hl} \\ e_{hh} &= S_h \sigma_{hh} \\ e_{ll} &= S_l \sigma_{ll} \end{aligned}\right\} \qquad \dots (4.15d)$$

4.5. Concluding Remarks

To sum up, the present chapter gives a detailed discussion of the methodology adopted in this study. That is, the specification and estimation of share equations and also the formula for computation of Allen-Uzawa own-cross elasticities of substitution, and own-cross price elasticities of demand, are discussed. The empirical results of the study are presented in the following chapter.

Chapter 5

Profile of Selected Industries and Companies

5.0. Introduction

The present study is based on data relating to three industries namely, textile, power and fertilizer and twenty five companies categorized into five fuel groups. The present chapter aims at providing background of the sample industries and companies, and also discussing the issues relating to data and variables.

5.1. Selected Energy Intensive Industries for the Study:

The three industries that are studied in this present work are fertilizer, power and textile. These three industries use fossil fuels like coal, oil, gas and oil products like high diesel oil and light diesel oil on a large scale.

5.1.1. Fertilizer Industry

India is the third largest producer and consumer of chemical fertilizers and accounts for around 12% of the world fertilizer consumption. Agriculture accounted for about one fifth of India’s GDP in 2005 (est.) and employed about 58% of the working population either directly or indirectly. Over the years, India has directed its efforts towards achieving self sufficiency and self reliance in food grain production and in doing so; chemical fertilizers have played a vital role.

The Indian Fertilizer industry consists of 57 large sized units manufacturing a wide variety of fertilizers. The industry consists of players from the public, private and the co-operative sectors. The industry, for long, has been under the government control and its fortunes are to a large extent, dependent on the government polices.

A wide variety of fertilizers are used in the country. The main categories of fertilizer nutrients used are Nitrogenous (N), Phosphatic (P), and Potassic (K). While N and P fertilizers are manufactured within the country, the entire requirement of potassic fertilizers is imported. The country produces several straight nitrogenous fertilizer products such as urea, ammonium sulphate, calcium ammonium nitrate and ammonium chloride, straight phosphatic fertilizers like Single Super Phosphate (SSP), complex fertilizers like Di-Ammonium Phosphate (DAP), and several grades of nitro-phosphates and NPK complexes. Urea and DAP are the main fertilizer products produced in the country, accounting for 79% and 56% of the overall nitrogenous and phosphatic fertilizer capacity, respectively.

For urea natural gas and naphtha are the main feedstock used in the manufacture of urea. Other feedstocks include fuel oil and coal. Feedstock costs account for about 60% of the cost of production in respect of gas based units and 75% of cost of production in respect of naphtha based units. Natural gas (NG) is the preferred feedstock for manufacturing of urea due to economic benefits arising out of lower capital and production costs, high energy efficiency, environmental safety, etc .in comparison to other feedstock. Government polices also favor the use of natural gas as a feedstock.

As per the policy announced in January 2004, new urea projects, expansion of existing units and capacity increase through de-bottlenecking /revamp/modernization were to be allowed if the production was based on LNG/NG. A policy for conversion of existing naphtha/FO/LSHS based units to gas based units has also been formulated encouraging conversion to gas as feedstock. Naphtha based plants currently account for about one-fourth of the urea capacity. With the government policy favoring conversion to gas based units, the proportion of off take of naphtha by the fertilizer sector has declined.

5.1.2. Power Sector

Indian power industry has been witnessing a widening demand-supply gap. Although electricity generation capacity has increased substantially in recent years, the demand for electricity in India is still substantially higher than supply. In 2006-07, India faced an energy shortage of approximately 8% of total energy requirement and 12.3% of peak demand requirement. So the industry needs to grow at a faster pace. Power is one of the key movers of economic development.

The level of availability and accessibility of affordable and quality power is one of the main determinants of quality of life. The government has given priority to this sector since independence while fixing the plan outlays. As a result, the installed generating capacity has risen from around 1,300 MW at the time of independence to more than 110,000 MW.

Generation of electric power from fossil fuels like gas, coal, oil, has always been crucial for the Indian power sector. This sector is primarily dominated by coal as a major fuel. Any possible opportunity for eco-friendly fuels like gas being used for generating power would be a better option compared to exploring the highly capital intensive renewable energy sources like solar and wind. Given this scenario an inter-fuel substitution possibility should be explored and exploited to its fullest advantage.

5.1.3. Textile Industry

The textiles industry accounts for around 20% of India's industrial production and 31% of its total exports. Besides, it provides employment to around 20 million people. Cotton is the most important segment of the textiles industry, accounting for around 57% of the domestic fiber consumption and exports.

With over 9 million hectares under cotton cultivation (which is the largest area employed for the purpose throughout the world) and an annual crop of around 2,600 million kg. India is amongst the world's largest potential reservoirs of this popular fiber. Currently, India is the third largest producer of raw cotton in the world, after China and the US. Textile industry apart from its highly labor intensiveness is energy intensive also.

Indian fabric is competitive in the international market, as cotton and labor are relatively cheap in the country. However, the high power and interest costs impair the advantage to a great extent. Hence a keen understanding about the substitution possibilities among the fossil fuels used for various other purposes of production in the textile industry is needed.

5.2. Selected Companies in Five Fuel Groups for the Study

The companies that are selected for the study under five fuel groups are a mixture of all segment of manufacturing. They are grouped into five sets according to the fuels used. Likewise a companies using coal-natural gas, high speed diesel oil-light diesel oil, natural gas-high speed diesel oil, coal-light diesel oil and coal-hsdo are grouped to five sets.

5.2.1. Coal-Natural Gas Fuel Group

Companies using coal and natural gas as fuel inputs for production are grouped under this. A brief company introduction is presented below.

5.2.1.1. Andhra sugars ltd

The Andhra Sugars Limited was established in 1947. Company operations are located at Tanuku, Kovvur, Guntur, Taduvai, Saggonda and Bhimadole in the state of Andhra Pradesh in Southern India producing 25 different products which are Sugar(Grade M31, S-31) Industrial Alcohol, Acetic Acid, Acetic Anhydride, Ethyl

Acetate, Aspirin Chloro Alkali Sulphuric Acid and Super Phosphate. Products such as Caustic Soda, Chlorine, Sulphuric Acid and other allied Chemicals are extensively used in paper, aluminum, soaps and detergents, paints and host of other industries. Caustic Soda is manufactured at Plants located at Kovvur and Saggonda.

The Caustic Soda Industry is classified as a power intensive Industry. As a measure of getting more power at an economical rate and to meet the power requirements of the two Caustic Soda Plants at Kovvur and Saggonda, the company invested in the equity capital of Andhra Pradesh Gas Power Corporation Ltd. (APGPCL), a gas based power generation Company.

Major power requirement for the production of Caustic Soda is met out of this source. To supplement and to ensure adequate and continuous availability of power for production purposes company, apart from gas also relies on other sources of fuels like coal and wind.

5.2.1.2. Andrew Yule & Co ltd

The company is engaged in manufacture, sale and servicing of various industrial products like industrial fans, tea machinery, air pollution control equipment, electrical equipments including switchgears and circuit breakers. Six tea companies consisting of 12 tea gardens in West Bengal and Assam engaged in cultivation, manufacture and processing of tea became a part of the company from 1st April, 1986.

Andrew Yule is a Government of India enterprise - a multi product, multi division conglomerate having a group turnover exceeding Rs. 400 crores. The group has eleven collaborations with world leaders in seven countries. In effect, it has many technologies under one name - 'Yule'.

The T&S (Chennai) unit functions under the Electrical Division of the Andrew Yule Group. The Range of Products Yule offers are Power & Distribution Transformers up to 50 MVA 132 KV Converter Transformers up to 20 MVA 33 KV Furnace Transformers up to 15 MVA 33 KV Dry type Transformers upto 15 MVA, 33 KV Dry type Transformers up to 33 MVA 11 KV, class 'C' Flame Proof Transformers, Earthing Transformers Series and Shunt Reactors, Auto Transformers and Twin Core Voltage Regulating Transformers. The estimates presented in the following chapter are considered only for the tea production segment of the company where both coal and natural gas are used as fuels.

5.2.1.3. Dhunseri Tea & Inds. Ltd

The company was formally incorporated on the 11th of May, 1916 when the two planters transferred this estate to Dhunseri Tea Company Limited which was actually founded with the main objective of buying the estate. The estate was named Dhunseri Tea Estate due to its close proximity with the Dhunseri River. With the Companies Act becoming effective from 1st April, 1956, certain restrictions were imposed on Managing Agents / Secretaries and Treasurers.

Mr. E.A. Hutchison, the Chairman, at that time agreed to terminate the agreement between the Company and James Finlay and Co. Ltd. which ushered in the new management. Presently there are no operations reported in the name of this company but with the available data of yester years was used in the analysis.

5.2.1.4. Gujarat Narmada Fertilizers Ltd

Gujarat Narmada Valley Fertilizers Company Ltd. (GNFC), is a joint sector enterprise promoted by the Government of Gujarat and the Gujarat State Fertilizer Company Ltd.(GSFC). It was set up in Bharuch, Gujarat in 1976. Located at Bharuch in an extremely prosperous industrial belt, GNFC draws on the resources of the natural wealth of the land as well as the industrially rich reserves of the area.

GNFC started its manufacturing and marketing operations by setting up in 1982, one of the world's largest single-stream ammonia-urea fertilizer complexes. Over the next few years, GNFC successfully commissioned different projects - in fields as diverse as chemicals, fertilizers and electronics.

5.2.1.5. Jagatjit Industries ltd.

Jagatjit Industries Limited(JIL) was founded in the year 1944 by Late Mr.L.P.Jaiswal in the erstwhile State of Kapurthala under the patronage of its Maharaja Jagatjit Singh. The company manufactures and markets alcoholic beverages, malt, malt extract, malted milk foods, milk powder, ghee, glass and pet containers. JIL manufactures the entire range of alcoholic beverages i.e. Whisky, Rum, Gin and Vodka. Ranked as a third largest IMFL (Indian Made Foreign Liquor) producer in the country.

The company has state-of-the-art manufacturing base which is located in the district of Kapurthala, Punjab. Ranked as a third largest IMFL (Indian Made Foreign Liquor) producer in the country, JIL's main focus of business lies in manufacture, distribution and sale of IMFL. The company has state-of-the-art manufacturing base which is located in the district of Kapurthala, Punjab. The company uses coal and natural gas for manufacturing processes of breweries as a fuel.

5.2.1.6. Jay Shree Tea & Inds.Ltd

Incorporated on the 27th of October, 1945 Jay Shree Tea & Industries Ltd, a well diversified conglomerate of B.K. Birla Group of Companies, acquired a growing number of tea estates in both North and South India. Jay Shree Tea Industries uses both coal and natural gas for fuel purposes in the production processes.

5.2.1.7. Tata Tea Ltd.

Set up in 1964 as a joint venture with UK-based James Finlay and Company to develop value-added tea, the Tata Tea Group of Companies, which includes Tata Tea and the UK-based Tetley Group, today represent the world's second largest global branded tea operation with product and brand presence in 40 countries. The consolidated worldwide branded tea business of the Tata Tea Group contributes to around 86 per cent of its consolidated turnover with the remaining 14 per cent coming from bulk tea, coffee, and investment income.

The Company is headquartered in Kolkata and owns 27 tea estates in the states of Assam and West Bengal in eastern India, and Kerala in the south. The company has five major brands in the Indian market - Tata Tea, Tetley, Kanan Devan, Chakra Gold and Gemini, catering to all major consumer segments for tea.

The Tata Tea brand leads market share in terms of value and volume in India and the Tata Tea brand is accorded "Super Brand" recognition in the country. The company has a 100% export-oriented unit (KOSHER & HACCP certified) manufacturing instant tea in Munnar, Kerala, which is the largest such facility outside the United States.

The unit's product is made from a unique process, developed in-house, of extraction from tea leaves, giving it a distinctive liquoring and taste profile. Instant Tea is used for light density 100% Teas, Iced Tea Mixes and in the preparation of Ready-to-drink (RTD) beverages. With an area of approx 15,900 hectares under tea cultivation, Tata Tea produces around 30 million kg of Black Tea annually. The company uses both coal and natural gas for various combustion purposes for the production of tea.

5.2.2. Hsdo-Ldo Fuel Group

Three companies using high speed diesel oil and light diesel oil are selected for the estimations in the present study.

5.2.2.1. Grasim Industries Ltd

Grasim Industries Limited, a flagship company of the Aditya Birla Group, ranks among India's largest private sector companies, with consolidated net revenues of Rs.141 billion (FY2007). Starting as a textiles manufacturer in 1948, today Grasim's businesses comprise Viscose Staple Fibre (VSF), Cement, Sponge Iron, Chemicals and Textiles in all of which the company holds a dominant position.

As a textiles major Grasim's premium brands, are the Grasim and Graviera, distinctively positioned themselves as 'the power of fashion' in India.

5.2.2.2. Hasimara Industries Ltd

Hasimara is a Kolkata based tea producing company. The company is however not operating due to certain circumstances. Using the data available for the period of 1991-2002, analysis is carried out in this study.

5.2.2.3. Hindusthan National Glass & Industries Ltd. (HNGIL)

HNG Group established in the year 1952 is the India's first fully automatic glass container manufacturing plant at Rishra, near Calcutta (INDIA). The company offers premium glass containers for every kind of application. HNGIL is an acknowledged market leader of today, producing 6 million bottles per day ranging from 5 ml to 3200 ml containers for multifarious industries like pharmaceuticals, beverages, processed foods, cosmetics, liquors etc.Cclientele of this company include leading companies like Pepsi

Co., Coca-Cola, Cadbury’s, Nestle ,Raun Pollack, Dabur, Bayer, Lakme, Glaxo, Pfizer, Reckitt & Coleman, Shaw Wallace, UB group. In the present context the two fuels hsdo and ldo are used by the company for various machinery in the production of glass.

5.2.3. Natural Gas-Hsdo Fuel Group

Companies using both Natural gas and High sulphur diesel oil for the production as inputs are considered for estimations in this group. However in some both the fuels are used as fuels and in some they are used as feed stock. And the pattern of usage is briefed in the company introduction presented below.

5.2.3.1. Reliance industries ltd

The Reliance Group, founded by Dhirubhai Ambani (1932-2002), is India's largest private sector enterprise, with businesses in the energy and materials value chain. Group's annual revenues are in excess of USD 22 billion. A flagship company, Reliance Industries Limited, is a Fortune Global 500 company and is the largest private sector company in India.

The group's activities span exploration and production of oil and gas, petroleum refining and marketing, petrochemicals (polyester, fibre intermediates, plastics and chemicals), textiles and retail. The present selection of fuels is made for its petrochemicals segments where both natural gas and hsdo are used as feedstock.

5.2.3.2. Rossell industries ltd

The company is a tea manufacturer which presently operates for Hindustan Leaver Limited and is no more operating under the title of Rossell Industries Ltd. And the data, collected to estimate the fuel substation possibilities in the company are for the period 1991-2002. The company was using both natural gas and hsdo as fuel inputs in the production.

5.2.3.3. Warren Tea Ltd

Warren Tea Limited. The Company's principal activities are to produce tea and travel related activities. It is engaged in the integrated process of growing, harvesting, manufacturing and sale of black tea and travel related activities. The Company operates in two segments, namely, Tea and Travels. Warren tea uses both Natural gas and Hsdo as fuels for combustion in the production of tea.

5.2.4. Coal-Ldo Fuel Goup

Companies using coal and light diesel oil for one single process of production are limited in number. And due to the certain data constraints only two companies in this fuel segment are considered for analysis.

5.2.4.1. Gujarat Ambuja Cements ltd

Ambuja Cements was set up in 1986. The total cement capacity of the company is 16 million tones. Ambuja is the most profitable cement company in India, and the lowest cost producer of cement in the world. Cement production is one of the major energy intensive industries.

But not much disaggregated data is available at company level for all the cement plants across India. Hence the present study considered only the company that is reporting the two fuels used within the company for combustion purposes in the machinery. In other words the company uses these fuels for production machinery.

5.2.4.2. Karnataka Soaps & Detergents Limited (KSDL)

The Government Soap Factory was established by the Maharaja of Mysore his Highness Nalwadi Krishnaraja Wodeyar and Diwan Sir.M.Visvesvaraya during the year 1916. In 1980, Government of Karnataka integrated the Sandal oil factories at Mysore and Shimoga and Government Soap Factory at Bangalore and formed Karnataka Soaps & Detergents Limited (KSDL), which has been incorporated as a company under Company's Act 1956. The company uses coal and light diesel oil for combustion purposes at the machinery level.

5.2.5. Coal-Hsdo Fuel Group

Coal and High sulphur diesel oil are two substitute fuels in many companies. And also they are fuels that are substituted well for each other in many companies for the power generation within the company or captive power generation.

5.2.5.1. Amrit Banaspati Co.Ltd

Amrit Banaspati Co. Ltd. (ABCL), the flagship Company of the Amrit Group, is a public limited company listed on various stock exchanges in India. Incorporated in 1940, ABCL is one of the largest producers of edible oils and fats in the country today having diverse interests in paper and milk processing businesses also. In the present case it uses both coal and high sulphur diesel oil for combustion purposes in the machinery.

5.2.5.2. C J Gelatine Products Ltd.

India is one of the world's largest exporters of crushed bones and Ossein, the basic raw materials for high grade Gelatine. From the late sixties to the early seventies, two plants had already been set up in India, one with French expertise and the other with U.K. assistance. This company too uses both the fuels for fuel combustion purposes.

5.2.5.3. Haryana Steel & Alloys Ltd.

Steel and alloys production is one of the major segments where energy is consumed in various forms. In the present case coal and high sulphur diesel oil are consumed in combustion purposes.

5.2.5.4. J k synthetics ltd

J.K. Synthetic Limited was founded in the year 1943. Previously, the company was engaged in manufacture and sale of man made fibers. Prior to 2005, it was also engaged in the production and sale of white cement, nylon and polyester filament yarns, polyester staple fibers, and acrylic staple fibers. The company was incorporated in 1943 as J.K. Investment Trust Limited and changed its name to J.K. Synthetics Limited in 1960. J.K. Synthetics is based in Kanpur, India. In this company both the fuels are used for combustion purposes.

5.2.5.5. Madras Cements Ltd.

Madras Cements, Ltd. engages in the production, marketing, and sale of cement and clinker in India. It also produces ready mix concrete and construction products, such as lime stone, dolomite, and dry mortar. The company also engages in the generation of electric power through wind power. Madras Cements is based in Chennai, India.

There is 20 MW (6MW * 2 and 4 MW * 2) captive power generation plant owned by the company, which is meeting 75 % of plant power demand of the company. Operating efficiency of the equipment in each section in the plant range from 100 to 115 % of installed capacity. Both coal and Hsdo are used for power generation purposes in the company.

5.2.5.6. Nestle India Ltd

Nestle India Limited engages in the manufacture and sale of nutritious food products to consumers in India. The company's products primarily comprise milk products, such as sweetened condensed milk, baby milk foods, milk powders, acidified infant food, and other milk products.

It also offers beverages, prepared dishes and cooking aids, and chocolates and confectionery under various brand names, such as NESCAFE, MAGGI, MILKYBAR, MILO, KIT KAT, BAR-ONE, MILKMAID, POLO, Eclairs, and NESTEA. The company was founded in 1912 and is headquartered in Gurgaon, India. The company uses both coal and High sulphur diesel oil for combustion purposes in various food processing units at its machinery.

5.2.5.7. Raymond Ltd

Raymond Limited engages in the manufacture and sale of fabric worldwide. It operates in three divisions: Textiles, Engineering, and Aviation. The Textiles division produces pure-wool, wool blended, and premium polyester viscose worsted suiting, as well as blankets and shawls.

It also offers a range of suiting using polyester and other specialty fibers, such as cashmere, angora, alpaca, pure silk, and linen. In addition, this division involves in the production and marketing of a range of plush-velvet furnishing fabrics. The Engineering division manufactures and sells steel files, cutting tools, hand tools, and agri tools, as well as offers automotive components, including starter ring gears, flexplate flywheel assembly, profile sheet formed metal pulleys, and integral shaft water pump bearings.

The Aviation division provides a range of air charter services, such as long distance travel, emergency stretcher services on helicopters, aerial sight seeing tours and joyrides, visits to places of pilgrimage, factory visits, film shootings, flower dropping, aerial photography/survey, and electronic news gathering services. The company was founded in 1925 and is based in Ratnagiri, India. Raymond Limited is a part of Raymond Group. In the present case the two fuels selected are utilized as fuels for combustion in the textile manufacturing plant of Raymond's.

5.2.5.8. Ruchi Soya Industries Ltd

The 20-year old Ruchi Soya Industries Limited is the flagship company of Ruchi Group of Industries. Its recent merger with sister concerns (Aneja Solvex Ltd, General Foods Ltd, Ruchi Credit Corporation, Ruchi Health Foods Ltd, Param Ind. Ltd, Ruchi Private Ltd and Soya Businesses of MP Glychem) has catapulted it among the top five FMCG players in the country, with a turnover of 7537 crores.

This merger illustrates the strength that is to be found in increased transparency, firm market position and better control of systems. Besides being a leading manufacturer of high quality edible oils, vanaspati, bakery fats and soya foods, Ruchi Soya is also the highest exporter of soya meal and lecithin from India. Nutrela (soya chunks, granules, soya flour) is the largest selling soya foods brand in the country today. This company uses both coal and high sulphur diesel oil for combustion purposes in the machinery.

5.2.5.9. Somaiya Organics (India) ltd

The company primarily produces white crystalline solid. And the company uses coal and Hsdo for fuel purposes for producing organic chemicals.

5.2.5.10. Tirrihannah company ltd

The Kolkata based company operates in the area of tea and coffee manufacturing. It uses both the fuels for combustion purposes in the processing plants.

5.3. Concluding Remarks

The present chapter presents a brief profile of the industries (sectors) and companies that are selected for the study purpose. The present chapter facilitates to understand the history and background of the industries and companies that are selected for the study. This also provides a theoretical understanding about the data chosen for the study.

Chapter 6

An Empirical Analysis of Fuel Substitution Possibilities

6.0. Introduction

The focus of the present chapter is to present the empirical results and interpret the same that is, the estimated translog cost share equations, Allen-Uzawa elasticities of substitution, and also own-cross price elasticities of demand across sample industries and companies. A brief description of the selected industries, and companies has been presented in Chapter 5 to facilitate the analysis. There are companies producing different products using different set of fuels. Data for estimating the cost shares equations is selected with due care and theoretical understating of the concept of inter-fuel substitution. In other words, the fuel inputs used and output generated are selected for one and the same set of production processes. The methodology adopted is the translog cost function approach as described in Chapter 4 of the thesis.

6.1. Data

The data collected for the present study, is at industry level for fertilizer, power and textile industries relating to the period 1981 to 2004. The selected three industries are highly energy consuming industries in India. In the manufacturing sector, textile and fertilizer stand as the two industries that are highly energy intensive. In earlier works of Murty(1986), and Kadekodi(1987) the data sample ends by late 70's. These studies however considered electricity as a fuel input which in the present study is as an industry itself.

At company level, data is collected for the period of 1991-2004 for a set of 25 companies. The companies using two fuels for one and the same purpose, be it fuel or feedstock, are selected on the basis of a thorough understanding of the company and its product range. For example, in fertilizer production natural gas and coal are used as feedstock and some other fuels are used as fuels for running the machinery. In such a case, only coal and gas used as feedstock are considered for the study. It may be noted that there are no studies in the Indian context to date that examined inter-fuel substitution possibilities at company level. The early possible data for the company analysis in the present study is for the year 1991.

1. For estimating translog cost function and deriving the demand for fuels of fertilizer and power industries, data collected on the selected fuels namely, coal, oil (naphtha), and natural gas are used.
2. Wholesale prices indices of the fuels namely coal, oil and gas are considered as proxy for prices at economy level. Also the previous studies (for instance, Murty, 86) considered WPI of the specified fuels as proxy for prices.
3. In case of textile industry, coal, fuel, oil high sulphur diesel oil, and light diesel oil are used as inputs in the production process. Hence a separate estimation is carried for this industry with respective WPIs.

6.2. Elasticites of Substitution

The two important parameters that are relevant in the present context are the elasticites of substitution and own-cross price elasticities of demand. A brief note on them is presented below:

The degree of substitutability between any given pair of factors may be measured by the elasticity of substitution. It has been designed to measure the case with which the varying factors can be substituted for others. In formal terms, it (elasticity of substitution) measures the percentage change in the factor proportions due to a change in marginal rate of technical substitution. The Allen-Uzawa partial elasticity of substitution is the proportionate change in the ratio of quantities of two inputs brought about by a change in the relative price ratio for these two inputs, allowing all other factors to adjust to their optimal levels. In the present study elasticities of substitution between sources of energy (inter-fuel substitutability) determines the marginal cost of replacing one fuel (coal, oil, gas, hsdo, ldo…) with another.

6.2.1. Own - Cross Price Elasticities of Demand

The own price elasticity of fuels on the side of demand can be explained as percentage change in quantity demanded of fuel(x) in response to a one percent change in the price of the fuel(x). In other words own price elasticity for coal, oil or natural gas can be described as percentage change in quantity demanded of coal, oil, or gas to a one percent change in the price of the respective fuels.

The cross price elasticity of demand a fuel on the demand side can be explained as percentage change in quantity demanded for fuel(x) in response to a one percent change in the price of fuel(y). In the present case, it may be explained as a the percentage change in quantity demanded of coal to a one percent change in the price of oil or gas or any other fuel used in the production as input.

Theoretically, it is expected that the own price elasticity co-efficient bear a negative sign and cross price elasticity a positive sign, showing that there exists a substitution possibility between the two fuel inputs. Coefficients signs contrary to expectation may reveal that the fuels are complements to each other, and not substitutes.

6.3. Industry Analysis - Fertilizer, Power and Textiles Industries

In this section, the estimated coefficients of the share equations, Allen-Uzawa elasticities of substitution, and own-cross price elasticities of demand for the sample industries, are presented. The functional form of the translog cost equations for the fertilizer and power are given in equations 4.8, and for textile industry equation 4.9 in Chapter 4 of the thesis.

Similarly, the cost share equations for the individual fuels are given in equations 4.8a, 4.8b for fertilizer and power, and equations 4.9a, to 4.9c for the textile industry in chapter 4 of the thesis. In the translog cost equations, the level (scale) of output has not appeared in the specifications, as the assumption of homothetic weakly separable (HWS) has been assumed, though not tested empirically here.

Table 6.1

Estimated Coefficients of Share Equations: Fertilizer and Power Industries *

	Fertilizer	**Power**
β_c	3.855(0.465)	4.888(0.4120)
β_o	3.628(0.687)	1.823(0.5448)
β_g	-6.483(…..)	-5.711(……)
β_{cc}	-0.748(0.690)	-0.371(0.278)
β_{co}	-2.404 (0.732)	-3.892(0.4234)
β_{cg}	3.153(…...)	4.264(……)
β_{oo}	-0.219 (0.883)	4.837(1.018)
β_{og}	2.624(…..)	-0.945(….)
β_{gg}	-5.777(….)	-3.319(….)

*Fuels: coal (c), oil (o), and natural gas (g). Values inside the parentheses are standard errors. Functional forms of the above share equations are given in equation 4.8a, 4.8b in Chapter 4.

From table 6.1 it is known that the price coefficient tends to be significant in the coal share equation with higher gas prices increasing expenditure on coal (β_{cg} is 3.153). But a rise in oil price is reduces the coal's share (β_{co} is -2.404). The price coefficient for oil-gas (β_{og} is 2.624) shows that gas price increment results in increased oil demand. R^2 value 0.72 in coal and oil equations of fertilizer industry (are not presented in the table) are impressive showing that at least 72% of variations in the cost shares is explained by the fuel prices in the equations in the fertilizer industry[1].

The price coefficient in power industry for coal equation tends to be significant. When gas prices rise coal share increases (β_{cg} is 4.264) and decreases when its own price increases. But like in fertilizer industry, for a price increment in oil, coal share tends to decrease (β_{co} is -3.892). In the share equation of oil for the power industry it is seen that oil share decreases when gas price increases. R^2 value at 0.85 for oil and natural gas in power industry was impressive. This shows that 85% of variations in cost shares of oil and gas are explained by the fuel prices in the equations. However the R^2 value at 0.67 for coal is relatively low.

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[1] It may be mentioned here that estimates of alternative set of cost-shares were generated dropping oil equation from the set of cost share equations. The R^2 value 0.70 of gas in these estimates was impressive. This shows that on an average 70% of the variations in cost shares are explained by the fuel prices in the equations in the fertilizer industry

Table 6.1a

Allen-Uzawa Elasticities of Substitution, and Own –Cross Price Elasticities: Fertilizer and Power Industries *

	Fertilizer	Power
σ_{cc}	0.244	-0.0279
σ_{oo}	0.224	0.0727
σ_{gg}	-0.067	-0.0680
σ_{co}	-0.279	-0.0755
σ_{cg}	0.069	0.0946
σ_{og}	0.011	-0.0086
e_{cc}	0.071	-0.008
e_{oo}	0.077	0.025
e_{gg}	-0.024	-0.024
e_{co}	-0.096	-0.026
e_{cg}	0.025	0.0343
e_{og}	0.004	-0.003

*Fuels: coal (c), oil (o), and natural gas (g). Functional forms of the above results of table 6.1a are given in equations 4.8c to 4.8f in Chapter 4.

In table 6.1a σij indicate theAllen-Uzawa elasticities of substitution. e_{ii} and e_{ij} indicate the own-cross price elasticities of demand for fuels c, o, g respectively. σ_{ij} in this case $\sigma_{co,}$ $\sigma_{co,}$ $\sigma_{cg,}$ $\sigma_{og,}$ are the percentage change in the ratio of input fuels used for a unit increase in their ratio of input prices. Allen partial elasticiteis of substitution for coal-oil (σ_{co} -0.279) is negative. For oil-gas however are positive (σ_{og} 0.011). As noted earlier, the own elasticity of substitution co-efficient should follow negative sign and cross co-efficient a positive sign. In case of fertilizer industry the own price elasticity co-efficient of oil is positive (e_{oo} 0.071) and cross price elasticity co-efficient with coal (e_{co} -0.096) a negative sign showing that these two fuels are complements in fertilizer industry. However it can be seen that oil-gas cross elasticity co-efficient (e_{og} 0.004) is positive showing a substitution possibility between the two fuels. Coal-gas cross price elasticity co-efficient (e_{cg} 0.069) depicted in table 6.1a shows that there is a 0.4% substitution possibility for a given price change of gas in the fertilizer industry. In power or electricity generation industry, coal remains as the mainstay fuel than oil and gas. The Allen partial easticities of substitution for power show that own elasticity of substitution for oil is positive which do not follow the expected sign (negative).

Fuels coal and gas follow the negative sign for own and cross price elasticities showing that both are substitutes. The own and cross price elasticities of demand for coal and gas again carry the expected signs (e_{cc} -0.008, e_{gg} -0.024, e_{cg} 0.0343). This is an interesting observation that given an opportunity coal and natural gas can become substitutes but oil remains a complement to coal but can be substituted to gas.

Table 6.2

Estimated Coefficients of Share Equations: Textiles Industry *

Coefficients	Textile
β_c	0.544(0.287)
β_o	0.900(0.198)
β_h	1.446 (0.126)
β_l	-1.891(……)
β_{cc}	-0.068(0.184)
β_{co}	0.464 (0.096)
β_{ch}	-0.095 (0.065)
β_{cl}	-0.300 (…...)
β_{oo}	-0.391(0.146)
β_{oh}	-0.263 (0.103)
β_{ol}	0.191 (……)
β_{hh}	-0.080(0.093)
β_{hl}	0.439(……)
β_{ll}	-0.330(…...)

*Fuels: coal (c), Fuel Oil (o), High Speed Diesel Oil (hdo), and Light Diesel Oil (ldo). Values in the parentheses are standard errors. The functional forms of the results preents in table 6.2 is presented in equations 4.9 a-4.9c in Chapter 4.

From the table 6.2 it is seen that the own price co-efficient values have the expected sign in all the cost share equations (β_{cc} -0.068, β_{oo} -0.391, β_{hh} -0.080, β_{ll} -0.330). The R^2 values at 0.65 are moderate for coal, oil and hdo showing that 65% of expected variation in cost shares is explained due to price changes but for ldo (when cross-checked dropping fuel oil equation) the R^2 value remains as low at 0.57. Looking at the cross price co-efficient values coal-oil (β_{co} 0.464) follow the expected negative sign showing if oil price increases demand for coal increases. Oil-ldo (β_{ol} 0.191) and ldo-hdo (β_{hl} 0.439) depict that the coefficient follows the expected positive sign. But the other two combinations of coal-ldo (β_{cl} -0.300), coal-hdo (-β_{ch} 0.095) do not follow the expected positive sign.

Table 6.2a

Allen-Uzawa Elasticities of Substitution, and Own –Cross Price Elasticities: Textile Industry *

	Textile
σ_{cc}	-0.060
σ_{oo}	-0.721
σ_{hh}	-0.433
σ_{ll}	-0.766
σ_{co}	1.389
σ_{ch}	-1.237
σ_{cl}	-0.006
σ_{oh}	0.146
σ_{ol}	-0.706
σ_{hl}	1.414
e_{cc}	-0.014
e_{oo}	-0.178

e_{hh}	-0.114
e_{ll}	-0.198
e_{co}	0.342
e_{ch}	-0.327
e_{cl}	-0.002
e_{oh}	0.039
e_{ol}	-0.182
e_{hl}	0.365

*Fuels: coal (c), fuel oil (o), high speed diesel oil (hdo), and light diesel oil (ldo). The functional form of the table 6.2a is presented in equations 4.9 d to 4.9g in chapter 4.

Table 6.2a depicts that Allen own elasticity of substitution of the fuels: coal, fuel oil, hdo, ldo(σ_{cc} -0.6, σ_{oo} -0.72, σ_{hh} -0.4, σ_{ll} -0.7) coefficients respectively have the expected negative sign. Substitution (σ_{ij}) among fuels depict that coal-oil (σ_{co} 1.389), oil-hdo(σ_{oh} 0.146), hdo-ldo(σ_{hl} 1.414) follow the expected signs. But the corresponding coefficients for coal-hdo (σ_{ch} -1.237), coal- ldo (σ_{cl} -0.006), oil-ldo (σ_{ol} -0.706) do not follow the expected positive sign, showing that these fuel sets donot share any substitution possibilities.

The own price elasticity of demand for fuels in textile industry shows that they cannot be substituted for price changes of their own (e_{cc} -0.014, e_{oo} -0.178, e_{hh} -0.114, e_{ll} -0.198). Looking at the cross price elasticities of demand it can be understood that coal-oil, oil-hdo, hdo-ldo tend to be substitutes with cross elasticity price co-efficient values (e_{co} 0.342, e_{oh} 0.039, e_{hl} 0.365) respectively comprising a positive sign. But the other three combinations of fuels in textile industry that is, coal-hdo (e_{ch} -0.327), coal-ldo (e_{cl} -0.002), oil-ldo (e_{ol} -0.182) do not follow the expected negative sign, showing that ldo and hdo remain as complements to coal. Also ldo remains as complement to oil. Coal can be substituted by oil but with no other fuel in textiles. It can also be seen that ldo and hdo can be substituted up to 0.3%.

To conclude in fertilizer industry gas remains and the dominant fuel. Both coal and oil remain as complements to gas in the fertilizer industry. In power generation industry coal remains as the dominant fuel. Oil remains as complement to both coal and gas in the power generation industry. Substitution possibility between coal-gas is up to 4% in power generation industry. The substitution possibility ratio of coal-gas up to 4% is found as the highest ratio than any other set of fuels in the present study. In textile industry coal and oil are substitutable up to 1.3%. Hdo and ldo share a substitution possibility of 0.3%. Hdo and ldo complements for coal and oil.

6.4. Company Analysis

Results of the estimates for the selected set of 25 companies under five fuel groups for the period 1991-2004 are presented in the following sub-sections.

6.4.1. Coal-Hsdo fuel group

Results of the estimated share equations, Allen-Uzawa elasticities of substitution, own-cross price elasticity of demand for the selected ten companies[2] (are numbered 1-10 respectively) in the following tables 6.3, 6.3a for the coal-high speed diesel oil fuel group.

[2] Companies estimated in the coal-hdo fuel group are Amrit Banaspati Co. Ltd, C J Gelatine Products Lt, Haryana Steel & Alloys Ltd, J K Synthetics Ltd, Madras Cements Ltd, Nestle India Ltd, Raymond Ltd Ruchi Soya Inds. Ltd, Somaiya Organics (India) Ltd, and Tirrihannah Company Ltd, numbered 1 to 10 respectively.

Table 6.3

Estimated Coefficients of Share Equation: Coal-Hsdo Fuel Group *

	1	2	3	4	5	6	7	8	9	10
β_c	0.255 (0.158)	0.0170 (0.043)	0.345 (0.159)	0.315 (0.082)	0.176 (.085)	0.245 (0.182)	1.146 (1.17)	0.247 (0.154)	0.255 (0.136)	0.616 (0.487)
β_{ch}	0.08 (0.10)	0.128 (0.033)	0.10 (0.155)	0.11 (0.195)	0.32 (0.081)	1.29 (0.300)	0.69 (0.885)	0.33 (0.170)	0.26 (0.129)	-1.21 (1.99)

*Fuels: coal(c), high sulphur diesel oil (h). Values inside parentheses are standard errors.Functional form of table 6.3 is given in equations 4.10a in chapter 4.

Table 6.3a

Allen-Uzawa Elasticities of Substitution and, Own –Cross Price Elasticities: Coal-Hsdo Fuel Group *

	1	2	3	4	5	6	7	8	9	10
σ_{cc}	8.001	6.18	6.0	5.58	2.33	0.54	1.11	2.32	2.6	-0.54
σ_{hh}	0.320	0.093	0.42	0.29	0.05	0.01	0.01	0.04	0.09	-0.03
σ_{ch}	-1.59	-0.76	-1.5	-1.29	-0.34	-0.10	-0.14	-0.32	-0.4	0.13
e_{cc}	1.333	0.677	1.25	1.04	0.30	0.086	0.130	0.281	0.41	-0.10
e_{hh}	0.266	0.083	0.33	0.24	0.04	0.016	0.017	0.039	0.08	-0.02
e_{ch}	-1.33	-0.67	-1.25	-1.04	-0.30	-0.08	-0.13	-0.28	-0.41	0.10
e_{hc}	-0.26	-0.08	-0.33	-0.24	-0.04	-0.01	-0.02	-0.03	-0.08	0.02

*Fuels: coal(c), high sulphur diesel oil (h). The functional form of results are generated in table 6.3a are presented in equations 4.10b to 4.10d in chapter 4.

In Amrit Banaspati (company 1 in table 6.3) comes under the food processing industry the price coefficient of share equation for coal and hsdo is 0.086 not following the expected negative sign. The R^2 value is impressive at 0.64 showing that the changes are cost share is explained by price variations at 64%.

The Allen own and Cross elasticity of substitution seen from table 6.3a depict that own elasticity is positive and cross negative (σ_{cc} 8.00, σ_{hh} 0.32). Also the own-cross price elastic of demand of fuels coal-hdo (e_{cc} 1.3, e_{hh} 0.26, e_{ch} -1.3, e_{hc} -0.26) for Amrit Banaspati show that there is no substitution possibility between two fuels in the company.

In CJ Gelatine (company 2 in table 6.3) the cross price coefficient of cost share is positive (β_{ch} 0.128) showing that there is no impact of hdo price increments on coal share. This trend of signs is also seen from table 6.3a Allen elasticities own cross elasticity of for substitution of fuels is positive for own and negative for cross (σ_{cc} 6.18, σ_{hh} 0.093). Also the price elasticity of demand for fuels coal-hdo are following the same trend of positive for own and negative signs for cross coefficients (e_{cc} 0.77, e_{hh} 0.266, e_{hc} -0.08). R^2 value at 0.58 shows that only 58% of the changes in cost share are explained by fuel prices.

For Haryana Steel and Alloy (company 3 in table 6.3) the R^2 value is impressive with 0.79 showing that about 79% of the cost share variations are explained by the fuel prices. The company is heavy manufacturing industry producing steel and alloys. The price co-efficient trend of the cost share for coal-hdo is positive which do not follow the expected sign (β_{ch} 0.10). Table 6.3a depicts the Allen elasticity of substitution of the fuels where own elasticity of substitution of coal and hdo are positive and cross elasticity is negative (σ_{cc} 6.0, σ_{hh} 0.42, σ_{ch} -1.5). Also the own cross price elasticity of demand for coal, hdo and coal-hdo follow the same trend (e_{cc} 1.25, e_{hh} 0.33, e_{hc} -1.25).

In J K Synthetics Ltd (company 4 in table 6.3) the R^2 value 0.53 shows that 42% of the variations in cost share are not explained by fuel prices. The price coefficient value of the coal-hdo (β_{ch} 0.11) cost share equation do not follow the expected negative sign. This shows that any changes in the hdo prices will not impact have impact on the coal demand. Table 6.3a depicts coal and hdo Allen elasticity of substitution within the company JK Synthetics. The AES of own for coal and hdo are positive (σ_{cc} 5.58, σ_{hh} 0.29). The cross AES of coal-hdo is negative (σ_{ch} -1.29). The own and cross price elasticity of demand for fuels also do not follow the expected sign (e_{cc} 1.04, e_{hh} 0.24, e_{hc} -1.04). This shows that both the fuels are complements to each within the company and not substitutes.

In Madras Cements Ltd (company 5 in table 6.3) the price coefficient of coal-hdo equation follows a positive sign (β_{ch} 0.32) showing there is no effect of hdo prices increments on the coal share within the company. Also the company has an impressive R^2 value of 0.67. Allen elasticity of substitution between the fuels and own elasticity of substitution for coal, hdo within the company are (σ_{cc} 2.33, σ_{hh} 0,05, σ_{ch} -0.34) not following the expected sign showing both are complements is depicted in table 6.3a. Looking at own cross price elasticity of demand for coal, hdo (e_{cc} 0.30, e_{hh} 0.04, e_{hc} -0.30) do not follow the expected signs showing both fuels are complements.

The price coefficient of Nestle, Raymond, Ruchi, Somaiya (companies 6 to 9 respectively in table 6.3) depict a positive sign, explain that the hdo price do not have any impact on the coal share within these companies (β_{ch} 1.29, β_{ch} 0.69, β_{ch} 0.33, β_{ch} 0.26 respectively for companies 6 to 9). The R^2 value of 0.68 in companies 6 to 9 is impressive showing that 68% of the variations in the cost shares are explained by fuel prices. In table 6.3a it can be seen that Allen own for coal (σ_{cc} 0.54, σ_{cc} 1.11, σ_{cc} 2.32, σ_{cc} 2.6,) hdo (σ_{hh} 0.01, σ_{hh} 0.01, σ_{hh} 0.04, σ_{hh} 0.09) follow a positive sign respectively for companies 6 to 9. And the cross elasticity of substitution for coal and hdo follow a negative sign (σ_{ch} -0.10, σ_{ch} -0.14, σ_{ch} -0.32, σ_{ch} -0.4). Own price elasticity of demand for coal (e_{cc} 0.086, e_{cc} 0.130, e_{cc} 0.281, e_{cc} 0.41), hdo (e_{hh} 0.016, e_{hh} 0.017, e_{hh} 0.039, e_{hh} 0.08) are also positive. And the cross price elasticity of demand for coal and hdo in these companies tends to be negative (e_{hc} -0.01, e_{hc} -0.02, e_{hc} -0.03, e_{hc} -0.08). To sum up in all these companies coal tends to be the dominant fuel than hdo and hdo is a complement to coal and are not substitutes.

In Tirihannah Tea company (company 10 in table 6.3), the price coefficient value of hdo-coal is negative (β_{ch} -1.21) showing that for a price change in hdo, demand for coal increases. The R^2 value at 0.52 is low for the company. Though the other weights follow the expected signs, it is quite possible that apart from fuel prices there could be some other factors which are influencing the cost shares. The Allen own elasticity of substitution coefficients for coal (σ_{cc} -0.54) and hdo (σ_{hh} -0.03) follow the expected negative sign. AES cross elasticity of substitution for coal-hdo (σ_{ch} 0.13) follows the expected positive sign in table 6.3a. The own price elasticity of demand for coal (e_{cc} -0.10) and hdo(e_{hh} -0.02) follow the expected negative sign. The cross price elasticity of demand for coal-hdo (e_{hc} 0.02) depicted in table 6.3a explains that a 0.2% possibility of substitution is possible between coal and hdo for given price changes.

To sum up tables 6.3 and 6.3a it is clear that none of the companies follow the expected signs leaving Tirihannah where a 0.10% substitutability of demand is seen for hdo to coal and only 0.2% from coal to hdo.

6.4.2. Coal-Light Diesel Oil Group

Results of the estimated share equations, Allen-Uzawa elasticities of substitution, own-cross price elasticiteis of demand for the selected two companies[3] in the coal-ldo fuel group are presented as 1 and 2 respectively in tables 6.4 and 6.4a.

Table 6.4

Estimated Coefficients of Share Equation: Coal-Ldo Fuel Group *

	1	2
β_c	0.033(0.024)	-0.055 (0.099)
β_{cl}	0.085 (0.021)	0.213 (0.119)

*Fuels: coal(c), light diesel oil (l). Values inside the parenthesis are standard errors. Functional form of the results presented in table 6.4 can be seen in equation 4.11a in chapter 4.

Gujarat Ambuja Cements (company 1 in table 6.4) is a cement major it is seen that the price coefficient (β_{cl} 0.085) value of the cost share coal and ldo tend to be positive, showing for a givens change in the price of ldo there is no change in the coal share. In Karnataka Soaps (company 2 in table 6.4) the same trend is followed with coal and ldo price coefficient (β_{cl} 0.213) tend to positive. For Gujarat Amhuja's R^2 value at 0.80 is quite impressive showing that 80% of the variations in cost share are explained by the fuel prices. However in Karnataka soaps the R^2 value at 0.46 is low showing that there could be other factors influencing the cost share apart from fuel prices.

[3] The selected two companies in coal-ldo fuel group are Gujarat Ambuja Cements Ltd., Karnataka Soaps & Detergents Ltd. numbered 1 and 2 respectively in table 6.4.

Table 6.4a

Allen-Uzawa Elasticities of Substitution, and Own –Cross Price Elasticities: Coal-Ldo Fuel Group *

	1	**2**
σ_{cc}	10.81	3.372
σ_{ll}	0.02	0.107
σ_{cl}	-0.46	-0.602
e_{cc}	0.444	0.511
e_{ll}	0.019	0.091
e_{cl}	-0.444	-0.511
e_{lc}	-0.019	-0.091

*Fuels: coal(c), light diesel oil (l) Functional form of the above table 6.4a is presented in equations 4.11b to 4.11d in chapter 4.

The Allen own elasticity of substitution for Gujarat Ambuja and Karnataka Soaps (companies 1 and 2 in table 6.4a) show a positive sign for coal (σ_{cc} 10.81, σ_{cc} 3.372) and ldo (σ_{ll} 0.02, σ_{ll} 0.107) which is not expected. Allen cross elasticity of substitution for coal-ldo in both the companies (σ_{cl} -0.46, σ_{cl} -0.602) follow a negative sign. Looking at the own price elasticity of demand for coal and ldo (e_{cc} 0.44, e_{ll} 0.511) in the two companies they tend to be positive. And the cross elasticity of demand for coal-ldo (e_{cl} -0.091) tend to be negative showing that both the fuels are complements and cannot be substitutes. To sum up in both the companies it is seen that coal remains as the dominant fuel and ldo is a complement and not a substitute to coal fuel.

6.4.3. Coal-Natural Gas Fuel Group

The following tables 6.5 and 6.5a respectively represent a group of seven companies[4] using coal and natural gas as fuel inputs.

Table 6.5
Estimated Coefficients of Share Equation: Coal-NG Fuel Group *

	1	2	3	4	5	6	7
β_c	-0.331 (0.738)	-0.813 (0.475)	-1.054 (1.401)	0.119 (0.229)	0.506 (0.408)	-1.59 (0.135)	6.501 (9.92)
β_{cg}	-0.146 (0.205)	1.842 (0.631)	2.617 (0.878)	0.498 (1.025)	-0.026 (0.418)	0.906 (0.236)	-6.498 (4.844)

*Fuels: coal(c), natural Gas (g). Values presented in the parenthesis are standard errors. Functional form of the above table 6.5 is presented in equation 4.12a in chapter 4.

The price coefficients of coal and natural gas using companies are depicted in the above table 6.5. The values give mixed results that in three companies both the fuels are substitutes and in four they are not. R^2 value at 0.67 for all companies in the coal-natural gas fuel group show that 33% of variations in the cost share are not explained by the fuel prices. In Andhra Sugars (company 1 in table 6.5) the price coefficient of coal-natural gas cost share (β_{cg} -0.146) tends to be negative and follows the expected sign. It can be seen that given a price increase in natural gas would change the coal share in the cost share. From table 6.5a it can be seen that the Allen elasticity of own substitution for coal (σ_{cc} -3.69) and natural gas (σ_{gg} -0.477) are negative following the expected sign. The cross elasticity of substitution of coal-natural gas tends to be positive (σ_{cg} 1.329). The

[4] Andhra Sugars Ltd, Andrew Yule & Co. Ltd, Dhunseri Tea & Inds. Ltd, Gujarat Narmada Fertilizers limited, Jagatjit Industries Ltd, Jay Shree Tea & Inds. Ltd, Tata Tea Ltd.

price elasticity of demand for own price changes of coal (e_{cc} -0.978) and natural gas(e_{gg} -0.35) are negative following the expected sign. The cross price elasticity of demand for coal-natural gas (e_{cg} 0.351) tends to follow the expected positive sign show that up to 3% in Andhra Sugars coal and natural gas can be substituted.

Table 6.5a

Allen-Uzawa Elasticities of Substitution, and Own –Cross Price Elasticities: Coal-NG Fuel Group *

	1	2	3	4	5	6	7
σ_{cc}	-3.698	0.208	0.108	0.818	-26.35	0.344	-0.062
σ_{gg}	-0.477	0.079	0.084	0.261	-1.00	0.215	-0.021
σ_{cg}	1.329	-0.128	-0.095	-0.463	5.14	-0.272	0.036
e_{cc}	-0.978	0.079	0.051	0.296	-4.3	0.152	-0.023
e_{gg}	-0.351	0.049	0.045	0.167	-0.8	0.120	-0.013
e_{cg}	0.978	-0.079	-0.051	-0.296	4.304	-0.152	0.023
e_{gc}	0.351	-0.049	-0.045	-0.167	0.840	-0.120	0.013

*Fuel: coal(c)-natural gas (g). Functional form of the above table 6.5a is presented in equation 4.12b to 4.12d in chapter 4.

In Andhrew Yule, Dhunseri Tea, and Gujarat Narmada Fertilizers (companies 2 to 4 in tables 6.5 and 6.5a) the price coefficients (β_{cg} 1.84, β_{cg} 2.61, β_{cg} 0.49) follow a positive sign showing that given changes in natural gas prices are not effecting the share of coal. Table 6.5a depicts the Allen own price elasticity of substitution for coal (σ_{cc} 0.20, σ_{cc} 0.10, σ_{cc} 0.81) and natural gas (σ_{gg} 0.07, σ_{gg} 0.08, σ_{gg} 0.26) are positive which do not follow the expected sign. The Allen cross price elasticity of substitution of coal and natural gas (σ_{cg} -0.12, σ_{cg} -0.09, σ_{cg} -0.463) follow a negative sign which is not the expected sign. The price elasticity of demand for own price changes of coal (e_{cc} 0.07, e_{cc}

0.051, e_{cc} 0.29) and natural gas (e_{gg} 0.04, e_{gg} 0.04, e_{gg} 0.16) in these companies do not follow the expected sign. Also the cross price elasticity of demand for coal and natural gas (e_{cg} -0.04, e_{cg} -0.045, e_{cg} -0.167) do not follow the expected sign of positive, showing that there is not substitution possibility between coal and natural gas in these companies.

In company Jagatjit Industries (company 6 in table 6.5 and 6.5a), the price coefficient of coal and natural gas (β_{cg} -0.026) cost share tend to be negative and follows the expected sign. The Allen own elasticity of coal (σ_{cc} -26.3) and natural gas (σ_{gg} -1.0) also follow the expected negative sign. The Allen cross elasticity of substitution for coal and natural gas is positive (σ_{cg} 5.14). The own price elasticity of demand for coal (e_{cc} -4.3) and natural gas (e_{gg} -0.8) tend to be negative depicting the expected sign. The cross price elasticity of demand for coal and natural gas (e_{cg} 4.304) tends to be positive showing that a given change in natural gas would bring in demand for coal in this company. Within the company there is substitution possibility up to 4% is seen between coal and gas.

In Jaya Shree Tea (company 6.5 in table 6.5a) the price coefficients of coal and natural gas (β_{cg} 0.90) cost shares do not follow the expected negative sign. Looking at the Allen elasticity of substitution own for coal (σ_{cc} 0.34) and natural gas (σ_{gg} 0.21) do not follow the negative sign. The cross elasticity of substitution of coal and natural gas (σ_{cg} -0.27) follows a negative sign. The own price elasticity of demand for coal (e_{cc} 0.152) and natural gas (e_{gg} 0.120) tend to be positive with cross elasticity of demand negative for coal and natural gas (e_{cg} -0.152) in Jaya Shree Tea company.

In Tata Tea (company 7 in tables 6.5 and 6.5a) coal and natural gas tend to be substitutes following the expected signs. The price co-efficient value of coal and natural gas (β_{cg} -6.498) cost share follows a negative sign. The Allen elasticity of substitution of coal (σ_{cc} -0.062) and natural gas (σ_{cc} -0.021) for own price changes is negative. The

Allen cross elasticity of substitution for coal-natural gas (σ_{cg} 0.036) depicts a positive sign showing the substitution possibility of 0.03% in the company. The own price elasticity of substitution for coal (e_{cc} -0.023) and natural gas (e_{gg} -0.013) follow the expected negative sign. The cross price elasticity of demand for coal and natural gas (e_{cg} 0.023) shows that a 0.02% of substitution possibility exists between the fuels in Tata Tea.

To sum up for companies Andhrew Yule, Dhunseri, and Gujarat Narmada and Jaya Shree numbered 2,3,4,6, respectively it is seen that the expected values are not followed. This shows that in these companies both coal and gas are complements and are not substitutes to each other in these companies. Companies Andhra Sugars, Jagatjit Industries and Tata Tea show 0.97%, 4.3%, and 0.023% of substitution possibility respectively between coal and natural gas within the company.

6.4.4. Natural Gas-High Sulphur Diesel Oil Group

Results of the estimated cost shares of fuels for three companies[5] using natural gas and high sulphur diesel oil are depicted in the following table 6.6 and 6.6a.

Table 6.6

Estimated Coefficients of Share Equation: Ng-Hdo Fuel Group *

	1	2	3
β_c	1.666(0.770)	0.007(0.161)	-0.52(0.515)
β_{gh}	3.841(1.127)	0.346(0.289)	0.532(0.523)

* Fuels: natural gas (g), high sulphur diesel oil. Values presented in the parenthesis are the standard errors. Functional form of the above table 6.6 can be seen in equations 4.13a in chapter 4.

[5] Reliance Industries Ltd, Rossell Industries Ltd, Warren Tea Ltd.

Table 6.6a

Allen-Uzawa Elasticities of Substitution, and Own –Cross Price Elasticities: Ng-Hdo Fuel Group *

	1	**2**	**3**
σ_{gg}	0.113	2.15	1.49
σ_{hh}	0.030	0.055	0.02
σ_{gh}	-0.058	-0.34	-0.18
e_{gg}	0.039	0.295	0.162
e_{hh}	0.020	0.047	0.020
e_{gh}	-0.039	-0.295	-0.162
e_{hg}	-0.020	-0.047	-0.020

*Fuels: natural gas (g), high sulphur diesel oil (hdo). Functional form of the above tables 6.6 and 6.6a are given in equations 4.13b to 4.13d in chapter 4.

Reliance Industries, Rosell and Warren Tea (companies 1 to 3 in tables 6.6 and 6.6a) depict that there is no substitution possibility existing between natural gas and hdo. The R^2 value at 0.53 for all the three companies is not very impressive. The price coefficients for the natural gas and hdo cost shares (β_{gh} 3.8, β_{gh} 0.34, β_{gh} 0.53) in these companies tend to be positive, showing that for given price increase of hdo there is no change in the natural gas share.

From Table 6.6a it can be seen that the Allen own elasticity substitution of for natural gas (σ_{gg} 0.1, σ_{gg} 2.1, σ_{gg} 1.49) and hdo (σ_{hh} 0.03, σ_{hh} 0.05, σ_{hh} 0.02) do not follow the expected negative sign. Allen cross elasticity of substitution for natural gas and hdo (σ_{gh} -0.05, σ_{gh} -0.34, σ_{gh} -0.18) in the companies do not follow the expected sign. The own price elasticity of demand for natural gas (e_{gg} 0.03, e_{gg} 0.2, e_{gg} 0.16) and hdo (e_{hh} 0.02, e_{hh} 0.04, e_{hh} 0.02) tend to be positive. The cross price elasticity of demand for fuels natural gas and hdo(e_{hg} -0.03, e_{hg} -0.2, e_{hg} -0.16) tend to be negative for all the three companies.

To sum up in reliance group both natural gas and hsdo are used as feedstock and it is seen that both natural gas and high sulphur diesel oil are complements and are not substitutes in this petrochemical company. Rossell industries is a tea manufacturing major in west Bengal. And the results show that hsdo is a complementary fuel for natural gas and not a substitute. Also in warren tea hsdo appears to be a complement for natural gas and not a substitute.

6.4.5. High Sulphur Diesel Oil-Light Diesel Oil Fuel Group

Companies[6] using high sulphur diesel oil and light diesel oil as fuels for one purpose in the company.

[6] Companies in Hdo-Ldo fuel group are Grasim Industries Ltd, Hasimara Industries Ltd, Hindusthan National Glass & Inds. Ltd. respectively numbered as 1,2, and 3.

Table 6.7

Estimated Coefficients of Share Equation: Hdo-Ldo Fuel Group *

	1	2	3
β_h	1.833(0.312)	0.811(0.216)	1.386(0.187)
β_{hl}	-0.61(0.238)	0.072(0.327)	-0.50(0.150)

*Fuel: high sulphur diesel oil (hdo) light diesel oil (ldo).Values inside parenthesis are standard errors. Functional form of the above tables 6.7 is presented in equation 4.14a in chapter 4.

Table 6.7a

Allen-Uzawa Elasticities of Substitution, and Own –Cross Price Elasticities: Hdo-Ldo Fuel Group *

	1	2	3
σ_{hh}	-0.350	2.861	-0.417
σ_{ll}	-0.472	4.078	-0.575
σ_{hl}	0.407	-3.416	0.490
e_{hh}	-0.188	1.557	-0.225
e_{ll}	-0.218	1.859	-0.264
e_{hl}	0.188	-1.557	0.225
e_{lh}	0.218	-1.859	0.26

*Fuels: high sulphur diesel oil, light diesel oil fuel group. Functional form of the results presented in table 6.7a can be seen in equation 4.14b to 4.14d in chapter 4.

In Grasim, Hasimara and Hindusthan Glass(companies 1 to 3 in table 6.7 and 6.7a), using hdo and ldo as fuel inputs it is seen that in two companies there exists a substitution possibility between the two fuels. The R^2 value at 0.62 appears moderate for all the companies. The price coefficients in Grasim for the hdo-ldo (β_{hl} -0.6) cost share equation show a negative sign which explains that for a given price rise in ldo there are changes in the demand for hdo in the company. The Allen elasticity of substitution for own price changes of hdo(σ_{hh} -0.35) and ldo(σ_{ll} -0.47) follow the expected positive sign.

In Hasimara (company 2 in 6.7 and 6.7a) a substitution possibility is seen between the fuels. The price co-efficient (β_{hl} 0.072) for cost share equation depicted in table 6.7 do not carry the expected sign. The Allen elasticities of own for hdo, ldo (σ_{hh} 2.86, σ_{ll} 4.07) and cross (σ_{hl} -3.41) hdo and ldo do not carry the expected negative signs. Also the own and cross price elasticity of demand for these fuels in

In Hindustan Glass (company 3 in table 6.7 and 6.7a), fuels hdo and ldo show substitution possibilities between them. The price coefficients (β_{hl} -0.5) carry the negative sign for the hdo-ldo cost share equation. The Allen elasticity of substitution for own prices of hdo(σ_{hh} -0.41) and ldo(σ_{ll} -0.57) tend to negative sign. The cross elasticity of substitution of hdo-ldo (σ_{hl} 0.49) depicts within the company the two fuels are substitutes to each other. The own price elasticity of demand for hdo and ldo (e_{hh} -0.2, e_{ll} -0.264) carry the expected signs. The cross price elasticity of demand for hdo and ldo (e_{lh} 0.22) carries a positive sign showing a 2% substitution is possible between hdo and ldo in Hindustan Glass.

To sum up out of the three companies using hdo and ldo only one company Hasimara tends to show that there is no substitution possibility and rest two show that there is a substitution possibility up to 2% between the fuels within the company.

6.5. Summary

The present chapter paves the way for drawing conclusions by explaining the results broadly. It is clearly seen from the chapter that the present work on inter-fuel substitution possibilities proves that coal happens to be dominant fuel in the commercial energy mix of the economy at both industry and also at company level. But in case where there is an option for technology or any other factor like it is used as feedstock the results are quite different from the earlier drawn.

Chapter 7

Summary and Conclusions

Inter-fuel substitution has been an important issue in the area of energy economics. It has implications to confirm the success or failure of an industry restructuring which depends on how producers and buyers adjust to evolving fuel prices, including substitution inside the industry between various fuels. Keeping in mind the contemporary relevance of this problem and also the back drop of rising fuel prices, the present study is undertaken. The specific objective of this study has been to examine the issues that center around inter-fuel substitution possibilities and also measure the same. The study has used the translog cost function approach. The cost share equations for fuels, are estimated, and the own-cross price elasticities, and Allen-Uzawa cross elasticities of substitution are estimated. The study was undertaken in the context of these industries namely, fertilizer, power and electricity industries and also 25 companies that fall under five homogeneous fuel groups.

The conclusions drawn from the estimated translog cost shares and Allen elasticity of substitution are given below. The conclusions drawn are mainly based on the empirical results.

7. 0. Conclusions Drawn from the Industry Level Aggregate Data

- In fertilizer industry gas remains and the dominant fuel. Both coal and oil remain as complements to gas in the fertilizer industry.

- In power generation industry coal remains as the dominant fuel. Oil remains as complement to both coal and gas in the power generation industry.
- Substitution possibility between coal-gas is up to 4% in power generation industry. The substitution possibility ratio of coal-gas up to 4% is found as the highest ratio than any other set of fuels in the present study.
- In textile industry coal and oil are substitutable up to 1.3%.
- Hdo and ldo share a substitution possibility of 0.3% in textile industry. Hdo and ldo complements for coal and oil in the textile industry.

7.1. Conclusions Drawn from Company Level Disaggregate Data

At the company level disaggregated estimates it is found that where the fuels are used as feedstock coal remains as a complementary fuel and not a substitute. Results of Gujarat Narmada Fertilizer and Reliance Petrochemicals prove that in companies using fuels for feed stock purposes fuel substitution is not possible.

- There is no substitution possibility found in the two fuel groups of Coal-Hdo and Coal and ldo. (Which is also seen in the textile industry where all the three fuels were fuel inputs)
- In coal and natural gas fuel group leaving Andhra Sugars ltd, Jagatjit industries ltd and Tata Tea all other companies prove that natural gas remains as complementary fuel to coal and coal is the dominant in the fuel mix.

Keeping in view the company profile of these three companies it is observed that all the three are established food processing and breweries producers. Based on this it can be concluded that in Fast Moving Consumer Goods (FMCG) companies natural gas appears as substitute for coal and might replace its position in near future.

- Out of the three companies considered for estimates in the light diesel oil and high sulphur fuel group two companies show a substitution possibility up to 2% between the fuels within the company.

- In case of coal and hsdo fuel group only one company shows that there exists a substitution possibility between the two. However the R^2 value is low and it is difficult to conclude that it is fuel prices that are explaining the changes the fuel demand.

- Comparing both the industry and company level results it is seen that coal and natural gas (both at industry and company level) can be substituted up to 4%.

- High sulphur diesel oil and Light diesel oil also share a substitution possibility both at industry and company level upto 2%.

- Natural gas is the only fuel that appears to be a substitute for coal in the energy mix.

- Broadly it is seen that inter-fuel substitution is possible mainly in fast moving consumer goods (FMCG) companies and in sectors/companies where fuels are used for captive power generation or say own generation of electricity in the company. And in energy intrinsic sectors like power and other manufacturing industries and companies its not possible to expect coal to be replaced in the near future.

Through abundant of literature is available for various forms of data, sectors, and industries and also across countries on inter-fuel substitution possibilities, it may not serve any purpose to compare the situation in India with well developed nations like United Kingdom or United States. It may be equally difficult to compare the present results with the earlier works [Murty 86, Debesh 86] as they were carried for the data of 80's when not many companies were using commercial forms of energy. Since then many changes have taken place thanks to the industrialization and modernization of industrial sector from the past two decades. The lack of empirical studies in the post reforms period at industry level and lack of company level analysis in India motivated the present study. In the commercial energy mix Coal remains as the dominant fuel across the sectors, (industries) and also at firm level. Added to this fact the following are the conclusions drawn towards inter-fuel substitution possibilities in the energy and non-energy industries of the Indian economy.

7.2. Concluding Remarks

A policy initiative from the Government of India (GOI) towards the resource allocation and utilization of the upcoming fuels like natural gas need to be designed carefully targeting FMCG sector and not targeting energy intensive sectors. Switching of fuels for the production processes needs machinery that is flexible for using two or more fuels. In many cases FMCG companies are small and medium level firms and are not established manufacturing giants, the present study proves that inter-fuel substitution possibilities are more in FMCG segments than heavy industry.

A policy imperative towards mini-natural gas power plants need to be mooted by GOI. For materializing this, uninterrupted natural gas supplies need to be guaranteed by the GOI. Supply constraints and other issues related to these doesn't comprise the purview of the study and with the assumption that all other things would change with the new resource findings, the present study strictly confines its horizon to inter-fuel substitution possibilities. To make a best fit of translog cost functions as explained in chapter 4 and chapter 6, due care about the utilization of fuels is considered, which was not given priority in earlier works. The following are certain limitations from the data side the present work has come across.

7.3. Areas of Enhancement

The present work can be better handled and could have generated a better understanding about the inter-fuel substitution among fuels, provided the sources of data were not scattered. In other words a lack of transparency in the information at disaggregated data hindered the sample expansion. If a transparency in reporting energy consumption patterns and fuel usage within the company, industry, and sector is reported the sample slot would increase and a better piece of work could be brought out.

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Appendix-I

Earlier Works on Inter-Fuel Input Substitution- Across Countries

Study	Period	Methodology
Berndt and Wood (1975)	U.S. Manufacturing for 1947-1971	Translog Cost Function
Griffin and Gregory (1976)	Nine Industrialized Countries at four years 1955,1960,1965,1969	Translog Cost Function
Atkinson and Halverson (1976)	U.S. Steam Electric Power Generation Sector for the year 1972	Translog Profit Function
Griffin (1977)	20 O.E.C.D. countries for five year intervals 1955,1960,1965,1969	Translog Cost Function
Halverson (1977)	U.S.Manufactuing for the year 1971	Translog Cost Function
Pindyck(1978)	Ten industrialized countries 1959-1973	Translog Cost Function
Catherine Morrison (1993)	U.S.Manufacturing Sector for years 1949-86	Translog Cost Function
Frondel and Christoph (2002)	German Manufacturing sector 1978-1900	Translog Cost Function
Clifton Jones (1995)	U.S. Industrial Energy Demand for years 1960-1991	Translog Cost function and Linier Logit Model
Soderholm(1999)	Eight Western European countries Power generating sector for years 1978-95	Translog model
Thomas and Henrik (2001)	Danish Industry 1983,85,88,90,93,95,1997	Translog Cost function and Linear Logit Model

Earlier Works on Inter-Fuel Substitution in India

Study	Period	Methodology
Uri (1978)	Indian energy intensive sectors for years 1960-1971	Translog Function
Vashist (1984)	Indian Manufacturing Industry	Translog Cost Function
Joashree and Debesh (1986)	Indian Manufacturing Industries for years 1959-71	Translog Cost function
Murty (1986)	Indian Manufacturing Industry	Translog Cost Function
Jha,Murty and Paul (1991)	Four Selected Indian Manufacturing Industries 1960-1983	Translog Cost Function
Joyashree et al (1999)	Six energy intensive sectors of India 1973-1993	Translog Cost function

Appendix-II

Sample Companies

Coal-Hsdo Fuel Group

1. Amrit Banaspati Co. Ltd,
2. C J Gelatine Products Lt,
3. Haryana Steel & Alloys Ltd,
4. J K Synthetics Ltd,
5. Madras Cements Ltd,
6. Nestle India Ltd,
7. Raymond Ltd
8. Ruchi Soya Inds. Ltd,
9. Somaiya Organics (India) Ltd,
10. Tirrihannah Company Ltd.

Coal-Ldo Fuel Group

1. Gujarat Ambuja Cements Ltd. ,
2. Karnataka Soaps & Detergents Ltd.

Coal-NG Fuel Group

1. Andhra Sugars Ltd
2. Andrew Yule & Co. Ltd,

3. Dhunseri Tea & Inds. Ltd,
4. Gujarat Narmada Fertilizers limited,
5. Jagatjit Industries Ltd,
6. Jay Shree Tea & Inds. Ltd,
7. Tata Tea Ltd.

Ng-Hdo Fuel Group

1. Reliance Industries Ltd,
2. Rossell Industries Ltd,
3. Warren Tea Ltd.

Hdo-Ldo Fuel Group

1. Grasim Industries Ltd,
2. Hasimara Industries Ltd,
3. Hindusthan National Glass & Inds. Ltd.