DEMAND FOR ELECTRICITY : AGGREGATIVE AND SECTORAL ANALYSIS FOR INDIA.

DISSERTATION SUBMITTED TO THE JAWAHARLAL NEHRU UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF

MASTER OF PHILOSOPHY

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CERTIFICATE

This is to certify that the dissertation entitled, **"DEMAND FOR ELECTRICITY : AGGREGATIVE AND SECTORAL ANALYSIS FOR INDIA"**, submitted by **SAMBIT BASU** in partial fulfilment of the requirements for the award of the degree of **Master of Philosophy (M.Phil)** of this University, is his original work and had not been submitted for the award of any other degree of this University or of any other University.

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ACKNOWLEDGEMENT

I take th opportunity to express my gratitude to the many who have helped me in this work, though to each of them I owe much more than I can possibly express.

Above all, I am extremely grateful to my supervisor, Professor Ramprasad Sengupta, for being so supportive and patient throughout the course of this work. His guidance, encouragement and affection gave me the strength to write this dissertation. I can never really recompense my debts to him.

I express my sincere gratitude to Prof. Anjan Mukherji, Dr. D.N. Rao, Prof. M.K. Premi, Dr. Abhijit Sen, Dr. A.N. Bhat and Dr. Archana Aggarwal for providing me with their precious time and suggestions.

I owe special debts to the library staff of the Central Statistical Organization (New Delhi), Central Electricity Authority (New Delhi), and National Institute of Public Finance and Policy (New Delhi).

I would like to acknowledge my debts to Mrs. Kakkar, Mr. P.S. Rajagopal, Mr. B.S. Bisht and Mr. B. Singh.

My special thanks goes to Anindita and Dipen. Helpful discussions with Anindita and Dipen's help in the early stages of the work are deeply appreciated.

I am also thankful to my seniors and colleagues Mrityunjoy, Krishnendu, Subroto, Soumen, Pronob, Pradyumna, Prosenjit and Ashis for helping and constantly encouraging me.

I am grateful to Bobby, Bipasha, Promila and Sumon for all that they have done for me.

I am extremely indebted to Bishakha, Gouranga, Sreejata, Subrata and Ranja for constantly encouraging me and pepping up my, at times, drooping spirits.

Last but not the least, I'd like to reserve my deepest gratitude for my parents and family members for being so supportive all the while. Their profound love and inspiration saw me through this dissertation.

I am solely responsible for any error committed in this dissertation, although the success is only partially mine.

Sambit

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CHAPTER I

AN OVERVIEW

Economics being an evolving science gave birth to Energy Economics, which with the passage of time has established itself as a mainstream economics. Ever since the oil embargo of 1973-74[1], the economies realized that energy plays a very vital role in deciding the fate of the economy. Energy is an indispensable input for sustainable economic development. The mere pervasiveness of energy use in economic activity reflects its great importance in the development process. "There is no substitute for energy; the whole edifice of modern life is built upon it".[2]

Empirical evidence suggest that there is an iron link between growth in Gross Domestic Product (GDP) and consumption of energy. Since, production process, transportation, consumption by households all require energy, so any increase in the activity level of one of these imposes a pressure on the energy requirement. The developing countries moving along the path of development requires enough energy to achieve the target growth and sustain the process. The rapid growth in demand for energy in developing countries may be attributed to the rapid growth in GDP and relatively high energy intensities. Chern (1985) has shown that GDP elasticities of aggregate energy demand are high and price elasticities low for the less developed countries.[3] There is

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1. Organisation of Petroleum Exporting Countries (OPEC) quadrupled world oil prices in 1973-74.

2. Geoffrey Kirk (edited), "Schumacher on Energy", Abacus, London, 1983, pg. 1.

3. W.S. Chern, "An Assessment of Future Energy Demand in Developing Countries", Natural Resource Forum, Vol. 9, 1985.

a strong correlation between industrialisation and energy use. To quote Schumacher (1992), "it might be said that energy is for the mechanical world what consciousness is for the human world. If energy fails, everything fails".[4]

The pattern of energy consumption in developing and the developed countries is different. The developed countries are characterised by a high consumption of commercial energy, unlike the developing countries where higher proportion of non-commercial energy is consumed. According to a report published by IGIDR (1991), the share in total world commercial energy consumption by developed and developing is 74.8% and 25.2%.[5] More than 80% of the gasolene and electricity are consumed by developed countries at the extreme, whereas more than 80% of the fuelwood is consumed by the developing country at the other extreme. The shares of total electricity consumption in total world consumption for developed and developing countries are 79% and 21% respectively.[6] The developing countries consume 28% of diesel, 18% of gasolene and 36% of coal in total world consumption.

However, consumption patterns undergo characteristic changes, gradually, as the economy moves along the development path. The metamorphosis from a traditional society to a industrialized economy requires a higher consumption of commercial energy, such as oil and electricity. The economy, thus, gets

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Chern carried out an econometric exercise to estimate and analyse the elasticities of 15 less developed countries.

[4] E.f. Schumacher, "Small is Beautiful", Abacus Books, London, 1992, pg. 101.

[5] "Consumption Pattern: The Driving Force of Environmental Stress", A report prepared for the UNCED by IGIDR, Bombay, 1991, pg. 11.

[6] ibid. pg. 12.

transformed from a net consumer of non-commercial energy to a net consumer of commercial energy. During the entire process of development the intensity of oil and electricity rises, but after the economy has developed this intensity gradually declines. The role of commercial energy is very crucial for the process of development.

Along with technological and structural changes, the share of manufacturing and export to GDP rises which causes the demand for commercial energy to go up. Besides this, in order to raise the agricultural productivity and the standard of living of rural masses, the consumption of commercial energy goes up. One of the main commercial forms of energy is electricity.

1.1 Role of Electricity

Electricity, which is a "secondary energy", being produced by primary energy, plays a vital role in the development process. As the economy moves along the traditional path of development, i.e., from primitive agricultural economy, to the development of small, light and heavy industries, and finally to the growing commercial and services sector, electricity requirement grows faster than all other energy forms. In developing countries electricity consumption has a growth rate higher than that of the developed economies. The reasons for such rapid growth in electricity requirement are higher economic growth and population growth rates, the transition from an agrarian to an industrial economy, and supressed demand in rural areas.

In underdeveloped countries industry is made the engine of growth to break the vicious circle of poverty. Through the advancement of the manufacturing sector, the productivity is raised which incrases the level of income and pushes the economy along the path of development. But such a development depends upon the development and efficient performance of the infrastructure, of which power is a major infrastructure.

As the economy grows, the requirement of electricity incrases, to fuel the development and increase productivity of the sectors which develop as a backward linkage effect of the manufacturing sector. In order to increase the agricultural output to cater to the needs of increased demand, agricultural productivity needs to be raised. Productivity may be increased through mechanisation of agriculture, use of fertilisers and high yielding varieties. The fertiliser industries are very power intensive. Mechanisation of agriculture includes use of electrified and diesel pumpsets, with electrified pumpsets gradually replacing diesels pumpsets as the economy grows. Thus, direct and indirect consumption of electricity goes up in agriculture. The importance of electricity increases with development of commercial and services sector, as it is required for vertical transportation and the use of various electrical and electronic appliances. A consequence of industrialization is rapid urbanisation. With urbanisation the use of power increases as it is required for a better urban lifestyle; i.e., from entertainment to public lighting and waterworks, everything requires electricity.

Moreover, most of the developing economies during the initial stages of development become excessively dependent on petroleum products and hence become quite vulnerable to sudden fuel shocks. The failing balance of payments situation, rising current account deficits and extreme vulnerability to oil shocks makes these economies substitute electricity for petroleum products wherever possible. This raises the importance of power further and explains why power intensiveness increases as the economy grows.

A very large proportion of the population, in developing countries, live in rural areas and are very poor. The objective of increasing the income level and standard of living of those rural masses prompts the government to take proactive efforts to introduce various programmes, which require the rural electrification programme to be implemented successfully as a prerequisite. There is a wide range of electricity uses in rural areas. The relative demands from households and producers, however, vary markedly from one area to another. Some areas may use electricity for a wide range of productive purposes, whereas others may use it for little more than domestic and lighting. The growth of agrobased industries is to a great extent dependent on the use of electricity. Moreover, as the economy grows, the income increases take place at a much greater speed in rural areas and modern infrastructure such as transport, telecommunications, education, hospital etc., gradually move into the rural areas thereby raising the potential for electricity consumption in these areas.

Electricity provides with a very efficient and environment friendly form of final energy. Environmental issues are very important from the point of sustainable development.[7] The increasing use of electricity somewhat ameliorates the severe pressure on natural resources and environment caused by excessive use of non-commercial forms of energy in less developed countries. However, the power sector itself being a heavy consumer of coal should attach increased importance to the hydroelectric potential.

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[7] Still some economists believe that developing countries cannot afford the luxury of environmental policies to be imposed. Contrary to this view, environmental policies do need to be implemented in LDC's. Otherwise what good are various policies of development, if that process of development is unsustainable.

In India electricity throughout has played a very vital role in her development process. Ever since independence, India initiated an ambitious industrialization programme, financially and technically aided by many developed countries. Rapid industrialization through energy intensive industries required the development of power sector as an important infrastructure. Gradual economic development over the years with increasing inadequacies of supply of energy resources and worsening foreign exchange situation have increased the use of electricity in the economy.

India adopted planning methods for industrial development. The objective for planning in India was to organise the efficient exploitation of resources, increase production and step up economic activity through industrial development to the maximum possible extent. It also meant, measures to be adopted to raise the standard of living of the people, and bring about equality and justice. Balanced regional development and dispersal of economic activity were thought to be two sides of the same coin. But in order to achieve the objective, development of infrastructure was essential, amongst which power was considered to be one of the main infrastructures.

Under the programmes of the Five-Year Plans, India has established a substantially large industrial sector consisting of small, light and heavy industries. The common feature to all these industries is that they are all quite electricity intensive. Thus, electricity played a very important role in making India reach the present situation and will play an even bigger role to shape the future of the economy. It is essentially because of the rapid industrialization, that demand for electricity in India have increased at a fast pace.

The Electricity Supply Act of 1948, was framed for the creation of the State Electricity Boards to integrate power systems and rationalise power development at the State level. The 1956 Industrial Policy Resolution guaranteed that power development would be exclusively in the public sector.[8] These Acts were formulated and implemented so as to make the power sector perform well, both at the national and state level, and help achieve the objectives of planning.

As development continued with successive plans, India's falling balance of payment situation required policies for the achievement of self reliance. In the areas of food, fertilisers, etc., imports were sought to be reduced through the policy of import substitution and planned investment. It was believed that selective import substitution should be carried out to improve the current account deficit of the economy. However, such policies of import substitution required the development of the power sector, as most of these industries were highly power intensive. Hence, the power sector in pursuance of import substitution grew and electricity requirement grew along with it, considerably over the plan years.

In India, the development of rural electrification has been influence more by economic development than by social benefits. Agricultural development and promotion of village based industries are the two major reasons for the extension of electricity to rural areas in India. However, the initial objectives were aimed at social benefits for the rural masses.

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8. Recently in the face of resource crunch, the government has invited the private sector to participate in electricity generation, supply and distribution. Accordingly, the Indian Electricity Act, 1910 and the Electricity Supply Act, 1948 have been amended.

Whatever the case may be, a consequence of such rural electrification programme nevertheless improved the quality of life in rural areas.

The rural electrification programme was aimed mainly towards the improvement in methods of agricultural production, encourage cottage and small scale industries, and finally to stem migration to the cities. Considerable momentum gathered after the country experienced a series of droughts in the early sixties. The aftermath of drought called upon the urgency in improvement of small scale irrigation to stabilise agricultural production. At about this time the Rural Electrification Corporation was set up as a consequence of the recommendation of Rural Credit Review Committee of RBI.

All these measures had a distinct impact on the use of electricity for productive purposes. Over the plan years an integrated development of agricultural, industrial and domestic use of electricity, including reduction in the wide difference in regional levels of infrastructural development is emphasized. Vigorous efforts in the development of rural electrification are aimed at stimulating the growth and lifestyle of the village economy.

Thus, the nature of development process in India has resulted in high priority being accorded to the development of electric power as an essential infrastructure. It has not only helped in industrialization and achieving self reliance, but also improve the lifestyle of the people, both in rural and urban areas.

Before we discuss the objective of the study, let us briefly outline here the trends in macro economic aggregates and the energy scenario, specially electricity in India.[9]

1.2 Trends in Macroeconomic Aggregates and Energy Scenario in India

India is a densely populated country with a total land area of 329 million hectares (mha), supporting a population of 844 million (m). The demographic trends show that total population as well as the urban population has increased considerably over the last two decades. According to CSO sources, total population registered 785m in 1987, when it was 541m in 1970. The share of urban population increased from 19.9% in 1970 to 25.7% in 1987. Therefore, density of population has increased from 164 persons per square kilometer in 1970 to 239 persons per square kilometer in 1987.

The growth rate in Gross Domestic Product (GDP), remained at around 3.5% per annum (p.a.) between 1950 and 1980, with as low as 2.84% p.a. between 1961 and 1966. It was only in the 80's that the growth rates picked up and was around 5.5% p.a. between 1981 and 1990. This growth was accompanied by a rise in growth of agriculture and per capita consumption, along with a decline in capital output ratio. However, growth rates fell to 4.9% between 1989-90 and 1990-91 and again to nearly 1% between 1990-91 and 1991-92.

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[9] Here we deal with the electricity demand scenario very briefly. A better overview of the trends in electricity demand are provided in chapters 3 to 7, along with the aggregative and sectoral demand analysis and projections.

Inspite of considerable structural shifts, agriculture still figures the predominant sector in the economy with the largest share in the total GDP. However, the share of agriculture in total GDP has come down over the last two decades and has stablilised to 33% as compared to 55% in the early fifties. The manufacturing sector after starting off well in the 1950's and early 1960's slowed down during the 1960's and 1970's. But in the 1980's it has picked up pace once again. The notable feature is that, the share of commercial and other services sector is gradually increasing and has a very high growth rate. This shift in favour of services sector is conducive to employment generation, better efficiency of system and improved quality of life. The improvement in industrial sector is mainly caused by the improvement in infrastructure. Hence, the success or failure of industrial sector rests on the performance of infrastructure.[10]

This structural change and shift in product mix in the economy has an important bearing on the pattern of energy consumption. In pursuance of self reliance the economy emphasized the development of heavy and basic industries, which are all energy intensive. Some energy intensive consumption goods industries also received high priority. With rise in income level and standards of living, the household consumption basket has undergone considerable change - which implies a change in the energy intensity of household consumption, along with a change in energy consumption patterns. The energy consumption for transportation has undergone changes in quantum and pattern, with an acceleration in the development process.

Initially the growth rate in consumption of commercial energy was high at 5.47% p.a. between 1953-54 and 1960-61. But, this growth rate declined over the decade of 1960's and 1970's,

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10. 8th Plan Document, Government of India.

with 4.21% p.a. between 1970-71 and 1980-81. However, it has increased marginally in the decade of 1980's and was 4.52% p.a. between 1980-81 and 1990-91. But the important aspect about consumption of commercial energy is that demand does not reflect the true demand as the consumption is supply constrained. Thus, growth rates reflect actual availability and not the potential demand.

The final use of commercial energy has increased considerably over time because a substantive portion of solid fuel is consumed by the power sector and is only used indirectly as a fuel by non energy sector. This is due to a substantial rise in the demand for electricity over the years. Among the final consumption of commercial energy, consumption of coal has increased from 52.20 million metric tones (MMT) in 1970-71 to 73.74 MMT in 1987-88, petroleum products rose from 14.95 MMT in 1970-71 to 37.40 MMT in 1987-88, natural gas increased from 131 million cubic metres (mm^3) in 1970-71 to 414 mm^3 in 1987-88, and electricity increased from 48.47 TWh in 1970-71 to 159.29 TWh in 1987-88[11] Even though coal consumption has gone up, but in unit calorific value the final use has declined according to Sengupta (1993). The growth rate in consumption of electricity has been maximum to be followed by petroleum products and natural gas.

According to the 8th Plan document percentage share of electricity in total consumption of commercial energy has increased from 6% in 1960-61 to 11.7% in 1980-81 and again to 17.6% in 1990-91. Share of oil and gas has also gone up from 20.9% in 1960-61 to 43.4% in 1990-91. But share of coal has declined. The noted feature is that there has been significant lowering in the elasticity of commercial energy consumption over the period 1953-54 to 1990-91, with respect to GDP. The elasticity

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[11] Sengupta (1993), pg. 8.

of total commercial energy has declined from 1.37 between 1953-54 and 1960-61 to 0.82 between 1980-81 and 1990-91. Even though elasticities for both oil and electricity has declined, still elasticity for electricity is the largest at 1.57 between 1980-81 and 1990-91. This to some extent explains the rapid increase in the requirement of electricity over the last two decades.[12]

Not only has the overall energy consumption pattern undergone changes but even the sectoral consumption of final energy undergone significant changes. This clearly brings out the structural shift in the economy over the years. The share of industry in total final energy consumption has increased considerably from 40.7% in 1960-61 to 57% in 1980-81, although declined to 50.4% in 1990-91. The share of agricultural has increased throughout from 1.8% in 1960-61 to 9% in 1990-91. the share of household sector increased till 1970-71 and declined slightly in 1980-81 but has increased again to 13.8% in 1990-91. However, the share of transport sector has been declining throughout from 44.9% in 1960-61 to 24.5% in 1990-91. The reason for declining share of transport sector could be explained by the replacement of coal in railways by more efficient fuels like diesel and electricity.

There has been a substantial increase in consumption of petroleum products, which has registered a three fold increase between 1970 and 1989. Even though the share of light and middle distillates increased, however, those of heavy distillates have declined. The policy of replacing steam locos caused the rise in relative share of consumption of light and middle distillates. This got aggravated by the excessive dependence on road transport, which has increased considerably over the years. However, in the industrial sector from the 80's deliberate efforts

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[12] 8th Plan Document, Vol. II, pg. 163.

are taken to conserve consumption of petroleum products through use of energy efficient technology and also substitution by electricity wherever possible. Industrial consumption of oil has declined from 28% in 1970 to 10% in 1989. Deliberate policies to increase productivity in agriculture has caused consumption of oil products to increase, with relative shares increasing from 4% in 1970 to 9% in 1989. However, with increasing pace of rural electrification and rising rural income level, consumption of electricity in the agricultural sector is going up fast. In the household sector consumption of petroleum products is declining. With increasing pace of rural electrification, Kerosene for lighting is getting replaced by electricity. Also with increasing standard of living both in rural and urban areas electricity is being used quite extensively in everyday life.

Electricity consumption has been continuously outstripping supply over the years. The consumption rose from 48.47 TWh in 1970 to 193 TWh in 1989, which means it grew at 7.5% p.a. between the same period. The sectoral consumption pattern has undergone considerable changes between 1970-71 and 1990-91. The Table 1.1 below shows how the relative shares of consumption of electricity changed between 1970-71 and 1990-91.

Table 1.1

Sectoral Shares of Electricity Consumption (%)

	1970-71	1975-76	1980-81	1985-86	1990-91
Domestic	8.8	9.7	11.2	14.0	16.8
Commercial	5.9	5.8	5.7	5.9	5.9
Industry	67.6	62.4	58.4	54.5	44.2
Traction	3.2	3.1	2.7	2.5	2.2
Agriculture	10.2	14.5	17.6	19.1	26.4
Others	4.3	4.5	4.4	4.0	4.5

Source: Economic Survey, Government of India, 1993-94.

The relative share of household and agricultural sector in total consumption of electricity has increased from 8.8% and 10.2% respectively to 16.8% and 26.4% between 1970-71 and 1990-91. This could be a consequence of the deliberate policy taken by government for rural electrification. Moreover, deliberate efforts are made to replace diesel pumpsets by electric pumpsets. Again in order to increase production in agriculture multiple cropping intensity has increased which causes utilisation rate of energised pumpsets to go up, thereby increasing the requirement of electricity. Recently, in addition, electricity consumption has also gone up due to increased activity of the rural non-agricultural sector. Further, since electricity is highly subsidised and there is no proper metering for agriculture, so wasteful consumption and pilferages have gone up considerably over the years.

The share of industry in total electricity consumption has declined from 67.6% in 1970-71 to 44.2% in 1990-91, which shows that energy saving techniques are already in use in the industrial sector. The excessive dependence of the transport sector on petroleum products is reflected in their relatively low share in total consumption of electricity. With the contribution of the commercial and services sector in total GDP increasing rapidly, the consumption of electricity in this sector is also growing at a rapid rate since electricity is the main energy consumed in this sector. Even though the relative share of services sector in total consumption of electricity has remained fairly constant, consumption of electricity is growing at a rapid rate.

Thus, it is essentially the household, agricultural, and commercial and services sector which have caused the consumption of electricity to grow rapidly, inspite of declining shares of industry and relatively small share of the transport sector. But still the lion's share in the consumption of electricity goes to the industrial sector.

Sengupta (1993) has worked out sectoral elasticities of electricity consumption with respect to sectoral GDP's and private final consumption expenditure (for household sector), which shows that the elasticities have been quite high, exceeding unity, for all sectors excepting the transport sector. Inspite of proactive efforts taken by the government on railway electrification, the output inelastic transport sector explains the limited scope of oil substitution by power in the transport sector. The elasticity turns out to be the largest for agricultural sector at 5.83 between 1980-81 and 1987-88 to be followed by the household sector at 2.76 between the same period.

The share of total plan outlay to energy sector has been increasing in the successive plans. It has increased to 28.2% of total plan outlay during 7th Plan from 12.4% during the 2nd Plan. The capital intensiveness of various forms of commercial energy is evident from steady increase in the relative shares of expenditure on energy sector in total plan expenditure over the successive plans. Among the various energy forms, the lion's share goes to the power sector, which is most capital intensive and involves long gestation periods. The share of power sector in total plan expenditure increased from 9.7% in 2nd Plan to 17.4% in the 7th Plan.

The increasing power intensity of the country and capital intensiveness of power sector is evident from the increasing share of plan allocation to the power sector over the successive plans; even in the 8th Plan the maximum relative share is allocated to the power sector. With the energy taking 26.62% of total plan outlay, power sector alone takes 18.33% of the total plan expenditure in the 8th Plan.

The average annual growth rates[13] for the consumption of electricity is very high, and with higher GDP growth rates it will be even higher, given the elasticities as highly elastic (refer Table 1.2 below).

The total installed generation capacity at the beginning of the 7th Plan was 42,585 MW of which 14,460 MW was hydro, 26311 MW thermal, 1095 MW was nuclear and 719 MW gas based generation. The details of capacity added during the 7th Plan are given in Table 1.3.

Table 1.2

Growth Rates (Average Annual) for Electricity Consumption

(per cent p.a.)

	1960-61 to 1970-71	1970-71 to 1980-81	1980-81 to 1990-91
Electricity	11.4	6.3	8.9
GDP	3.7	3.1	5.6

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[13] The average annual growth rate is obtained be estimating the regression equation : $\ln y = a + bt$ where $b = \ln(1+r)$, obtained by log transformation of the compound growth rate formula. The reason for carrying out such a transformation is to nullify the influence of choice of initial value of y on the growth rate. The growth rate for y is obtained by taking antilog of b and subtracting 1 from it. If multiplied by 100 we obtain the percentage average annual growth rate of y.

Table 1.3

Additions to Installed Capacity During Seventh Plan (in MW)

	Hydro	Thermal	Nuclear	Windmill	Total
Target	5541	15999	705	-	22245
Achievement	3827	17093	470	11	21401

Source: Eighth Plan Document, Government of India, pg. 187.

During the 7th Plan, the average annual rate of capacity addition was of the order 4280 MW. The total capacity addition during 1990-91 and 1991-92 has been 5803 MW, comprising 4702 MW thermal, 881 MW hydel and 22 MW nuclear capacity. This, however, represents a much lower annual rate of capacity addition than in to the 7th Plan. Recently there has been persistent shortfall of achievements over the targets set by the government in the area of capacity addition. In 1990-91 the shortfall was as much as 36.49%. In 1991-92 we fell short by 20.49% and in 1992-93 it was 20.66%. These regular shortfalls are bound to cost us dearly in future.

The total electricity generation has increased from 61.2 TWh in 1970-71 to 289.4 TWh in 1990-91; in 1980-81 generation was 119.3 TWh. Total electricity generation (utilities) recorded a growth rate of 8.4% at 286.7 TWh during 1991-92 as compared with 7.8% i.e., 264.6 TWh in 1990-91 and 10.8% or 245.4 TWh in 1989-90. But in 1992-93 the growth rate decelerated to 5% mainly because of the decline in hydro generation compared to 1991-92. In fact the contribution of hydel power in total generation fell to 23.2%

during 1992-93 from 25.3% in 1991-92; the share was 27% in 1990-91. The ideal share in hydel-thermal mix is considered good at 40% instead of the present level of about 25%.

The power generation performance in recent years leave much to be desired. The poor performance coupled with resource constraints may trip targets, as it did in the past. Even assuming that revised expectations of additional capacity is achieved, a demand supply gap of about 10% is being forecasted by the end of 8th Plan.[14] However, Tata Energy Research Institute placed the gap at 12.24%.[15] And if industrial and agricultural growth rate picks up and rate of urbanisation continues unabated, this gap could increase further in future.

1.3 Objective and Scope of the Study

The availability of power, being a fundamental infrastructural input, sets an effective constraint on the rate of growth of the economy. Capacities of production remain underutilised, which in turn would have an adverse effect on the overall productivity at the aggregate level, if supply of power is not adequate. Power being non importable, non storable and highly capital intensive, is privileged with a higher relative share of total plan allocation in order to set up enough capacity, so that the energy required to sustain a given pace of development is met. But short run and long run projections of electricity requirements presupposes the decisions regarding plan allocations and growth rates of the economy. Yet another important aspect is that power sector is characterised by long gestation lag of investment, varying between 5 and 15 years. The capital intensity

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[14] The Economic Times, Response Feature, October 5, 1993, pg. 1.

[15] Seminar, The Monthly Symposium, edited by Raj and Romesh Thapar, Issue: 414, February 1994, pg. 12.

and time intensity of capital formation in the power sector, would necessitate the current plant size to take account of the need of the perspective plan over about 15 year horizon. All these together necessitates the long run projections for electricity demands.

In this study we obtain the long run normative demand for electricity, for the given target growth rates of GDP, for the terminal years of the 8th, 9th and 10th Plans respectively. Instead of employing the long run trend approach to forecasting, we have used econometric models based on correlation techniques, for forecasting. The basic rationale underlying such correlation techniques is that the consumption of electricity is linked to several other variables, whose future evolution are being taken as targets to be achieved.

For forecasting we have considered two types of models - aggregative and sectoral. At the aggregative level forecasting is made for the demand for electricity for the economy as a whole. This demand includes demand for utility as well as non-utility. Whereas for the sectoral projections we have considered demand for utilities only. Due to limitations of data it was difficult to choose a common base year for projection. However, for the sake of uniformity we have chosen the common base year of our projections as 1990-91. The target growth rates for causal variables are either taken from official governmental sources or obtained using elasticity factors to those growth rates; and technoeconomic norms are taken from government sources.

For the aggregative analysis we have considered three models - simple expectations model, learning model, and the translog functional form model. In the simple expectation model we tried to incorporate the dynamics of consumption of electricity through the principle of expectation on level of economic activity. It is thus assumed that consumption depends on the expected level of economic activity; where expectation on level of economic activity is related to the per capita consumption of electricity through a linear function. We have also considered a variant of the model, where the expectation is related to the per capita consumption through a log-linear form. The data needed for estimation are on population, per capita consumption and GDP. The consumption data is taken from General Review (CEA) and the population and GDP data are taken from CSO sources. The target growth rates for causal variables are used for projection, after estimation of the model.

The learning model is based on the principle that as consumption continues, knowledge gets accumulated over time which has its impact felt on the consumption at the margin. In this model cumulative GDP is related to cumulative consumption of electricity through a learning function. A variant of the model is also considered where cumulative per capita GDP is related to the cumulative consumption of electricity through the learning function. The data required are on cumulative values which are obtained from the data on GDP, consumption and their respective per capita variables. The data sources remain the same as in the simple expectations model. Target growth rates on causal variables are used to make forecasts.

The translog functional form considered for the projection is obtained from the relation that intensity of consumption of electricity takes the shape of log normal function with respect to per capita GDP, as the economy grows. The variables required are obtained from the data on GDP, consumption of electricity, prices of electricity and oil. The data are obtained from CEA and CSO sources, and India Database. The target growth rates obtained from official sources are used to make forecasts along with the estimates of model.

On the basis of test for accuracy we chose the model with the highest degree of accuracy and used it to make ex ante or future forecasts for the terminal years of target plans.

For the sectoral demand analysis we have considered separate models for household sector, industrial sector, agricultural sector and commercial sector.

For the Household Sector we have considered two models, in which we estimate the demand for electricity in two stages. In the first stage we estimate the total expenditure on all fuels and in the second stage we obtain the expenditure on electricity within the total expenditure on all fuels. Then using our assumption on prices in the terminal years of target plans, we obtain the demand for electricity. The first of the two models we have considered is a very simple regression relationship, where we have related monthly per capita expenditure on fuel and light to the total monthly per capita expenditure, for the first stage of the model. We easily obtain projections for the terminal years using the estimated elasticity and other assumptions on various factors such as urbanisation factor, growth rate of GDP etc. We also make assumptions on population growth rates. Once we have obtained the prognosticated figures for the total expenditure on fuel and light, we use the assumption of the share of expenditure on electricity in total expenditure on fuel and light for the terminal years of the target plans, to obtain expenditure on electricity. This is our second stage of the model. Finally, assumptions on price are used to obtain electricity demand in physical units.

The second model for household sector is more or less the same as that of the first. However, the second model is more advanced than the first model in the sense that we incorporate the poverty ratios in second model and take into consideration the expenditure class distribution, by assuming the distribution to be a log normal distribution. Thus, by assuming the poverty ratios for the terminal years and a poverty line, we make projectins of population distribution of expenditure classes for terminal years of the target plans. Then using estimated elasticities we obtain forecasts for expenditure on fuel and light for the terminal years in the first stage of the model. The second stage of the model is same as that of the first model. We make the same assumptions as the first model, except that we add our assumptions of poverty ratios.

The data used for the analysis of the models are the NSSO data for the three quinquennial rounds, i.e., 27th, 32nd and 38th rounds. For assumptions we have used the 8th Five Year Plan Document, Planning Commission bulletin on Sectoral Energy Demand in India, and data from NSSO rounds. We carry out separate analysis for rural and urban sector. Once we have obtained the projections for the terminal years, we carry out a sensitivity analysis to check the robustness of the results for alternative growth rate scenarios and alternative poverty ratios.

The <u>industrial sector</u> model is slightly more complicated. We have estimated the demand for electricity in two stages. In the first stage we estimate the expenditure on fuel and light by using a translog cost function, taking into consideration substitution possibilities between fuel and non fuel inputs. In the second stage we estimate the expenditure on electricity as a function of expenditure on fuel and light. This we do for the registered sector only. Once we have estimated the model using ASI data, we use the estimates along with the assumptions on various growth rates and elasticity factors to make projections of expenditure on electricity by the registered sector, in the terminal years of the target Plans. Then using our assumption on price ratio we obtain demand for electricity in physical units. Finally, using a proportionality constant based on past data, we obtained the demand by the unregistered sector in the terminal years of the target plans.

In addition to this model we have considered another model and may be viewed as a sensitivity model. In this model we keep the first stage, same as the previous model. In second stage, however, we try to observe how demand for electricity changes if expenditure on electricity in total expenditure on all fuel increases over time i.e., how demand for electricity increases if electricity is substituted for other fuels. We have considered a logistic function for share of expenditure on electricity in total expenditure on all fuels over time. The data for variables are taken from CSO sources and India Database.

The model for the Agricultural Sector is a simple two stage model. In the first stage we obtain estimate for total energy consumption by energised pumpsets (diesel and electrified). The total energy consumption for irrigation purposes is related as function of gross value added in agriculture. In the second stage we incorporate the substitution possibilities between electrified pumpsets and diesel pumpsets by assuming that the energy consumed by electrified pumpsets in total energy consumed for irrigation purposes takes a logistic function over time. Using the estimated model, assumption on growth rates and elasticity factors, we obtain projections for the energy consumption by electrified pumpsets. Then using norms and conversion table we obtain forecasted demand for electricity in physical units.

We have considered another model for the agriculture which takes an indirect approach in estimating the demand for electricity. In this model the first stage also estimates the total energy required for irrigation, but takes an indirect approach in doing so. Here the gross irrigated area is related to gross output and then total energy for irrigation purposes is related to gross irrigated area. However, the second stage of the model remains the same as first model. Then in a similar fashion we make forecasts of demand for electricity.

A conversion table is used to obtain calorific values of energy consumed. The assumptions on technoeconomic norms and other assumptions are used to make projectins of demand for electricity. The data for estimation are taken from Economic Survey and CSO sources.

The model for <u>Commercial Sector</u> is the simplest of all the sectoral models considered. We obtained estimates of elasticity of electricity demand with respect to gross value added in this sector. Then using this estimated elasticity and assumptions on growth rate we obtain the forecast of electricity demand for the terminal years of the target plans. The data for estimation are taken from CEA and CSO sources.

The three successive Plan periods considered for the purpose of projection are:

VIII Plan	1992-93 to 1996-97
IX Plan	1996-97 to 2001-02
X Plan	2001-02 to 2006-07

Projections are made for the terminal years of the above plans.

Before we get involved in the discussion of electricity demand models and projections, let us briefly provide the <u>chapter plans of the study</u>.

In the next chapter we discuss about some methodological issues which arise in modeling demand for any commodity specially for electricity; to be followed by a brief review of literature.

In the subsequent chapter, we discuss the aggregative models of demand for electricity and forecasts made for the terminal years of the target plans.

Chapters IV to VII deal with the various sectoral models of demand for electricity and forecasts made for the terminal years of the target plans.

Finally, in the concluding section we compare our total sectoral projections with aggregative projections and also our sectoral projections with forecasts made by previous studies. This is followed by our comments on needs and measures to improve the present power sector scenario so as to tackle the demand forecasted efficiently.

CHAPTER II

METHODOLOGICAL ISSUES AND LITERATURE SURVEY

Sir George Bernard Shaw once remarked that any reasonable intelligent parrot, provided that he was not tongue tied, could be indoctrinated in economics; he needed only to be taught to say "supply" and "demand". Though an exaggeration, the basic truth underlying this is that as new problems and issues arise periodically, we need to analyse afresh these two important aspects - 'Supply and Demand'. The periodic on slaught of energy crisis have inspired scholars, all over the world, to explore the energy issues and problems of future planning for energy. This has led to a vast treasury of literature accumulated over a very short period. Moreover, due to better availability of data for electricity and the theoretical complications involved in modelling demand for electricity, the literature on demand for electricity is also quite extensive. But before we make a brief review of the literature, it would be appropriate to discuss the methodological issues that arise in empirical research and particularly while modelling demand for electricity.

2.1 Review of Some Methodological Issues

All demand models are based on the same fundamental principle of competitive markets; the demand for energy is no exception in this regard. The main determinants of demand being prices (both own and substitute) and income level. But lots of problems are involved in making systematic use of economic theory to estimate demand functions. First, complications arise because of the use of data based on market observations to test the economic theory or analyse it, which is based on individual behaviour. This complicates interpretation of elasticities. The obvious question that follows and intrigues the mind is that, "do market demands exist?" This raises a conceptual discussion - without going into such a discussion, for the sake of simplicity, we assume that such market demand functions are plausible.

The next issue in demand modelling arises from the fact that energy products are not consumed for their own sake, but in conjunction with energy using equipment for the services provided. The demand for a specific fuel depends on the total demand for services and the choice of fuel using equipment. Thus, a complex correlation exists between price of a specific fuel, the characteristics of stocks of the fuel using equipment and the amount of fuel consumed. The causality of such a relationship exist both way. Another, related issue, in modelling demand for fuels, is that consumers do not immediately respond to price changes. The reason for this is two fold - first, in demand for fuels, durable and costly fuel using equipments are involved, which often needs some time to get replaced, implying expectations to play a big role in the individual decision making process. Second, consumer often develops a habit in consuming the services of such fuel using equipments, which they cannot immediately give up. Whatever the main force in operation, it takes a long time for stocks to get adjusted, to price changes. For the industry, the existing technology and structure may not permit immediate adjustments to price changes. Thus, dynamics of adjustment needs to be introduced in the models. The, interrelationships between fuel demands, capital stocks and time dimension of consumption behaviour are interrelated and interlocking issues. Discussing dynamic processes, another aspect comes to mind - long run elasticities of demand. Long run elasticities may be obtained analysing cross section data and may also be obtained from dynamic models using time series data. But the two long run demand elasticities should not be interpreted the same way - this raises conceptual problems.

A very common problem that arises in the case of demand models is that the theory of demand is defined in terms of individual units consuming homogenous commodities, but the data usually relate to groups of consumers purchasing a category of heterogeneous products for a variety of uses. This brings the aggregation problem to the forefront. While modelling demand for electricity, income and price responsiveness may differ with the variety of electrical appliances put to use and also propensities to consume. But responsiveness is in most cases measured for aggregate consumption. This raises question regarding their credibility and validity as individual household neither have the same array of electrical appliances, nor the same propensity for utilizing them. Such aggregation problems arise in industrial and commercial sectors too. In fact the individual characteristics are even more diverse in industrial and commercial sectors, giving rise to some form of aggregation bias, thereby questioning the credibility of the estimates. The minimum level of disaggregation is by the five major consuming sectors - residential, industrial, agricultural, commercial and transportation. The motivation for consumption is different in these sector. But within sectors also disaggregatin should be resorted to while analysing. But often the paucity of availability of data may not permit such a disaggregated analysis within sectors themselves. The problem of aggregation is the most common and widespread impediment to econometric analysis.

Yet another issue that impairs statistical analysis of demand or supply is the general problem of identification. To quote Schultz (1938),[1] the basic question is whether it is possible to deduce statistically the theoretical demand or supply functions where we know only the observations corresponding to the intersections of unknown demand and supply curves at different points in time or across different classes of consumers. Thus, each such pair of observations of price and quantity are points on both the demand and supply curves. With good reasons to believe that the demand relationship is stable, by shifting supply from one unit of observation to another, on can trace the demand curve. The converse is applicable for the supply curve to be traced. But unless this is the case, the analysis must proceed as if the parameter estimates reflect a hybrid of supply and demand having no economic meaning. Such identification problem arises because there are two or more variables which are causally interdependent and it becomes difficult to isolate exogenous from endogenous variables in a model. At times the exogenous variables are not entirely exogenous, and estimation techniques have to employed which can take care of this. The estimates obtained may have desirable large sample properties but small sample bias remains. Such interdependence among variables, thought to be exogenous, are common in energy modelling. A common identification problem in energy modelling arises from interrelationships between fuel consumption and equipment prices. Consumption of each fuel is dependent on its availability and price. The price and availability of fuel using equipment is determined, partly, by the quantity of equipment demanded; which in turn is dependent upon the quantity of fuels demanded. Unless the supply of equipment is perfectly elastic, an increase in fuel demand will alter the price of equipment, which in turn alter fuel demand.

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[1] Henry Schultz (1938), "The Theory And Measurement of Demand", Chicago, University of Chicago Press; Reproduced from Bohi (1981) pg. 33.

Often government regulations at different times and varying degrees interrupt the normal equilibrating function of prices in a fuel market. Prices may not record equilibrium points on supply and demand curves, making it difficult, and sometimes impossible, to infer from data the true characteristics of unrestricted behavioural relationships. In these cases, models based on equilibrium market conditions are not appropriate. Disequilibirum markets often complicates demand modelling. While analysing demand for a specific energy form, the situation commonly experienced is one of supply constraint, where both price and quantity consumed would not reflect the true demand, since supply is constrained. Through regulations, prices are not allowed to close the demand-supply gap. Such disequilibrium causes prices to move in discrete jumps rather than as market conditions might dictate.

Demand for electricity has some unique features unlike other commodities. While modelling demand for electricity these features create conceptual problems. Problems are encountered in modelling demand for electricity because of the existence of multipart (e.g., fixed and variable charges) and multiblock (e.g., varying prices for different consumption blocks) tariffs, as well as discontinuities in the demand function; distinguishing between short-versus long term, and static versus dynamic adjustments; incorporating the resulting changes in the prices of competing fuels. The presence of multi block tariffs makes utility maximization subject to budget constraint nearly impossible. Actually, the problem is that the consumer, instead of facing a single price, faces a price schedule, where unit price declines in discrete steps as consumption increases. Such price schedules have serious implications for the equilibrium. The decreasing block schedule gives rise to a piece wise kinked budget line. Even though demand functions do exist, they cannot be derived analytically. The demand functions, so obtained, are discontinuous with jumps at the points where equilibrium switches from one segment of the budget constraint to another. The same holds for the Engel curves. A consequence of the non-convexity of the budget constraint is that there might exist a plethora of equilibria. However, consideration of empirical research asks for relaxation of the criticism of non analyticalness of demand functions, otherwise any applied research on electricity demand would be impossible.

Coming to the discussion of empirical research in the presence of such a price schedule, the problem gets transformed to one of specification of the model i.e., what price variables to be included. Any specification error on the part of modelling will give rise to a specification bias; which in turn will question the credibility of the elasticity estimates. According to Houthakker (1951),[2] a marginal price should be included in demand equation. Whereas, Taylor (1977)[3] is of view that besides marginal price, some quantity which measures customer charge and intra-marginal prices, should also be included in the demand function, because individuals will be consuming within different rate blocks. It is difficult to associate an appropriate "average" rate schedule to average consumption. Behaviourally the individuals react to expected prices. Specification of the model is biggest and

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2. H.S. Houthakker, "Some Calculations of Electricity Consumption in Great Britain", Journal of the Royal Statistical Society (A), Vol. 114, Part III, (1951), pg. 351-371.

   According to Houthakker, marginal price is relevant in the demand equation because the consumer achieves equilibrium by equating costs and utility at the margin.

3. L.D. Taylor (1977), "The Demand for Energy: A Survey of Price and Income Elasticities", in W.D. Nordhans (ed.), International Studies of the Demand for Energy, Amsterdam, North-Holland.

gravest of all problems that the empirical research faces. Ideally both average and marginal prices should be incorporated in the model. But paucity of data often does not permit so. This imposes a specification error in the model.

The fact that demand for electricity is essentially a demand from the services of electricity using appliances, requires a distinction to be made between the short run and the long run, as most of these electrical appliances are durable. Therefore, short run demand for electricity can be seen as arising from the choice of a short run utilization rate of the existing capital stock, while long run demand is tantamount to the demand for capital stock itself. Thus, capital stocks need to be considered explicitly. While modelling demand for energy, one needs to consider fuel substitutes explicitly. Fuels often have specific uses and may not act as perfect substitutes. Thus, inclusion of these substitutes may yield cross price elasticities whose credibility as substitutes are questioned. Where the substitutes themselves have a price schedule, additional problems may be invited while modelling demand for electricity.

These issues pose a challenge to the scholars, interested in empirical research. This has inspired them to deal with the above issues and model demand for energy, in particular electricity. But no single study could account for all the issues in the same model. Without going into the details of these studies, we propose to carry out a survey, in the next section, of the various model based analyses of the demand for electricity. Then we survey a few studies undertaken at the governmental or official level in India to make long range demand forecasting of energy. But before we do so, let us categorise, under broad subdivisions, the type of models used to analyse demand for electricity and other energy forms in various studies.

Models can be categorised as - reduced form models and structural models. The reduced form models estimate fuel consumption directly and incorporates the interfuel substitution, capital stock adjustments along with elements that affect rate of utilization of existing stocks. Reduced form models are quite simple to understand and estimate. But it has its own drawbacks also - first often data for equipment prices and other capital stock characteristics are not available. Second, it does not specify the adjustment process of the stocks. However, models need to be specified in such a way that short run and long run distinction is explicitly considered. Three groups of reduced form models are distinguished - static consumption models, dynamic consumption models and fuel share models.

The structural demand models attempt to estimate the separate components that combine to derive the reduced form models. Common procedure is to estimate the changes in utilization rate with a short run consumption model. The long run adjustments to fuel price changes are then separately estimated from a durable goods demand model. Structural models, compared to reduced form models, are much superior as they separate the dynamic elements of demand and permit identification of sources of consumption behaviour.[4] But from practical convenience, the availability of data and simplicity reduced form models are more popular.

2.2 Review of Literature

In this section we present a brief review of the literature on various model based studies of demand for electricity. As reviewed in the preceding section, modelling demand for electricity is hindered by a number of methodological

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[4] D.R. Bohi, "Analyzing Demand Behaviour: A Study of Energy Elasticities", The Johns Hopkins University Press, Baltimore, 1981.

issues. It is this challenge, posed by these issues, that gave birth to the vast treasury of such studies. The studies arrived at different results mainly because of diverse approaches taken to model demand for electricity.

Way back in 1951, Houthakker[5] studied the demand for electricity for residential sector in United Kingdom. He used cross section data on provincial towns for 1937 to 1938. He considered price of electricity, which is in some sense pioneering as he considered a two part tariff. He also had as determinants an average income per household facing a domestic two part tariff, the marginal price of gas on domestic tariffs, and finally be included the average holdings of heavy domestic equipment per customer in his model, to analyse the average annual electricity consumption per consumer. He tried to overcome the problem of identification by introducing lags to the price variables. He thus considered two period lags on price of electricity and gas. The two most interesting features of his study are his explicit consideration of two part tariff[6] and the inclusion of average holdings of heavy domestic equipment as a proxy for prices of complementary goods. He considered the model both in linear and double log form and obtained elastic income elasticity and inelastic own and cross price elasticities.

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[5] H.S. Houthakker, "Some Calculations of Electricity Consumption in Great Britain", Journal of the Royal Statistical Society (A), Vol. 114, Part III, (1951), pg. 351-371.

According to Houthakker, marginal price is relevant in the demand equation because the consumer achieves equilibrium by equating costs and utility at the margin.

[6] A two part tariff consists of a fixed charge that is independent of amount of electricity considered, i.e., a form of reservation charge, and a running charge that is proportional to the consumption.

However, Houthakker was silent as to whether his elasticities where short run or long run. The inclusion of heavy electrical equipments as determinants means that income and price responsiveness is subject to holding this variable fixed. So in that sense the elasticities were short run.

Relatively few studies have attempted to estimate the influence of energy prices on appliance stocks, mainly because of paucity of data. One such study was carried out by Fisher and Kaysen (1962).[7] Such data problems that these models face is clearly evident from their study. They tried to construct aggregate indexes of appliance stocks by State in order to estimate the ratio of the current to last periods stock. They analysed both residential demand and industrial demand for electricity in United States. They also explicitly distinguished between short run and long run. In their structural equation framework, short run elasticity is identified with choice of utilization rate, while long run responsiveness is associated to choice of the size of the capital goods.

Using a time series of cross section data, they defined their model as the total metered use of electricity by all households in the community during a period to be equal to the aggregate product of stock of "white goods" (i.e., stock of electricity consuming capital goods) and average intensity of use of that white good during the same period. Average intensity depended on price of electricity and community per capita personal income. Through some approximations they arrived at the final equation to be estimated, with consumption of electricity depending on price, income and average stock of white good. The equation is in double log form. Given the amount of stock of white

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[7] F.M. Fisher and C. Kaysen (1962), "A Study in Econometrics: The Demand for Electricity in United States", North-Holland, Amsterdam.

good they obtain estimates of price and income responsiveness. Being unsatisfied with their measure of white good, they reformulated the model to make the white good grow at an exponential rate. By taking first difference of model, then, they made the final equation to be estimated free of white good measure, but dependent on the exponential rate which became the constant term in the final equation to be estimated. It is this intercept term which captured the influence of white goods. For the price variable was taken as an implicit average price, but they considered real price and income variables.

For the long run model they rejected stock adjustment kind of dynamic models on the basis that actual stock that matters is zero. Instead they proposed a model, where the ratio of stocks of a particular white good of current period to that of previous period, as a measure of growth of stock was to be explained. They explained the ratio as a proportionality function of ratio of permanent income of current to previous period, current income, price of white good involved, price of gas using appliance, price of electricity, price of gas, ratio of proportion of houses wired in this to previous period, total population, proportion of new marriages. They estimated the log transformation to this functional relationship and was estimated for five classes of white goods separately using time series data. Because of large numbers of explanatory variables involved they pooled the data using time series of group cross sections, where grouping was done as in their short run analysis. According to their findings, price of electricity have little effect on prices of appliances; if saturation of appliance stocks is not reached them economic variables have strong influence but otherwise demographic variables play a bigger role; and income, demographic factors and wired houses have strong influence on the ratio of white goods.

A major problem with the Fisher-Kaysen model is an appropriate measure of appliance stocks. Even with accurate sales figures for each period, it is difficult to construct an index that appropriately reflects changes in the age or quality of appliance stock. Halvorsen argued that the poor results in Fisher and Kaysen's model were due to specification problem of the model. A number of studies were initiated by the debate of what price to include in demand models for electricity. Some of the scholars suggested an average price specification in the model. Among the average price specifications, the most common is an ex post measure of average revenue paid by group of customers, obtained by dividing total expenditures by total quantity consumed.

Halvorsen (1975)[8] suggested an instrumental variable estimation technique. He did not consider price to be entirely exogenous. The price function was estimated using average price data associated with corresponding consumption levels. Halvorsen demonstrated that this procedure will not bias price elasticities of demand, if linear representation is valid (log linear price function), because the use of average price data rather than marginal prices only affects the intercept term and intercept term does not affect the price elasticity coefficient.

He considered the general form of residential demand - average consumption of electric energy per consumer as a proportional function of marginal price of electricity and vector of all other determinants. Since electric energy consumers face a price schedule so, to avoid identification, he also had a price equation where marginal price was a proportional function of average annual sales, cost of labour, percentage of generation produced by publicly owned utilities, cost of fuel per kilowalt

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[8] Robert, Halvorsen, "Residential Demand for Electric Energy", Review of Economics and Statistics, Vol. 57, 1975, pg. 12-18.

hours of generation, percentage of population living in rural areas, ratio of total industrial sales to total residential sales and time. Thus he had a price equation and a quantity equation (both in log linear form). However, data for marginal price is not easily available. So the indirect method used was to derive the elasticities of demand for the model incorporating marginal price from demand and price equations estimated using data for average prices. He therefore obtained a relationship between marginal price and average price. Estimated marginal prices (estimated using average prices) were thus used to derive demand elasticities. Because of simultaneous kind of framework of the model, there will be feedbacks in the model, with indirect effects on demand affecting elasticities. Thus elasticities calculated from the structural demand equation were called direct elasticities and elasticities obtained from the reduced form models were referred to as total elasticities.

All equations were estimated with cross section data for States for the years 1961 to 1969. Although the equations were static, Halvorsen believed that, they should provide consistent estimates of the long run elasticities of demand because cross sectional differences in the values of the dependent and explanatory variables had been very stable for a long period of time. The dynamic equations were estimated by constructing weighted averages of the current and lagged values of explanatory variables to reflect different assumptions concerning the form of lag structure. He estimated long run direct price elasticity to be elastic (at least unity in absolute value). The estimated direct income elasticities were obtained as less than unity. He also showed that cross price elasticities with respect to gas prices was surprisingly very small. His results, thus, indicate that the long run own price elasticity of demand is equal to at least unity, contrary to the common assumption that demand is not responsive to price.

However, Halvorsen's argument does not resolve the issue of whether more than one characteristic of the rate schedule should be included. Each measure, by itself, conveys only part of the information contained in the rate schedule. In addition, his price equation averages across different blocks on the same rate schedule. The fitted price equation will approximate the characteristics of a family of rate schedules, and may have a slope which is flatter or steeper than any of the individual rate schedules used to obtain it. Which means that the aggregate schedule may convey a price response quite different from that reflected by any of the individual components.

Houthakker and Taylor (1970)[9] estimated an equation for personal consumption expenditure for electricity, using time series data. They based their model on the State Adjustment model of consumption. Their model consisted of two equations - a behavioural relationship that specifies consumption as a function of stocks, income and relative prices and a relationship that expresses the rate of change in stocks to consumption and depreciation which is assumed to be an exponential rate. In the model stocks refer not only to physical inventories but also to psychological quantities, in particular to the accumulated force of habit. If stocks refer to physical inventories of durable goods then it affects consumption negatively contrary to the case when stocks refer to psychological habit formation. Combining both the behavioural relationship and the rate of change of stock relationship we obtain the estimating form of the model, after carrying out a finite approximation. Thus, the final equation does not contain stocks but lagged value of per capita consumption as an explanatory variable.

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[9] H.S. Houthakker and L.D. Taylor, "Consumer Demand in the United States", Cambridge University Press, Cambridge, 2nd ed., 1970.

The short run elasticities for both price and income are very low but the long run elasticities for both are quite substantial (exceeding unity in absolute value). Thus they have shown that elasticities are small when only utilization rates are allowed to vary. Moreover, they show that if stocks refer to accumulated force of habit from past consumption, then the services of electricity consuming appliances are subject to strong habit formation. An application of time series data assumes that the structure of the model applies without change over the entire sample period.

However the above procedure to some extent is ad hoc with no underlying theory of adjustment to justify the declining geometric pattern. The largest response to any price change need not occur in the first period, nor decline geometrically thereafter. Moreover, when the model is expanded to include additional explanatory variables - such as competing fuel prices, income and non-economic variables - the same lag coefficient is used to obtain all long run parameters. this is a slightly absurd proposition in the presence of too many explanatory variables. Another aspect of this model that encounters frequent criticism is that consumers react to price changes by continuously adjusting actual purchases of durable goods to some desired stock over time. However, the nature of acquisition process is often one of discrete consumer choices, where the consumer either has or does not have a given appliance.

Baxter and Rees (1968)[10] focuses entirely on industrial demand for electricity. They rejected the aggregate energy approach, explicitly, because of the requirement to reduce

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[10] R. E. Baxter and R. Rees, "Analysis of the Industrial Demand for Electricity", Economic Journal, Vol. 78, 1968 (June), pgs. 277-298.

different fuels to a common denominator, which ignores the fact that separate fuels are not equally efficient converters into final usable energy. Thus, they used a two stage procedure to estimate their demand for electricity for industrial sector. In the first stage output was related to capital, labour and energy as inputs via the conventional production function. Once derived demand for total energy input is determined, this is then allocated among the various fuels according to their relative prices. This is the second stage of the analysis.

They used three models to estimate demand for electricity. The first model was a general Cobb Douglas production function kind of model. In the second model they emphasized the effect of changes in fuel technology by making electric power consumption related to output and a Surrogate for technology in place of input prices. Finally, in the third model they constructed a proportional relationship between changes in output and electricity consumption and the deviations from this relationship are induced by changes in relative prices and changes in labour and capital intensity. They pooled the data for industry groups and quarterly observations over the period 1954 to 1964., and used dummy variables to account for seasonal effects. The first and third model was log linear and second model was linear in functional form.

Wilson (1971)[11] estimated average consumption per household using cross section data for 1966, adding measures of income, average number of rooms per household and number of degree days. Amongst all the variables that he considered only coefficients of average price of electricity and natural gas are significantly different from zero. He used a static model to

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[11] J.W. Wilson, "Residential Demand for Electricity", Quarterly Review of Economics and Business, Vol. II, No. 1, (Spring 1971), pgs. 7-22.

estimate the elasticities. He also analysed the demand for six different categories of household appliances. For this analysis the year of reference was 1960. For both the models he considered two alternative measures of electricity price - the average price paid per Kwh and typical electricity bills for 500 kwhs per month. However, because of interdependence between electricity consumption and average prices, he reports the results for the second alternative only. Since cross sectional data was employed, he reported the elasticities as long run elasticities. Like Halvorsen (he too found a significant relationship between price of electricity and electricity consumption. Wilson in his other model used as dependent variable the percentage of households owning at least one unit of the appliance in question.

K.P. Anderson carried out various model based studies on demand for electricity. In 1971[12], he studied the industrial energy demand and was concerned more with the development of methodology rather than the obtainment of results. The methodology is more or less on the same lines as that of Fisher and Kaysen but the focus is on the total producers demand for energy and not just electric power. Allowance is made for quality discounts in the purchase of energy inputs, effect of supply on demand, competing and related energy inputs and finally, the effects of variation in the composition of the industry. He attempts to take account of the locational effects by estimating energy consumption by state adjusted for regional mix. The dependent variable is calculated as electricity consumption per unit of value added (by State) divided by national average electricity consumption weighted by the proportion of total value added attributed to each State.

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[12] Kent P. Anderson, "Toward Economic Estimation of Industrial Energy Demand: An Experimental Application to Primary Metals Industry", Report R-719-NSF (Santa Monica, California, Rand Corporation), 1971. Reference: L.D. Taylor (1975) and D.R. Bohi (1981).

Compared to Fisher and Kaysen's estimates, their price elasticity of demand for electricity is negative, substantial and highly significant.

In Anderson's 1973[13] study of residential demand for electricity he used cross sectional data from the census of housing for 1960 and 1970. He uses a static model. The motivation behind his study are - first, the interdependencies between household demand for one type of energy and that for competing energy sources are not adequately considered in most of the models; secondly, even if competing fuel prices are considered, only a simple competing fuel price is considered; thirdly, price responses are not clear, whether they represent interfuel substitution, role of alternations in utilization rate or the size, efficiency and features of new and renovated equipment. He analyses two different classes of models - first predicting stocks of energy using equipment and second predicting energy consumption. He expressed the model as a double logarithmic form with prices (own and competing fuels) and demographic quantities as determinants. For the second model he uses consumption of electricity per household as the dependent variable.

His model for predicting stocks of energy consuming equipment is much less conventional, and involves estimation of equations of the double logarithmic form. Thus he considers fraction of total installation that consume energy type i as proportional to prices, income and other demographic variables. He then takes the ratio of the share that consume energy type i to that which consume energy type j ($i \neq j$) and carries out log transformation to the relationship. The equations for a given j

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13. K.P. Anderson, "Residential Energy Use: An Econometric Analysis", Report R-1296-NSF (Santa Monica, California, Rand Corporation), 1973. Reference: L.D. Taylor (1975) and D.R. Bohi (1981).

and for each i are estimated jointly as a system of equations, with appropriate restrictions imposed on the intercept term of each equation i.e., they should all be same in all the equations of the system.

The energy consumption model is estimated for both 1960 and 1970 data sets but the stock equations is restricted to the 1970 data set only. With regard to the stock equations, Anderson observes that the price of energy, specially the price of electricity, and price of gas, are the strongest predictors. As demand for electricity in the long run is tantamount to the demand for energy consuming equipment, Anderson uses his stock equations to obtain the long run price elasticities of demand.

Anderson also estimates a dynamic version of the model in his attempt in 1974[14], to avoid the problem of measuring existing appliance stocks. He considered the share of new appliances that use a specific fuel which he called the "new" or "non-captive" demand. The share of new purchases of appliance j using fuel i is posited as a function of relative fuel and appliance prices, income and number of other variables reflecting demographic and residence characteristics. As in 1973 study, the estimating equations are normalised taking ratio of two fuel shares, and were called appliance saturation equations. Choice of denominator share does not matter even though statistical results do differ and depend on choice. Anderson arrived at appliance saturation demand elasticities by taking a weighted average of significant price coefficients of each appliance. Fuel consumption elasticities are obtained by adding utilization rate price

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14. K.P. Anderson, "The Price Elasticity of Residential Energy Use", Report R-518--NSF (Santa Monica, California, Rand Corporation), 1974. Reference: L.D. Taylor (1975) and D.R. Boh8 (1991).

elasticities to the saturation elasticities. The utilization rate price elasticities are obtained from a standard reduced form model of consumption for each fuel.

Mount, Chapman and Tyrrell (1973)[15] in their study analysed both short run and long run demand for electricity for residential, industrial and commercial sectors. They considered a model in reciprocal form which took account of elasticities being variable with the price level. They considered a lagged adjustment model with the one period lagged endogenous variable entering as an explanatory variable among other variables such as reciprocal of price and income as an independent variable. The lagged variables presence as an explanatory variable implies Koyck type of adjustment model. They also considered dummy or shift variables to take account of seasonal influence on consumption. They used pooled cross section time series data and used both ordinary least square and instrumental variable estimation procedure but failed to mention the instrument used for lagged endogenous variable. They observed that long run price elasticity for electricity demand is generally elastic for all sectors and becomes increasingly elastic as price rises. But for income elasticity the case is exactly opposite. They also considered a traditional log linear version of the model, in which they did not consider the inverse as variables and used ordinary least squares to estimate the model.

Houthakker, Verleger and Sheehan (1974)[16] used a flow

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15. T.D. Mount, L.D. Chapman and T,J. Tyrrell , "Electricity Demand in the United States: A Econometric Analysis", Oak Ridge National Laboratory (ORNL-NSF-49), Oak Ridge, June 1973. Reference: D.R. Bohi (1981).

16. H.S. Houthakker, P.K. Verleger and D.P. Sheehan (1974), "Dynamic Demand Analysis for Gasolene and Residential Electricity", American Journal of Agricultural Economics, Vol. 56, No. 2, pgs. 412-418.

adjustment model, very similar to the Houthakker and Taylor's State adjustment model. They analysed the residential demand for electricity using a time series and cross section sample of annual aggregates. They employed a logarithmic flow adjustment model, in which the ratio of demand for the current period to demand for last period is proportional to the ratio of the desired demand for this period to the actual demand for last period. Logarithmic transformation is carried out to this proportional relationship. They ensured that desired demand has a proportional relationship with prices and income. So after carrying out the necessary substitution, the final equation to be estimated is arrived at. Both short run and long run elasticities were arrived at after using the estimates of the model. They considered per capita consumption of electricity and per capita income along with marginal price of electricity. By considering different marginal rates the main difference in their results was observed in the long run elasticities.

Baughman and Joskow (1975)[17] used a fuel shares model to estimate demand for electricity. The procedure involves two stage model where in the first stage total energy consumption by the sector is estimated, to be followed by the second stage. In the second stage, fuel shares defined as ratios of individual fuels to total energy consumption by the sector are related in a functional form with the intention to analyse the interfuel substitution. The fuel shares are related to relative fuel prices in a function form.

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17. M. Baughman and P. Joskow (1975), "Energy Consumption and Fuel Choice by Residential and Commercial Consumers in United States", Report MIT-EL-75-024 (Cambridge, Mass, Massachusetts Institute of Technology Energy Laboratory). Reference: D.R. Bohi (1981).

The problem with this model is that it takes the relative prices as entirely exogenous and also the case that total demand for energy is determined independently of individual fuel shares. There is also an aggregation problem involved in total fuel represented in a single unit of measurement. This model additionally suffers from the aspect that the fuel shares need not sum to unity, a shortcoming that arises from the measurement of fuel shares in logarithms. Baughman and Joskow used an instrumental variable estimation procedure, where lagged dependent variable is estimated from the other exogenous variables in the system and substituted for actual values in the consumption equation. They considered a relatively small sample period (1969-72). They obtained an elastic long run price elasticity. Both fuel choice and total energy consumption was observed to be price responsive; but only total energy consumption was income responsive according to this model.

Another sophisticated model for residential demand analysis of electricity was given by Mcfadden, Puig and Krishner (1977).[18] They used the conditional logit model to capture discrete consumer choice between the fuels. This model is however, not the first of its kind to use logit model - Baughman and Joskow (1975) makes use of multinominal logit model to capture discrete choices. A two stage model was formulated where short run elasticities were obtained from the appliance utilization model which is a static reduced form consumption model. In the second stage the appliance saturation equation estimate the share of household owning a given appliance portfolio where determinants of ownership include price, income and other variables. The long run elasticities are given by summation of utilization rate elasticity

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[18] D. Mcfadden, C Puig and D. Krishner (1977), "Determinants of Long Run Demand for Electricity", in American Statistical Association, 1977 Proceedings of the Business and Economic Statistics Section (Part 2), pgs. 109-117. Reference: D.R. Bohi (1981).

and saturation elasticity. They used marginal prices and obtained price elasticities below unity. Moreover, this model gives elasticities that vary with appliance stocks.

Chern (1987)[19] in a study concerning energy demand analysis in Taiwan developed a model following Baughman and Joskow (1975). Basically, he also assumed that there exists a two stage decision making process. First, the consumer decides on the total amount of energy services required to satisfy a given level of utility or for producing a given amount of goods and services. Second the consumer chooses among alternative energy forms such as electiricty or other fuels to produce the desired amount of energy services. So the model consists of an aggregate energy demand equation and a set of fuel choice equations.

For the first stage a traditional double logarithmic static or dynamic reduced form is used and for the second stage the model is based on conditional logit model to yield a set of equations based on discrete fuel choice. Here the dependent variable is the logarithmic ratio of market shares of fuels. In this fuel split equations, dynamics of adjustment is incorporated with inclusion of lagged dependent variable as an explnatory variable. Some parameteric restrictions are imposed to increase the theoretical consistency of the model. He was aware of the drawback of the model, i.e., the irrelevance of the third alternative; which refers to the fact that other prices do not appear in the fuel split equations. However, he failed to overcome this because of multicollinearity in a more generalised model. He followed Baughman and Joskow to obtain market share elasticities. Chern,

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[19] Chern, W.S. "An Econometric Analysis of Sectoral Energy Demand in Taiwan", in R.K. Pachauri (ed.), Global Energy Interactions, Allied Publishers Pvt. Ltd., New Delhi, 1987, pgs. 121-141.

used a time series data between 1956-1979 for 12 sectors. The estimation procedure used for second stage is Zellner's Seemingly Unrelated Regression estimation procedure.

Such conditional logit models, inspite of its limitations are quite sophisticated econometric tools for demand analysis and yield market share elasticities for both short run and long run quite easily. But the models which has received enormous popularity amongst the scholars, seeking to analyse the demand for energy, are the flexible functional form models. Most of the models based on economic theory, for the demand analysis impose a plethora of restrictions on the elasticities of demand. It is often the case that their existence is presumed by the model right from the start rather than a result of the empirical analysis. The flexible functional form imposes fewer restrictions on underlying utility functions or production functions as part of the maintained hypothesis. The most common flexible function form used in energy demand analysis is the translog function developed by Christensen, Jorgenson and Lau (1973, 1975).[20] "For utility based consumer analysis, this approach specifies a quadratic logarithmic approximation of utility functions that allows expenditure shares to vary with total expenditures and where substitution patterns among pairs of commodities are not constant and equal".[21]

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[20] L.R. Christensen, B. Jorgenson and L. Lau (1973), "Transcendental Logarithmic Production Frontiers", The American Economic Review, Vol. 51, No. 1, pgs. 28-45.

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[21] D.R. Bohi (1981).

A production frontier subject to second order Taylor's expansion specifies the translog form on the production side - also called translog production frontier. This translog form permits more flexible patterns of substitution than models giving rise to constant elasticities of substitution. The most interesting feature of this form is that they can be used along with the duality theory to yield derived demand by consumers and also derived input demand by producers. Because of the application of the duality theory, translog cost functions have also become quite popular on the production side. Most of the translog form models applied to energy demand have concentrated on the production sectors and very few have been applied to the household sector.

Pindyck (1979) have used translog utility function to analyse energy demand for the household sector. He used cross country data to obtain substitution elasticities, for fuels. By assuming separable utility function, he isolated the energy group and could thereby analyse the substitution possibilities among the various energy sources. As we are not really interested in a comparative study, we will not go into the details of the results.

Most of the translog models are employed in static form in order to avoid internal inconsistencies which arise from the addition of lag adjustment process. The most crucial assumption is that, a local approximation has to be considered to the production function (utility function) to arrive at the translog function. In that sense the global validity of the model is questioned. For the duality theory to hold the translog form requires some restrictions to be satisfied, which if rejected, rejects the model altogether. However, inspite of limitations the most usefulness of this functional form is that, on the production side, demand for energy inputs can be analysed along with demand for other forms of inputs. In fact application of translog function on the production side led to the much debated issue of capital energy substitution. One such study was carried out by Field and Grebenstein (1980).[22]

Application of translog functions on production side, made it possible to tackle a plethora of interesting issues - non energy - energy substitution, whether scale economies exist, interfuel substitution possibility, structure of the manufacturing sector, impact of technology on the production process and many others related to production process. The literature in this area is quite extensive, but to name just a few important studies are those by Berndt and Wood (1975), Humphrey and Moroney (1975), Griffin and Gregory (1976), Christensen and Greene (1976), Halvorsen (1977), Williams and Laumas (1981), McRae (1981).[23] These studies however arrived at different results for substitution between energy and non-energy inputs. The difference, however, mainly arose from the type of data used (cross section or time series) and also from the choice of variables. Demand for electricity in these models were treated as derived demand for one of the energy sources, by assuming production function to be separable in energy inputs and using a translog cost function for energy with relative fuel prices as determinants.

Apte (1983-84), Murty (1986) and Lynk (1983-84) used translog model to capture the interfuel substitution in Indian manufacturing sector. Lynk further used the model to analyse the long run constraints to industrial development in India. All used an energy submodel, by assuming separable energy inputs to analyse specific fuel demands and interfuel substitution possibilities. Demand for electricity worked out from the sub model for energy.

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22. B.C. Field and C. Grebenstern, "Capital Energy Substitution in U.S. Manufacturing", Review of Economics and Statistics, Vol. 62, 1980, pg. 207-212.

23. See bibliography.

Jyoti Parikh while engaged in a project of the International Institute of Applied Systems Analysis (IIASA) developed the SIMCRED model (simulation model based on cross country regression for energy demand) to estimate commercial, non-commercial and electrical energy demand. She used cross country data (both developing and developed countries) to estimate the regressions. The inclusion of developed countries in the data would help determine the future of developing countries, if they are to develop over time. The estimates are then used to estimate urban and rural energy demand. The distinction between urban and rural is maintained, as consumption and income patterns are different in these two sectors. The estimates of the regression are then used to simulate the future forecasting of energy demands. In this model, share of agricultural GNP to total GNP is determined by relationship of GNP to rural-urban population and per capita GNP. The share of non-agricultural GNP in total GNP, consumption per capita determines demand for commercial energy. The demand for non-commercial energy is determined by the relationship between rural population and GNP per capita. Finally, demand for electrical energy is determined by the relationship between urban population and GNP per capita. The four submodels are estimated by multiple regression using cross country data. Technological changes are not explicitly incorporated although structural changes are incorporated through cross country data. The model is quite simple, with simple formulations and the computerized simulation technique is very useful.

Another model based study of energy sector in India was carried out by Majumdar and Parikh (1993). They pointed out that if the energy demand is forecasted without proper linkages with other sectors of the economy, then there is no guarantee that investment and imports will be available to meet the needs of the energy sector. Thus, according to the current practices the energy demand is estimated at the ministerial level and production targets for various energy are fixed, which often require unrealistically high investment and imports. This happens because such linkages with other sectors are not taken into consideration. In order to explicitly consider such linkages they proposed a simulation model, "SIMA"[24] which comprehends the behaviour of the energy system of India and its inter-dependence on the macro economic variables. "The model generates macro economic growth scenarios and energy demand scenarios simultaneously, so that the feedback from the energy sector to the economy is accounted for in an approximate measure". The model operates in two stages - generation of macroeconomic growth scenarios and generation of energy demand scenario consistent with the macroeconomic frame work. After working this out, if necessary, revision of macroeconomic frame work and fresh iterations are carried out. This is long term projection model, combining analysis of past with the assessment of the future. The model's sensitivity is worked out for two relevant scenarios i.e., higher oil prices and higher export growth rate (HOP and HER). As far as demand for electrical energy is concerned, it is related to number of villages electrified and per capita GDP.The concept of integrating the macro sector to the energy sector is no doubt a wise proposition, as the energy sector, being a highly capital intensive sector, will be adversely affecting the economy unless appropriate resources are made available.

2.3 Review of Studies Undertaken at the Official Level in India

Even prior to the first oil shock, Government of India's concern for an integrated approach to energy planning was recognized. Several studies have been undertaken over the years to

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[24] Simulation of Macroeconomic Model.

analyze the present and future energy demand and supply situations. During the early 1960's the Energy Survey of India Committee (ESIC)(1965) was assigned the task of furnishing the government with an exhaustive report of energy sector and development planning in energy upto 1981. Rural energy requirement was given special attention. Even though this Committee clearly brought out the problems of energy sector, it failed to provide an adequate basis for formulation of a national fuel policy.

The Fuel Policy Committee (FPC), set up in 1970, was assigned to provide a blue print of the national fuel policy for a horizon of fifteen years. The underlying assumption of their study was that future energy demand would depend on the economic development process. They further assumed that the rate of growth of the economy's national product beyond the fifth Plan would be at the rate of 6% per annum. This study used regression techniques and end use technique to analyse energy demand and make future projections. Along with the use of historical data, some norms and assumptions were made to take account of technological and structural changes in the economy, to analyse the demand. Discussion on various fuel sources was made with reference to the "normal case" level of demand. The normal case essentially refers to the Business As Usual (BAU) case. The policy recommendations of the Committee were greatly influenced by the 1973 fuel shock. However, the study was biased towards supply side compared to the sectoral demand analysis.

Various approaches are taken to analyse energy demand. Some of these approaches are based on an extrapotation of past trends. While others are based on econometric methods which assume a statistical relationship between energy demand and certain explanatory variables. Then there are others which employ input-output techniques to analyse energy demand. We consider those studies as "model based", which explicitly take into consideration economy-energy interaction. Thus, model is a series of interrelationship expressed mathematically so that the impact of a change in any one or more of the factors on the total system can be spelt out and easily predicted.

The Government of India set up a Working Group on Energy Policy (WGEP) in 1977 to estimate the prospective energy demand and assess the demand over the next fifteen years, survey present and prospective energy supplies and recommend policy measures over the next fifteen years. It was also given the responsibility of suggesting possible conservation policies. The group submitted its report in 1979. After serious considerations the group extended the period of study to 200-01 A.D. Considering the unpredictability of the various factors affecting energy sector the group attempted to project Reference Level Forecast (RLF) of energy demand which referred to the case where no deliberate measures are initiated to correct such growth and has also suggested Optimal Level Forecast (OLF) which considered measures that might help in moderating the demand to a more desirable level. In the OLF possibility of inter fuel substitution, specially oil, was explicitly considered within the framework of existing technology. However, their impact on the future energy scene has not been quantified. The group estimated regression models correlating energy consumption with activity levels of the economy as a whole and on the sectoral level also. It was found that linear and exponential models were statistically significant. GDP at factor cost and value added in the sectors were taken as causal variables in the models. Besides using regression techniques they also employed enduse methods for forecasting (which assumed certain norms for consumer categories). The assumptions made in this study regarding the macroaggregates and other variables and parameters were not based on projections made by any government bodies. They were simply adopted on the basis of beliefs of energy problems and the direction of energy policies. For the sectoral analysis the sectors considered were - household, agriculture, industries, transport and others. The average annual growth rate of GDP was taken as 5.5% till 1987-1988 and 6% thereafter. The study thus considered a higher growth rate in future, in order to analyse if energy sector imposes a problem in achieving that growth rate. The WGEP study was the first major study which illuminated the two central issues in energy planing - internal substitution and energy conservation. The basic approach taken by WGEP in their analysis was similar to that of FPC.

As a Consultant in the Planning Commission in 1979-80, J.K. Parikh formulated a detailed econometric simultation model to forecast sectoral energy consumption of the Indian economy. The final report, "Modelling Energy Demand for Policy Analysis" was published in 1981. The objective of the study was to develop a national energy modelling system which would incorporate consistent assumptions and help in assessing implications of various energy policies. The models reflected on the interconnections between various energy policies, end use activities and energy demand in some detail. This model to some extent was superior to the input output model which treated all the sectors of the economy equally in the planning process. Parikh, to forecast energy consumption till 2000-01 made use of a model which consisted of a set of non linear equations expressing relationship between energy consumption and certain variables that were postulated to explain variations in energy consumption. The equations were estimated through the use of multiple regression techniques. She also used a model to project macroeconomic parameters like GDP, private final consumption expenditure and industrial GDP which, along with the demographic variable forecasts, were used as inputs to the model estimating energy consumption.

Thus, the entire modelling system was composed of three sub models:

SIMA : A model to estimate and forecast macro aggregates.

ENDIM : Multiperiod, multisectoral models to estimate energy demand, split up into many categories of end uses, some of which used econometric techniques for forecasting.

INVEST: A model used for calculating the investment required by the energy sector, and for crosschecking the consistency with the results of the macroeconomic model.

Therefore, in a nutshell, the study is based on a model which is a combination of the relationships derived from multiple regression, end use approach and simulation of alternative scenarios. She considered two macro economic scenarios for low and high demand. The high scenario is the one used by WGEP which assumed a long term GDP growth rate of 5.87% per annum but has a high share of urban population (32% of total in 2000 A.D.). The low scenario uses results obtained from the SIMA model. Here long term GDP growth is 4.4% per annum and share of urban population is 26% of the total in 2000 A.D. As everything is discussed in terms of final energy, this study fails to provide an integrated approach to energy demand and supply. In the ENDIM model the dependent variables are essentially end use activities of the different sectors. Regional distribution of energy is not built in the models but has been discussed separately. The overall results regarding oil and electricity conform to WGEP study results but their sectoral distribution differs substantially, what is really lacking in this study is a supply side study along side the demand side study. Otherwise the approach taken, being the first of its kind in India, is a very useful model in energy analysis and perspective planning.

The Central Electricity Authority submitted its Report on National Power Plan (NPP) in 1983.[25] The objective of the long range (1981-82 to 1994-95) study was to formulate a power development programme in such a manner that the economy and its consumers necessitated minimum cost. The study considered the absolute level of demand of power, in terms of energy and peak demand; rates of growth of demand for power; relationships between electricity and the fuel forms as well as the impact of overall energy policy on electricity demand; options for power development. Besides these the environmental and ecological impacts of various options were also considered. Policies were adopted at different levels and their impact on adopting various options were studied. An important aspect considered was the management of power resources development.

The analysis was carried out regionwise and forecasted till 2000-01. After examining the data base CEA decided to estimate the demand for electricity at a disaggregtated level. The disaggregation they considered was - Industries, Agriculture and all other categories of consumers (including household and commercial sector). The models used for forecasting electricity demand in the industrial sector consisted of regression methods and end use method. For regression analysis of electricity demand, value added in mining and manufacturing at constant prices was taken as the causal variable. The models considered were of, both, linear and double log functional forms. The regression equations were estimated for each region and the linear relationship was used for the purpose of forecasting. Thus alternative scenarios -

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[25] Refer ABE REport. 1985.

"High Scenarios" and "Low Scenarios" - were considered for each region. For the High Scenario the value added in mining and manufacturing was assumed to grow at a rate of 7% per annum during the period 1979-80 to 2000-01; for the Low Scenario the growth rate taken was 5.5% per annum. It was observed that the result obtained by end use method lie mid way between those estimated for High and Low Scenarios using regression techniques. The methodology used for estimating electricity demand in the agricultural sector is based on the use of norms given by governmental agencies. The entire electricity consumed in the agricultural sector is assumed to be for the purpose of irrigation (operating electric pumpsets). The equation considered was that electricity consumed depends on number of energised pumpsets and specific consumption per pumpsets. The forecasting was made regionwise. Using the number of electric pumps to be installed in the terminal years of the plans, the total electricity requirement in agricultural sector was estimated. It was assumed that the total number of feasible wells will be energised by electricity and all diesel pumpsets will be gradually replaced by electric pumpsets. This assumption was in tune with the recommendations of WGEP that by 2000 A.D the diesel pumps will stabilise to 27% of total number of wells. However CEA adopted a faster rate of addition to electrified pumpsets compared to the rate suggested by WGEP. Whereas for the other categories projection is based on past trend in consumption of electricity. The forecast, however, is made regionwise.

Electricity consumption requirements have also been worked out by CEA using AOKI's method. The method is based on world wide correlation of gross electricity generation per capita on GNP per capita observed over a number of years. The average relationship for all countries studied forms the main trend line. The countries whose present does not lie on the main trend is likely to lie on the indicative lines on either side of the trend line. Past historical trend of per capita generation and per capita GNP of a country selects the indicative line. Then on the basis of the projection of per capita GNP and corresponding indivative line projections for per capita generation are obtained. The projections, thus, were quite sensitive to GNP and population estimates. The AOKI's method yielded estimates of electricity requirement lower than what was worked out by CEA. This was mainly because of a discrepancy in population estimates. Long term generation capacity planning studies have been carried out by CEA using probabilistic method, and deterministic method have been used for transmission system planning. Dynamic programming techniques had been employed for the generation expansion study. The results of the optimization studies have indicated a desirable capacity mix by 1994-95 for each of the regions. CEA also estimated the consumption of coal in thermal power plans for 1994-95. This estimate was based on the assumption that all generation plants operated optimally, which means that with any plant operating sub-optimally would increase the consumption of coal. CEA thus carried out an extensive study of what the power requirements will be and suggested actions needed to be taken to meet the requirement.

The Advisory Board of Energy (ABE) was set up on the eve of the Seventh Plan in 1984, which submitted its report in 1985. It was set up with objective of carrying out detailed analysis and forecasting of energy demand in the country upto year 2004, under diverse macroeconomic scenarios. The methodology adopted by the study consisted of a combination of end use techniques and regression techniques to analyse and forecast demand. Besides forecasting, it made important suggestions regarding technical, financial and institutional aspects of energy planning in India.

THE ABE started by making a comparative study of WGEP estimates with the actual estimates for 1982-83 and suggested the possible reasons for the difference in the results. The exercise was extended to an analysis of regional energy consumption although WGEP clearly stayed away from such analysis, due to data problems (excepting for the case of electricity) which they clearly mentioned in their report.

This was followed by the independent projections carried out by ABE. Assumptions on macro aggregates were made, in order to carry out the estimation and forecasting. Because of the ambiguity involved in the choice of population projections, they assumed three alternative population estimates - Planning Commission figures, 1984 estimate by the Registrar General's office, and projections by Dr. Sundaram in EPW August 1984 issue. In order to capture the impact of urbanization on commercial energy consumption urban-rural population shares for 2004 A.D. were assumed to be 67.2% and 32.8% respectively. Besides this two alternative GDP growth rates were assumed, i.e., 4% per annum and 5% per annum between 1984-85 and 2004-05 A.D. The sectoral GDP growth rates were worked out on the basis of historical trends and elasticity coefficients, excepting for private final consumption expenditure which they assumed would grow at the same rate as GDP. For the household sector they used NSS 31st round data. For the Agricultural Sector they used data for the period 1950-51 to 1982-83 and used regression techniques together with norms on energised pumpsets (both diesel and electrified). They estimated the regression growth rate of ratio of diesel pumpsets to electrified pumpsets. This, conforming to WGEP suggestions, was found to be declining. They also estimated the number of electrified pumpsets for which the independent variables considered were time and output of agricultural sector at constant 1970-71 prices. After estimating the total number of electrified pumpsets and ratio of diesel to electrified pumpsets, norms on pumpsets were used to project total energy requirements and also demand for electricity by agriculture sector for the purpose of pumping. Energy required for non-irrigation purposes is also estimated using econometric methods. An alternative estimation approach was also taken to forecast energy requirement for pumping. Regression techniques were applied in two stages to the functional relationship between per capita total energy requirement for irrigation, per capita net area sown and number of villages electrified per 1000 villages in the first stage and in the second stage to the functional relationship between share of oil in energy consumption in pumping, number of electrified villages per 1000 villages and crude oil price index. This method has the theoretical advantage that projections are not based just on number of irrigation pumps and effects of policies on rural electrification and area expansion vis-a-vis policies on intensification of agriculture can be worked out. However, calibration of these equations for the years 1976-77 to 1982-83 showed considerable difference between actual and predicted values. Since the actual are also estimates so there really is no way of knowing how reliable they are in the absence of actual measurements. The regression analysis carried out for the industrial sector by regressing log value of electricity consumption on time and log value of industrial value added. End use technique was also used to estimate coal and electricity requirements in industrial sector, where output levels of various industries have been taken from reports of various Working Groups constituted by Planning Commission for the Seventh Plan. In order to carry out projections for energy consumption in transport sector a combination of regression techniques, end use methods and official norms were used. The ABE took the supply side options for meeting energy demand in India, into consideration before arriving at their policy conclusions. Even though important policy guidelines where provided by ABE, it was felt that long run economic resource cost needs to be explicitly taken into account in order to formulate an optimum energy strategy. Mainly motivated by this belief Planning Commission undertook long term energy modelling studies which included resource cost optimization on the supply side along with sectoral energy demand analysis. But, in the process they emphasized more on the optimization issue on the supply side.

R.P. Sengupta in his book, "Energy Modelling for India: Towards A Policy for Commercial Energy (1993)", puts forward the study on energy modelling for India, which was carried out between 1986 and 1989 in the Planning Commission. The study was based on an integrated system of models. The objective of the study was to carry out a quantitative analysis of the issues related to perspective planning and policy for the commercial energy sector of India. The Commission developed definite criteria of choice in the various dimensions of energy planning. To quote Sengupta (1993), with the beginning of the era of liberalization of the Indian economy in the mid-eighties, the consistency exercises of macro-economic multisectoral projections were no longer considered adequate to meet the requirements of planning. Sectoral planning was conceived to achieve the objective of improvement in investment productivity by optimizing choices in the relevant areas. The efficiency of the growth process was contingent on proper Energy Planning, which would reduce the energy cost of the economy. Energy planning was supposed to provide the strategies which in turn depended on a criterion of choice which would be objective, quantifiable and capable of systematically reflecting changing situations and priorities.

This study, named "Perspective Planning and Policy for Commercial Energy" carried out under the supervision of Sengupta, was submitted to the Planning Commission in 1988-89. In the study a energy model system was developed, comprising of a large number of interrelated models of relationships on the demand and the supply side of different commercial energy resources and energy products. In a nutshell, an integrated system was developed to determine the strategy of improving resource use efficiency of the macro economic growth process through both consumption and supply of energy. Long run models of energy demand projections, availability of coal resources, coal production and sectoral supply linkages, discovery and production of crude oil and natural gas, crude refining, oil import and natural gas, crude refining, oil import and petroleum products distribution, regional supply and utilization of natural gas, generation and supply of electricity, where developed in this study. Most of these models consisted of several submodels to carry out details stage wise analysis and were used to carry out long range forecasting. The models in their mathematical structure were either of consistency or optimization type. The optimization exercises were worked out using mathematical programming techniques.

The assumptions made by the demand projection models were alternative target rates of growth, about income of distribution, energy conservation and conservation of environmental resources. The supply side models were concerned with optimum utilisation of energy resources and minimization of economic resource cost of energy supply. This study was an improvement over the previous studies of Planning Commission because the previous studies mostly did not provide projections for alternative development scenario; and it is also the case that there is no a priori reason to believe that those studies have an optimality implication. The previous studies did not explicitly consider least cost option for meeting energy needs of the development process, which this study for the first time considered. Thus, in most of the studies the validity of intersectoral consistency was questioned.

Sengupta in the study considered three alternative GDP growth rates between 1989-90 and 2004-05 - 5.5%, 6% and 7% per annum compounded. The sectoral growth rates for value added were obtained on the basis of macrospecifications. To carry out projections the role of prices was not taken into consideration, as it was believed that all necessary changes in the structure of energy prices will be made so as to meet energy conservation targets. Finally, it was clearly pointed out in the study that, as the conventional sources of energy are exhaustible, so the development and research in the area of non-conventional sources of energy is absolutely necessary.

The requirement of electricity is projected at the national level under a system of periodic power surveys for which Power Survey Committees are set up by the Department of Power, Government of India. The Fourteenth Electric Power Survey Committee was set up in 1989 and submitted the report in 1991. It was held responsible for reviewing the demand projections keeping in view the Eigth Plan proposals and to project the perspective demand upto the year 2009-10.

The methodology adopted for forecasting demand was the Partial End-Use Method. The Committee felt that this method was comprehensive and consistent with the available data base and could be adopted for projecting the power demands over a short term period. This method takes into consideration all the parameters affecting demand for electricity in various sectors. Where sufficient data for the past was available and the programme for future was well defined for the sectors, an End-Use Technique was used. The variables considered for forecasting were economic, demographic, and non economic - population, number of households, number of consumers, percentage of electrified households, per capita consumption. They took a trend approach to carryout long range forecasting, because of paucity of Statewise development profile, data, at various disaggregated level. The long range forecasting covered the period 1995-96 to 2009-10 with 1994-95 the base year.

Data, for the projection, was obtained from State Electricity Board, public utilities in private sector, concerned Departments of State Governments and various Ministries and Departments of Government of India. Past growth rate in number of consumers has been studied for each State and Union Territories. In States where power shortage were experienced recently, long term trend analysis of growth in number of consumers is considered to decide on number of consumers to be used for purpose of forecasting. Similarly, for State and Union Territories where past performance was poor, due consideration was given to increased rate of future electrification of households to obtain estimates of number of consumers. Higher level of electrification expected in certain States is also given due consideration. Again, past trends had been used to obtain estimates of per capita energy consumption. The rising trend and effect of power cuts recently has been considered for determining the future consumption. Consumption in domestic, commercial and miscellaneous sectors has been estimated on the basis of number of consumers and per capita consumption. For public lighting and water works the connected load was forecasted on the basis of past trend, likely increase in public lighting and improvement in water supply facilities. Past trends were used to obtain estimates of numbers of hours of operation with due consideration given to power cuts. Electricity requirement for dewatering and irrigation was obtained by the products of number of pumpsets in KW at the middle of the year and average consumption per year per kilowatt of connected load. The Committee after consultation with State Electricity Board, giving due consideration to trend in actual progress achieved an ultimate ground water potential, decided on the programme of energisation of pumpsets upto 1994-95. Future capacity of pumpsets was decided on by considering the past trend in capacity of pumpsets, mid year figures of connected load, and total number of pumpsets in the past. Extensive irrigation practices and multiple cropping, the average consumption by irrigation pumpsets were taken into consideration while projecting average consumption by pumpsets. For the projection of requirements for lift irrigation purposes the connected load and expected hours of operation were taken into consideration. The electricity requirements for the industrial sector has been estimated for the three sub categories - low tension industries, high tension industries with demand less than 1MW, and high tension industries with demand 1 MW and above. The consumption requirements of the first two categories have been made on the basis of past trend. For the third category, however, projections were carried out for each industry separately on the basis of their expected production. From the overall energy requirement so obtained the demand to be met by captive power plants was deducted to arrive at the demand on the utility system. The generation by captive plants was projected on the basis of their past trends. For the projection of bulk supply to non-industrial consumers, trend analysis was carried out. Thus, total electricity requirements by consumers arrived at by aggregating all the above mentioned electricity requirements.

This study also considers transmission and distribution losses and suggests possible ways of bringing down both technical losses and commercial losses. Generation requirements at bus bars were arrived at by adding transmission and distribution losses to total consumer requirements for both State and Union territories. Future annual load factors were also forecasted on the basis of past trends and after due consideration being given to changing pattern of utilisation of different classes of load. Peak load for each State/Union territory has been arrived at by applying the annual load factor on the energy requirement at busbars. Forecasts beyond 1994-95 upto 2009-10 have been carried out by extrapolation technique, of the overall energy requirement. The growth rates used for extrapolation were arrived at by studying past growth rates till 1994-95 and keeping in view the enlarging base. The study assumed that as the long term forecast is only an indicative forecast which would facilitate identification of resources of power for advance action, so the methodology they adopted would meet the requirements. However, it was also recognised that the long term forecasts needed to be reviewed from time to time. Both short term and long term forecasts on supply side were carried out. The supply side forecasts were essentially based on norms of allowances suggested by working group on power of 8th Plan.

Government of India in cooperation with ESCAP, UNDP, and Government of France undertook a major study on sectoral energy demand, under the Regional Energy Development Programme. They submitted their report, "Sectoral Energy Demand in India", in 1991. According to this study neither the trend techniques nor econometric methods can be used to carry out long range projection, if the objective of the study is to make forecasts on the basis of structural stability of the energy demand and macro economic variable relationships. These relationships may not be consistent over time, so as to provide the basis for long range demand estimation. There ar a number of techno-economic factors associated with the end-use activities in the energy sector which determine the final demand for energy. The methodology that they adopted was the MEDEE's Approach. The important feature of the model is that energy demand being directly related to end-use categories. Interaction between macroeconomic aggregates and end-use activity levels is given due consideration, technological choices and fuel mix choices are also considered and finally structural changes are considered. In order to test for the robustness of the results of the model a sensitivity analysis is also carried out by considering alternative scenario.

The assumptions of the base case scenario are made on macro-economic and technoeconomic factors. It is assumed that the population growth in country will decline during the coming years; however the expected rise in share of urban population in total population will considerably affect the pattern of energy consumption. It is further assumed that agriculture will undergo technological and structural change and rapid industrialization will create employment opportunities.Thus, it is assumed that progressive economic development will be oriented towards elimination of poverty. It was assumed that reduction in the dependence on import and strengthening self reliance will be accorded high priority in the successive plan periods. Through appropriate structural and technological changes, interfuel substitution wherever possible and conscious efforts in energy conservation, the economy will bring down its energy intensiveness. These assumptions regarding plan objectives were incorporated in the macro aggregate and techno-economic assumption. The energy demand was forecasted till 2009. It was assumed that the GDP growth rate between 1989 and 2009 would be 6%. The share of agricultural sector in GDP was expected to decline while share of industrial sector was expected to go up. Population was assumed to be 1140 million in 2009 with urban share at 39%. Wide ranging energisation of pumpsets for irrigational purposes, with an objective of increasing agricultural production was assumed. It was also assumed in the study, that by 2009 all diesel pumpsets will be replaced by electric pumpsets for irrigational purposes. Substantial technological change was assumed to take place in the industrial sector with an eye on fuel substitution and fuel conservation. The study assumed that growth of energy intensive industries would decline. The study took into account the expected increase in traffic and shifts in inter-modal pattern while estimating demand for energy in transport sector. For the household sector changes in income distribution and their impact on standard of living and consumption of fuel use have been explicitly taken into consideration, in the Base Case Scenario. The Base Case Scenario also takes into consideration extensive rural electrification and substitution of noncommercial fuels by commercial fuels and their impact on the demand for energy.

However, the study does not consider the impact of relative resource cost of different sources of energy on the demand for energy. This, as shown by Sengupta (1993) is a drawback of any study, which does not take an integrated approach of demand-supply analysis along with the optimization of resource cost of energy.

2.4 Present Study

The models that we have considered, for analysis and projection, in the present study do not swear strong allegiance to any particular conventional model. We have tried to use models, which we feel are fundamentally credible as representation of actual behaviour and phenomenon we are trying to understand. Thus, while modelling demand for electricity we pay more emphasis to the empirical evidence and frame models which are suitable to the data evidence made available to us. However, while modelling, the lack of appropriate database was severely felt.

Broadly speaking, in all the models we have used regression techniques to analyse demand for electricity and make projections, with the objective of taking into consideration the historical pattern of consumption and its interrelationship with the various variables. As already described in the objective of study, we have considered the analysis at two levels - aggregative and sectoral. The variables used in modelling have a lot common to most of the studies undertaken at the official level. The assumptions made in our study, like most of these studies at official level, are on macroeconomic aggregates and technoeconomic factors.

The simple expectation model considered for aggregative analysis in our study are somewhat similar to the lagged dynamic models reviewed in this chapter; particularly to Houthakker and Taylor (1970), and Houthakker, Verleger and Sheehan (1973). However, unlike Houthakker and Taylor, in modelling we have not considered stocks of equipments. Even though we ultimately arrive at the same final estimable equation form, we have taken a different approach. Moreover, unlike both the studies, we have not considered price (own or substitute) as an explanatory variable. Since we are considering an aggregative model, this should not affect our analysis considerably. Moreover, since price of electricity is administered, this would have led to other complications in the model as discussed under methodological issues. Finally, GDP being a robust and important long range forecasting tool should be quite suitable for an aggregative analysis. However, we have considered the influence of price in our translog form model. Thus, in order to avoid the complications of aggregating and averaging the price to obtain an index, we worked with wholesale price indices. By doing that we tried to avoid the compliacted issue of average and marginal prices on the one hand, and the problem of indexing our electricity tariff schedules on the other. The learning model, amongst our aggregative models do not have anything common to any of the models reviewed here, excepting that like some of the models, dynamics is built in the model, though in a different way. The translog form model in our study takes the translog functional form and is not exactly the translog model that we have discussed in the chapter.

Amongst the sectoral models, the second model for residential sector in our study is similar to the model for residential sector considered by Energy Policy Division (1991). The first model for residential sector is not really similar to any of the models. However, the idea of two stage modelling, which we have used here, was taken from the studies reviewed here. Unlike some of the residential sector models discussed here, we have not considered price to be an endogenous variable. Nor have we considered the marginal price schedule. There was an additional data problem, the major one, that is how to obtain an average or marginal price when price data is published according to the appliance category wise and quantity data at an aggregative level. But, we have used the implicit average price obtained from the NSSO data, to arrive at demand in physical units. This, however, might raise the question of misspecification of the model.

The model for industrial sector in the present study, is a somewhat non conventional model. It has similarities with a number of studies reviewed here, but not exactly identical to any of them. It is similar to the study by Baughman and Joskow (1975, Chern (1987) in the sense that a two stage procedure is adopted, where in the first stage total expenditure on fuels is estimated and in the second stage the expenditure on a specific fuel is related to the total expenditure on all fuels. But in one of our models, in the second stage, we have related the expenditure on electricity to total expenditure on all fuels; and in the other model, in second stage, we have related their share in a functional form to time. The first stage of our model has similarities with all those translog studies which analyse fuel input and non fuel input substitution possibilities in manufacturing sector. However, we have not considered a translog energy sub-model, mainly due to lack of availability of data, within the time constraint.

The basic principle behind formulation of the agricultural sector model in our study, is same as that for ABE Study (1985). However, we took the more direct approach model for our final projections because we observed that the indirect approach, like ABE's, was yielding us with infeasible demands given the groundwater supply constraint. Moreover, the second stage of our model is somewhat dissimilar, as we tried to model demand as a functional relationship between the share of energy required by electrified pumpsets in total energy demand for irrigation and time. Through this functional form we tried to incorporate the substitution possibility of diesel pumpsets by electrified pumpsets.

For, commercial sector we took a very direct approach, relating consumption demand for electricity to value added in the sector. This procedure is identical to the method adopted by the Energy Policy Division (1991). Unlike other studies reviewed, we did not consider stock of electricity using appliances because of the lack of appropriate database. Such an approach definitely would have been better, provided appropriate data was available.

For the transport sector we did not consider an independent analysis but accepted the projections of Energy Policy Division (1991).

Unlike some of the studies, we have not taken the trend approach for projection but relied entirely on regression analysis. Our assumptions on macroeconomic aggregates are different from the base case assumptions of most studies. The technoeconomic assumptions of our study, sometimes overlap with some of the studies, but are broadly different. For example the assumption on consumption by pumpsets is taken from the study by Energy Policy Divisions (1991). We have considered an uniform utilisation rate over time, whereas they assumed an increasing utilisation rate and consumption of diesel by diesel pumpsets; in that sense our assumption differs from theirs. Thus, the present study has a few similarities with some of the studies reviewed here,but are not exactly identical to any of them.

2.5 Conclusion

We did not make a comparative survey of the results of the various studies, as we intended to review the various methodologies and assumptions of these studies. But we should take note of the fact that the difference in methodologies and assumptions would have a significant impact on the results of the models and only a comparative study of the results would judge the stability and consistency of the models. The objective of this review was, to provide a brief exposure of the various methodologies that may be adopted to analyse demand, and may be adopted to make long range forecasts of demand.

Considering the vastness of the existing literature on energy demand and forecasting, it is impossible to cover each and every one of them. However, due to scarcity of time, we could not carry out a more extensive survey which would otherwise have been much more illuminating.

CHAPTER III

AGGREGATE DEMAND FOR ELECTRICITY

The demand for electricity has been continuously growing at a rapid rate in the country. According to the 14th Power Survey, the rate of growth of electricity consumption grew at an average annual growth rate of 12.19% p.a. in the decade of 1960's and then declined sharply to 6.54% p.a. in the decade of 1970's. Ever since the 1980's the growth rate has picked up and has averaged to 9.16% p.a. in period ending 1989-90. The decline in growth rate in the decade of 1970's was mainly due to supply shortages. With increase in the pace of rural electrification and energisation of more number of wells to utilise the available ground water potential the share of consumption of electricity in agriculture and household sector has gone up considerably over the years. Even though the share of industry in total consumption of electricity has been declining, it still accounts for the lion's share of total consumption. The growing electricity demand is accounted by these three sectors mainly. The contribution of transport sector in total consumption of electricity is rather insignificant, though commercial sectors contribution is gradually increasing.

The decline in growth rate of consumption of electricity in the decade of the 1970's could be explained by sudden fall in the GDP growth rate of the economy. The growth rate in Gross Domestic Product (GDP) remained lower than expected during the decade of the 1970's. It was only in the '80's that a clear break from this was observed. Along with this change agricultural income and per capita consumption grew and capital output ratio declined. All these contributed to the increase in consumption of electricity during the 1980's. However, it can also be argued that, may be, because of supply shortage of electricity the growth rates of GDP kept low during the decade of 1970's and then improved in the decade of 1980's with an improvement in the supply of electricity. It is difficult to say which one was the cause and which the effect, as the causality runs both ways.

The consumption of electricity, ever since, has been increasing quite rapidly. The overall consumption of electricity increased from 48.6 billion KWh (BKWh) in 1970-71 to 212 BKWh in 1990-91. Per capita electricity requirement has increased from 89.8 KWh/person in 1970-71 to to 252.77 KWh/person in 1990-91 (refer Annexure Table s1). This could be partly accounted for by the rise in share of urban population to total population, from 20% in 1970-71 to 25.9% in 1990-91.

The proportion of villages electrified increased from 18.8% in 1970-71 to and 86.5% in 1990-91.[1] This could be one of the causal determinants of increase in growth rate of electricity consumption after the 1980's (refer Statistical Table S1). The electricity intensity of the economy has increased from 0.054 KWh/Rs in 1970-71 to 0.073 KWh/Rs in 1980-81 and to 0.1 KWh/Rs in 1990-91. Thus, the electricity intensiveness of the economy is increasing at a decreasing rate. This could be mainly explained by the influence of the industrial sector, due to use of more efficient technology, and also more efficient electricity using appliances in the other sectors, excepting for the agricultural sector.[2]

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[1] Total number of villages are assumed to be 5.56 lakhs.

[2] Due to various reasons, which we will discuss later, there is a lot of wasteful use of electricity in the agricultural and rural sector - which adds to unnecessary consumption of electricity and raises the electricity intensity of the economy.

As GDP elasticity of electricity consumption is greater than unity, so with higher plan targets in future considerable electricity will be required. In order to achieve the target growth rates, supply of electricity should not act as a constraint. As a prerequisite to plan our supply sufficiently in advance of the actual requirement forecasting of electricity requirement for the next 10 to 15 years becomes absolutely imperative. Besides, projection of the future electricity requirement also indicates the steps to be taken now so that electricity does not pose as a constraint to the development process. In fact, as accurate forecasting is a difficult proposition, indicative or normative demand projections are more appealing.

In this chapter we propose to forecast the overall electricity demand (utilities plus non-utilities) in India for the terminal years of the 8th, 9th and 10th Plans (i.e., 1996-97, 2001-02, 2006-07 respectively) based upon simple expectation model, learning model and translog form model. We have employed time series data for the period 1960-61 to 1990-91 and have used econometric techniques to estimate the demand for electricity. In all the three models we have considered the relation between the evolution of electricity consumption and economic activity.

In the next three section we deal with the discussion of the three alternative models in details; to be followed by a section dealing with the projections using the models considered; and finally followed by the concluding section.

3.1 Simple Expectation Model

It is quite clear from the empirical evidence, already considered, that there is a strong interrelationship between electricity consumption and GDP. In fact, the impact of the development process on electricity consumption and vice versa cannot be overstated. However, without going into the complex causality issue, we use this interrelationship to model demand for electricity. The state of development of an economy is defined in terms of the level of economic activity. We use per capita income as the level of economic activity to formulate our model. We assume that there exists a functional relationship between per capita consumption of electricity and level of economic activity or per capita income.

In the simple case where we assume that demand adjusts instantaneously to price and income changes, the model takes the form of a simple static model. The functional relationship may be either linear or proportional form, as:

In linear form,

$$C_t = a_0 + a_1 y_t + u_t \tag{1}$$

where

C_t = per capita consumption of electricity in period t
y_t = per capita GDP in period t
u_t = disturbance term in period t

In proportional functional form,

$$C_t = a_0 y_t^{a_1} \tag{2}$$

By, logarithmic transformation to equation (2) we obtain,

$$\ln C_t = \ln a_0 + a_1 \ln y_t + v_t \tag{2'}$$

v_t = error term in period t.

In order to obtain elasticities of demand, we estimate equation (2'), where the estimated parameter a_1 gives the elasticity directly.

But the simple case considered here has a very important shortcoming - it exhibits a static framework and assumes instantaneous adjustment process. It, thus, does not distinguish between short run and long run elasticities.[3] Realistic formulation of economic relations require the insertion of lagged values as explanatory variables in the model. So we consider a dynamic adjustment model, through which we explicitly incorporate adjustment mechanism into the model.

3.1.1 Model and Estimation Procedure

In the revised extended model we assume a dynamic adjustment process and the model takes the form of an Adaptive Expectation model.[4] Since expectations play a big role in any decision making process of the economy, so we assume the following behavioural hypothesis - the consumption requirement of electricity depends on the expected level of economic activity. Electricity is used as an intermediate input, which is consumed in

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[3] By short run and long run elasticities we really mean elasticities in equilibrium and disequilibrium situations. Such long run elasticities also depend on substitution possibilities. But as discussed earlier, since we are more interested in long range forecasting and as prices of oil and electricity are administered in India, we frame our dynamic model simply on the basis of per capita consumption and per capita GDP, and have left out prices completely from the model. Later, however, we mention an alternative model, where we incorporate price of electricity; with details in the Appendix 3.A.1.

[4] A Koutsoyiannis, "Theory of Econometrics" (2nd ed.), MacMillan Education Limited, 1986, pg. 313.

order to achieve a level of production or to obtain the services of electricity using appliances. Thus, consumption of electricity may be viewed as consumption for production.

Therefore, model takes the form:

$$C_t = a_0 + a_1 y_t^* \qquad (3)$$

where,

C_t = per capita consumption of electricity in period t.

y_t^* = expected per capita income at the end of period t.

Since expectations are not directly observable, so it is customary to add an auxiliary hypothesis about the formation of expectations. We thus postulate here an adaptive expectation scheme, where expectations are updated each period on the basis of actual information available each period - expectations, therefore, are adaptive.[5]

The adaptive rule is given by,

$$y_t^* = y_t - \cap\,(y_t - y_{t-1}^*),\ 0 \le \cap \le 1 \qquad (4)$$

where,

y_t^* = expectations formed at the end of t^{th} period,

y_t = per capita income in t^{th} period,

$\cap$ = expectation coefficient, implying expectation elasticity is less than 1.

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[5] J. Johnston, "Econometric Methods", McGraw Hill Books Company, 3rd edn. 1984, pg. 348.

Therefore,

$$y_t^* - y_{t-1}^* = (1-\cap)\ (y_t - y_{t-1}^*) \qquad (4')$$

Now,

$\cap =$ 0, implies expectations adjust period by period to the current observations and all previous observations are important; the case of instantaneous adjustment.

$\cap =$ 1, implies expectations once formed remains unchanged every period; state of equilibrium in a dynamic framework.

$0 < \cap < 1$ is the disequilibrium state, when expectations get adjusted in the light of past periods experience.

Note that, the simple model we already discussed is a special case of this more general case when $\cap = 0$.

Now since, $y_t^* - y_{t-1}^* = (1-\cap)\ (y_t - y_{t-1}^*)$

Therefore,

$$y_t^* - y_{t-1}^* + (1-\cap)y_{t-1}^* = (1-\cap)\ y_t$$

Thus, using lag operator we obtain,

$y_t^*\ (1-\cap L) = (1-\cap)y_t$, where L = lag operator.

or

$$y_t^* = \frac{(1-\cap)}{(1-\cap L)} \cdot y_t \qquad (4'')$$

therefore,

$$y_t^* = (1-\cap)y_t + \cap(1-\cap)y_{t-1} + \cap^2(1-\cap)y_{t-2} + \ldots\ldots ,$$

Because,

$$(1-\cap L)^{-1} = 1 + \cap L + \cap^2 L^2 + \ldots\ldots\ldots ,$$

So, adaptive expectation scheme gives current expectation as a weighted combination of current and all previous period income levels, with weights declining continuously following the pattern of a geometric progression.

Now, substituting equation (4") in equation (3) we obtain:

$$C_t = a_0 + a_1 \frac{(1-\cap)}{(1-\cap L)} \cdot y_t$$

Therefore,

$$C_t - \cap C_{t-1} = a_0(1-\cap) + a_1 (1-\cap)y_t$$

or

$$C_t = a_0(1-\cap) + a_1 (1-\cap)y_t + \cap C_{t-1} \qquad (5)$$

Therefore, consumption requirement per capita depends not only on the level of economic activity but also on preceeding periods consumption requirement per capita. As far as consumption of electricity is concerned, this is not an unrealistic assumption. The existing technology and habit formation may influence the level of consumption of electricity. Whether it be firms or individual consumers, it is impossible to carry out adjustments to demand immediately without taking past consumption into account.

However, in order to estimate the model, it needs to be embedded in a stochastic framework.

Thus, if we append to the equation (3) an additive disturbance term, u_t, then equation (3) may be written as:

$$C_t = a_0 + a_1 y_t^* + u_t \tag{6}$$

Now on substituting equation (4") in equation (6) and making necessary manipulations we arrive at,

$$C_t = a_0 (1-\cap) + a_1 (1-\cap) y_t + \cap C_{t-1} + v_t, \tag{7}$$

where

$$v_t = u_t - \cap u_{t-1}.$$

The above model, which finally leads to equation (7) was based on an assumption that the per capita consumption assumes a linear relation with the expected level of economic activity.

So, let us modify equation (3) slightly, to assume a proportional relation. This model we consider as an alternative to the above model.

Therefore, the model takes the form:

$$C_t = A(y_t^*)^b \tag{8}$$

since demand functions are often expressed in constant elasticity form, so this macro or aggregate demand function is not altogether arbitrary.

In order to make the function estimable we assume a product disturbance term. So equation (8) becomes,

$$C_t = A(y_t^*)^b . u_t \tag{9}$$

where,

u_t = disturbance term

Now, carrying out logarithmic transformation to equation (9) we obtain,

$$\ln C_t = a_0 + a_1 \ln y_t^* + w_t \tag{10}$$

where,

$a_0 = \ln A$

$a_1 = b$

$w_t = \ln u_t$

As, y_t^* is not observable in equation (10) so we assume the adaptive rule,

$$\frac{y_t^*}{y_{t-1}^*} = \left(\frac{y_t}{y_{t-1}^*} \right)^{(1-\cap)} , \quad 0 \leq \cap \leq 1 \tag{11}$$

therefore,

$$\ln y_t^* - \ln y_{t-1}^* = (1-\cap) \; [\; \ln y_t - \ln y_{t-1}^*] \tag{11'}$$

therefore using lag operator, we obtain,

$$\ln y_t^* = \frac{(1-\cap)}{(1-\cap L)} \ln y_t \tag{11"}$$

Now substituting equation (11") in equation (10) and making necessary manipulation we arrive at,

$$\ln C_t = a_0\ (1-\cap) + a_1(1-\cap)\ln y_t + \cap \ln C_{t-1} + \epsilon_t \qquad (12)$$

where,

$$\epsilon_t = w_t - \cap w_{t-1}$$

This model yields the electricity demand elasticities with respect to per capita GDP. Both short run and long run elasticities may be obtained from this model.

The short run elasticity, i.e., when $0 < \cap < 1$, is given as:

$$\mu_s = \frac{\delta \ln C_t}{\delta \ln y_t} = a_1\ (1-\cap) \qquad (13)$$

The long run elasticity, i.e., elasticity in the equilibrium state, when expectations remain unchanged, is given by the coefficient a_1 since,

$$\ln C_t = a_0 + a_1 \ln y_t^* + w_t$$

therefore,

$$\mu_L = \frac{\mu_S}{(1-\cap)} = a_1 \qquad (14)$$

Complications arise in estimation of the models. The appearance of lagged dependent variable among the explanatory variables, in both the above models, has undesirable consequences. First, the error terms v_t in equation (7) and ϵ_t in equation (12) may be autocorrelated despite the fact that u_t in equation (7) and w_t in equation (12) may be uncorrelated, when

$v_t = u_t - \rho u_{t-1}$ in equation (7) and

$\epsilon_t = w_t - \rho w_{t-1}$ in equation (12)

Also the converse is possible. The existence of autocorrelation, renders not only ordinary least square (OLS) estimates biased in small samples, but also inconsistent in large samples because asymptotic bias does not vanish.

Second, the lagged dependent variable, C_{t-1}, is not independent of the error terms, i.e., since,

$$E(C_t, V_t) \neq 0 \text{ , so } E(C_{t+1}, V_t) \neq 0$$

$E(C_{t+s}, V_t) \neq 0$ for $s \geq 0$ and all t, for equation (7). The same argument is applicable for equation (12). As a consequence of these, OLS estimation procedure breaks down. First, test needs to be carried out for the detection of presence of autocorrelation. But the presence of lagged dependent variable as an explanatory variable invalidates the use of Durbin-Watson 'd-statistic', as it is biased towards 2.[6] So, we use Durbin's 'h-test' to check for autocorrelation, which is a large sample test. In order to do so we compute the h-statistic which is,

$$h = r \sqrt{(n/1-n\hat{V}(\beta))}, \quad n = \text{sample size} \qquad (15)$$

where, $\hat{V}(\beta)$ = estimate of the sample variance of the coefficient of the lagged dependent variable, obtained by applying OLS estimation to the equation to be estimated, where

$$r \approx 1 - (d/2),$$

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[6] A. Johnston, "Econometric Methods", (3rd edn.), pg. 318.

d = Durbin-Watson test statistic, obtained on carrying out OLS to the equation to be estimated.

Thus, after computing h-statistic, h is then tested as a standard normal distribution. Thus $|h| > 1.96$ implies reject the hypothesis of zero autocorrelation of disturbance term at 5% level of significance.

Because of the presence of lagged dependent variable, OLS estimation may not yield consistent estimates.[7] But in order to ensure consistent estimates we employ instrumental variable estimation procedure here. This is a two stage procedure that we use to estimate for the coefficients of the model. In the first stage we obtain instrument for the lagged dependent variable and in the second stage we replace the lagged dependent variable by its instrument and estimate the equation applying OLS.

In the above models, to obtain instrument for C_{t-1}, we regress C_t on y_t and lagged values of y_t; the number of lags is decided on the basis of improvement in the fit as additional lagged values of y_t are introduced. Normally a good fit (or high R^2) is obtained with two or three lagged values. In our case we obtained a very good fit with two lags. Therefore, we obtain estimates of C_t as,

$$\hat{C}_t = \hat{\alpha}_0 + \hat{\alpha}_1 y_t + \hat{\alpha}_2 y_{t-1} + \hat{\alpha}_3 y_{t-2} \tag{16}$$

where

$\hat{C}_t$ = estimated value of C_t

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[7] According to Johnston (1984), OLS estimates may be consistent if disturbance terms are not autocorrelated and are independently and identically distributed.

$\hat{\alpha}_i$ = estimated parameters, i=0,....,2

Thus, $\hat{C}_{t-1}$ is used as an instrument for C_{t-1}

We replace estimated C_{t-1} for C_{t-1} in the original model and apply OLS to the model. The estimates so obtained would still be biased for small samples but will be asymptotically consistent. This sums up the estimation procedure we have applied in the above models.

3.1.2 Data and Variables

We have used time series data for the period 1960-61 to 1990-91 to estimate the models. Both the models require data on per capita consumption of electricity (utilities and non-utilities) and per capita GDP.

The CEA general review publishes all India time series data for per capita electricity consumption (utilities and non-utilities together). All India population figures were taken from the National Accounts Statistic, CSO. GDP at factor cost, at 1980-81 prices are taken from Economic Survey, 1992-93. Per capita GDP data is generated using GDP data and population data.

3.1.3 Results

The results to the above static and dynamic models are presented here.

OLS estimation was carried out to equation (1) to obtain the estimates of the coefficients. In this model per capita income explains 97% of the total variation in per capita consumption. However Durbin-Watson statistic lies in the zone of ignorance at 1% level of significance. But on carrying out non parameteric runs' test for randomness of disturbance term we find that the model does not exhibit autocorrelation. The estimated coefficients are given in Table 3.1.

Table 3.1

Regression Results

Dependent Variable = C_t

$\bar{R}^2 = 0.9718$

Variable	Coefficients	t-statistics	2 tail significance
Constant	-229.939	-20.882	0.000
y_t	0.196	32.192	0.000

D.W. = 1.656

All the coefficient of per capita income is highly significant at 5% level of significance. This shows that level of economic activity is a good determinant for per capita consumption of electricity, so that as per capita income increases, per capita consumption of electricity also goes up at the aggregate level.

To the other static model, given by equation (2') we carry out OLS. Here, the log of per capita income explains 89% of the total variation in log of per capita consumption. The Durbin-Watson statistic shows existence of positive autocorrelation. Then to correct for autocorrelation, we carry out correction for first order autocorrelation i.e., AR(1). The results are given in Tables 3.2 and 3.3 respectively.

Table 3.2

Regression Results

Dependent Variable = ln C_t

$\bar{R}^2 = 0.8930$

Variable	Coefficients	t-statistics	2 tail significance
Constant	-18.459	-12.654	0.000
ln y_t	3.093	15.856	0.000

D.W. = 0.39

Carrying out correction for AR(1) we observe that D-W=1.692 and autocorrelation is corrected by assumption of first order autoregressive scheme.

Table 3.3

Regression Results

Dependent Variable = ln C_t

$\bar{R}^2 = 0.9962$

Variable	Coefficients	t-statistics	2 tail significance
Constant	3.319	2.169	0.039
ln y_t	0.379	2.321	0.028
AR(1)	0.963	71.499	0.000

D.W. = 1.692

This shows that all the coefficients are significant at 5% level of significance and $\bar{R}^2$ has improved to 0.9962, showing a better fit in the model.

The estimated income elasticity is 0.38. But this essentially gives a short run elasticity, as we are considering time series data and estimating the model in a static framework. Thus, in the short run demand for electricity is income inelastic. This conforms to the theory that adjustments in the short run is a difficult proposition due to various factors.

As explained in section 3.1.1, the dynamic models represented by equations (7) and (12) are estimated using instrumental variable estimation procedure, using estimated C_t with one period lag as an instrument for C_{t-1}. But before we do so, we test for the existence of autocorrelation. But the presence of a lagged dependent variable as an explanatory variable invalidates Durbin-Watson's test for autocorrelation. Since, we have a fairly large sample (1960-61 to 1990-91), so we propose a large sample test - Durbin's h test to test for the existence of autocorrelation in the model.

The results corresponding to equation 7 show that Durbin's h-statistic has the value, $h=-0.6616$. Since $|h| < 1.96$, so we do not reject the null hypothesis of non existence of autocorrelation in the model. Estimated C_t is calculated after regressing C_t on y_t, y_{t-1} and y_{t-2}, where the explanatory variables explain nearly 98% of total variation in C_t, with all coefficients significant. Estimated C_t with one period lag is used in place of C_{t-1} as an instrument, to estimate the model. Estimation of equation (7) shows that the explanatory variables explain more than 99% of the total variation in the dependent variable C_t. In the final estimated equation there is no autocorrelation. In this model the dependent variable is C_t and the results of the coefficients of the explanatory variables are tabulated in Table 3.4.

Table 3.4

Regression Results

Dependent Variable = C_t

$\bar{R}^2 = 0.9979$

Variable	Coefficients	t-statistics	2 tail significance
Constant	-46.753	-3.939	0.001
y_t	0.039	3.849	0.001
C_{t-1}	0.856	15.026	0.000

D.W. = 2.239

The estimated coefficients of the model turn out to be significant at 5% level of significance. The estimates of the model are:

$$a_0 = -333.93, \quad a_1 = 0.286 , \quad \cap = 0.86$$

The rate of adjustment is quite high. Past periods consumption has a positive influence on the present consumption. This implies that in the short run, besides level of economic activity, various other factors such as habits, existing appliance stock etc., has a strong influence on present consumption. It also supports our hypothesis that economy cannot immediately adjust their level of consumption as a consequence of changes in factors affecting consumption.

In a similar way we estimated equation (12). Estimating the value of h-statistic we obtained h=-0.2480, i.e., $|h|<1.96$, which shows that there does not exist autocorrelation in the model at 5% level of significance. We have, used instrumental variable technique to estimate the model. Similar, to the previous case, we have used logarithm of estimated value of C_t with one period lag in place of $\ln C_{t-1}$. This procedure yields us with asymptotically consistent coefficient estimates. As, Table 3.5 shows all the estimated coefficients are significant at 5% level of significance. The explanatory power of the model is also very high.

Table 3.5

Regression Results

Dependent Variable = $\ln C_t$

$\bar{R}^2 = 0.9975$

Variable	Coefficients	t-statistics	2 tail significance
Constant	-3.127	-3.214	0.003
$\ln y_t$	0.545	3.319	0.003
$\ln C_{t-1}$	0.808	14.368	0.000

D.W. = 2.036

The estimated coefficients of the equation (1) are:

$a_0 = -16.32$, $a_1 = 2.84$

and adjustment rate $\cap$=0.808

The estimated short run and long run elasticities, as defined in equations (13) and (14) respectively, are:

$$\mu_S = 0.545$$
$$\mu_L = 2.84$$

Thus, the long run elasticity of demand with respect to income turns out to be greater than short run elasticity and is greater than unity. This conforms to our hypothesis that in the long run demand is much more responsive to income, than in short run. Consumption of electricity in short run is much more restrictive; the elasticity less than one supports this hypothesis.

Both the models represented by equations (7) and (12) support the view that inclusion of dynamics in the demand system becomes important for a proper analysis incorporating short run and long run behaviour. Even though, equation (7) and (12) both yield significant estimates, equation (7) yields better results with a higher $\bar{R}^2$ and coefficients have a smaller type I error compared to equation (12). We have used both the models for forecasting of demand.

Both the above models do not consider price as a determinant of demand. Even though it can be rationalised that rate structures being regulated by the government and public utility commissions cannot be considered to affect consumption to a great extent in the long run. Chances of price affecting consumption in the short run is even less. This is so because existing technology, appliance stock, switching cost, habits etc., may not permit significant changes in consumption of electricity due to price rise. At least the bias would not be as strong as in the other commodity markets. And in the Indian context this is all the more applicable because of the low price structure. But, in order to substantiate we have used a different model where price of electricity was incorporated. However, instead of using average tariffs or marginal rate schedules or both, we have used real prices of electricity generated from price index of electricity. But we believe that this should not affect our results to a great extent since we are estimating a macro demand model. Besides, data availability problem, price of electricity imposes additional problems. Estimation of the model reveals that our belief is not altogether baseless, as the coefficients of price variables turned out to be insignificant. This conforms our hypothesis that electricity demand at the aggregate level is insensitive to price changes. The details of the model are worked out in Appendix 3.A.1. We have not used this model for projection of future electricity demand.

3.2 Learning Model

Learning is an integral part of the production process. It is also true that learning is a subjective phenomenon. But, nevertheless it would be quite useful to incorporate this phenomenon into a model, various techniques have been used in different fields of economics to capture this learning phenomenon. In the area of energy economics and resource economics, too, some efforts have been made to capture learning in the form of a model. We try to incorporate these studies in our model to estimate demand for electricity, which we use later to carry out future projections.

It is believed that improvement of system performance that is repetitive and predictable is a consequence of learning. Consumption pattern of electricity may be viewed as a consequence of learning. As more and more electricity is consumed in the production process, knowledge of technology and input requirements, including electricity, accumulates. This knowledge, in turn, affects further consumption of electricity at the margin.[8] Thus, the process of learning is captured in a model where through cumulative values the empirical relationship between input and output is described. The motivation for using such a model are two fold:

i. Energy consumption must reflect to some degree the energy savings created by technical changes in the energy utilization and these changes are evidences of learning.

ii. To incorporate dynamics within the framework through the use of cumulative variables.

Thus, cumulative variables generated from time series data are used so that changes due to learning at the margin may be captured and its effects are reflected at the margins.

3.2.1 **The Model**

The model we adopt is given by,

$$\overset{\approx}{W}_t = \frac{\overset{\approx}{D}_t}{\overset{\approx}{Y}_t} \qquad (17)$$

where,

$\overset{\approx}{D}_t$ = cumulative consumption of electricity in t^{th} period.

$\overset{\approx}{Y}_t$ = cumulative GDP in t^{th} period.

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[8] This is a common experience in the steel industry. As stocks and inventories accumulate, knowledge accumulates and its impact is felt at the margin.

$\overset{\approx}{D}_t/\overset{\approx}{Y}_t$ can be defined as cumulative intensity of consumption of electricity.

$\overset{\approx}{W}_t = L(.)$ is the learning function.

The most widely used learning function[9] is,

$$L(\overset{\approx}{Y}_t) = A\,\overset{\approx}{Y}_t^{\,b} \qquad (18)$$

where

$$b = \frac{\ln\Theta}{\ln 2}\ , \text{ i.e., } \Theta = 2^b$$

and,

Θ = learning rate

$1-\Theta$ = rate of progress.

using this learning function in our model we obtain,

$$\frac{\overset{\approx}{D}_t}{\overset{\approx}{Y}_t} = L(\overset{\approx}{Y}_t) = A(\overset{\approx}{Y}_t)^b \qquad (19)$$

therefore,

$$\overset{\approx}{D}_t = \overset{\approx}{Y}_t \cdot L(\overset{\approx}{Y}_t)$$

Then,

$$\frac{d}{dt}(\overset{\approx}{D}_t) = \frac{d}{dt}\left[\overset{\approx}{Y}_t \cdot L(\overset{\approx}{Y}_t)\right] \qquad (20)$$

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[9] A.Belkaouni, "The Learning Curve: A Management Accounting Tool", (1st ed.), Quorum Books, London, 1986, pg. 245.

or,

$$D_t = L'\,(\overset{\approx}{Y}_t)\ .\ \frac{d\overset{\approx}{Y}_t}{dt}\ .\ \overset{\approx}{Y}_t + L(\overset{\approx}{Y}_t)\ .\ \frac{d\overset{\approx}{Y}_t}{dt},$$

where

D_t = total consumption in period t

and Y_t = GDP in period t.

or,

$$D_t = Y_t\ [\ L'\,(\overset{\approx}{Y}_t)\ .\ \overset{\approx}{Y}_t + L(\overset{\approx}{Y}_t)\ ] \qquad (21)$$

Now from equation (18) $L(\overset{\approx}{Y}_t) = A\overset{\approx}{Y}_t^{\,b}$,

therefore,

$$L'\,(\overset{\approx}{Y}_t) = \frac{A.b.\overset{\approx}{Y}_t^{\,b}}{\overset{\approx}{Y}_t} \qquad (22)$$

therefore,

$$L'\,(\overset{\approx}{Y}_t) = \frac{b.L\,(\overset{\approx}{Y}_t)}{\overset{\approx}{Y}_t} \qquad (23)$$

Substituting equation (23) in equation (21) we obtain

$$D_t = Y_t\ [\ b.\ L(\overset{\approx}{Y}_t) + L\,(\overset{\approx}{Y}_t)\ ]$$

or,

$$D_t = (1+b)\ .\ L(\overset{\approx}{Y}_t)\ .\ Y_t$$

or,

$$D_t = A(1+b) . \overset{\approx}{Y}{}_t^{b} . Y_t \tag{24}$$

therefore

$$D_t = K . (\overset{\approx}{Y}_t)^b . Y_t, \quad \text{where} \quad K = A(1+b) \tag{25}$$

Equation (25) is the demand function for electricity.

Now carrying out log-transformation we can linearise equation (25) to obtain,

$$\ln (D_t/Y_t) = a + b \ln\overset{\approx}{Y}_t \tag{26}$$

where, $a = \ln K$

Similarly equation (19) may be written as,

$$\ln (\overset{\approx}{D}_t/\overset{\approx}{Y}_t) = a_1 + b \ln(\overset{\approx}{Y}_t) \tag{27}$$

where

$a_1 = \ln A$

In order to make the model estimable we need to specify the disturbance term. Thus, equations (26) and (27) may be written as,

$$\ln (D_t/Y_t) = a + b \ln\overset{\approx}{Y}_t + u_t \quad , \; u_t = \text{error term} \tag{28}$$

and

$$\ln(\overset{\approx}{D}_t/\overset{\approx}{Y}_t) = a_1 + b \ln\overset{\approx}{Y}_t + v_t \, , \quad v_t = \text{error term} \qquad (29)$$

Another model that we have considered here is a variant of the above model; with aggregate variables being replaced by per capita variables.

Therefore, if we define:

d_t = per capita consumption in period t

$\overset{\approx}{d}_t$ = cumulative per capita consumption in period t

y_t = per capita income in period t

$\overset{\approx}{y}_t$ = cumulative per capita income in period t

then, we have,

$$\ln(d_t/y_t) = a_2 + b_1 \ln\overset{\approx}{y}_t + e_t \, , \quad e_t = \text{error term} \qquad (30)$$

and

$$\ln(\overset{\approx}{d}_t/\overset{\approx}{y}_t) = a_3 + b_1 \ln\overset{\approx}{y}_t + \epsilon_t \, , \quad \epsilon_t = \text{error term} \qquad (31)$$

OLS estimation technique is used to estimate equations (28) to (31). But before we state the results, let us discuss the variables and data used to estimate the equations in the next subsection.

3.2.2 Data and Variables

In order to estimate the models we have used time series data, spanning the period 1960-61 to 1990-91. The models require data on cumulative GDP, cumulative total consumption of electricity, GDP, total consumption of electricity, per capita GDP, per capita electricity consumption, cumulative per capita GDP and finally cumulative per capita consumption of electricity. Since, all the models considered in this chapter, are used to forecast macro level electricity requirements, the total consumption of electricity data are taken as sum of consumption from both utilities and non-utilities.

Now, CEA's General Review provides total consumption data for electricity for utilities only. But the way we defined aggregate consumption here, i.e., as sum of utilities and non-utilities, we need to generate this variable. However, General Review provides with per capita aggregate consumption data which is inclusive of utilities and non-utilities. We make use of this data along with the population figures taken, from National Accounts Statistics (NAS), to generate aggregate consumption figures. In order to check for the validity of using these figures we compare these aggregate consumption figures with those generated from another source. Economic Survey (1992-93) provides with figures for electricity generation for the years 1975-76 to 1990-91 (complete series). Hence, we have assumed 10% as the auxiliary loss and deducted this loss from total generation of non-utilities to arrive at, approximate figures for, consumption of non-utilities. On the other hand, we deduct General Review figures of consumption of utilities from aggregate utility and non-utility consumption figures, generated from per capita consumption figures of General Review. The two consumption from non-utilities are compared to observe that there is little discrepancy. So, we proceed with the figures generated from General Review data and NAS data.

GDP at constant 1980-81 prices are taken from Economic Survey for the same period as above. Per capita GDP figures are generated using GDP and population data.

By taking cumulative values for the per capita electricity consumption, per capita GDP, GDP and aggregate consumption of electricity we arrive at the data for cumulative variables (refer Annexure Table S1).

3.2.3 Estimation and Results

On estimating equation (28) by OLS, it is observed that independent variables have high explanatory power. Both the coefficients of the equation are significant. But the estimated disturbance terms show existence of autocorrelation. The results are tabulated in Table 3.6.

Table 3.6

Regression Results

Dependent Variable = ln (D_t/Y_t)

$\bar{R}^2 = 0.9794$

Variable	Coefficients	t-statistics	2 tail significance
Constant	-7.78	-59.046	0.000
$\ln (\overset{\approx}{Y}_t)$	0.36	37.803	0.000

D.W. = 0.667

in order to take care of the existence of autocorrelation in the model we carry out correction for AR(1) to the equation (28). The results have improved as a consequence with a better goodness of fit and with no autocorrelation present in the model. The autocorrelation coefficient is significant at 5% level. This shows that a first order autocorrelation was present in the initial model. The coefficient estimates are also significant in the newly defined scheme. The results are tabulated in 3.7.

Table 3.7

Regression Results

Dependent Variable = ln (D_t/Y_t)

$\bar{R}^2 = 0.9925$

Variable	Coefficients	t-statistics	2 tail significance
Constant	-8.426	-37.786	0.000
ln $(\overset{\approx}{Y}_t)$	0.404	25.698	0.000
AR(1)	0.472	0.096	0.000

D.W. = 2.416

Thus, estimated equation (25) can be written as,

$$D_t = \frac{2.2}{10^4} \quad (\overset{\approx}{Y}_t)^{0.404} \quad \cdot Y_t$$

On estimating equation (29) by OLS, it is once again observed that the model has a high goodness of fit. But there is existence of autocorrelation in the model, as the D-W. statistics, rejects the null hypothesis in favour of existence of positive autocorrelation. Still the estimated coefficients are highly significant at 5% level as shown in Table 3.8. However, autocorrelation is corrected by applying correction for first order autocorrelation i.e., AR(1). The $\bar{R}^2$ shows improvement and the estimation still yields significant estimates of the coefficients. The results are given in Tables 3.8 and 3.9 respectively for uncorrected and corrected AR(1).

Table 3.8

Regression Results

Dependent Variable = ln $(\overset{\approx}{D}_t/\overset{\approx}{Y}_t)$

$\bar{R}^2 = 0.9613$

Variable	Coefficients	t-statistics	2 tail significance
Constant	-6.888	-49.036	0.000
ln $(\overset{\approx}{Y}_t)$	0.276	27.303	0.000

D.W. = 0.241

Table 3.9

Regression Results

Dependent Variable = ln $(\overset{\approx}{D}_t/\overset{\approx}{Y}_t)$

$\bar{R}^2 = 0.9997$

Variable	Coefficients	t-statistics	2 tail significance
Constant	-8.229	-85.024	0.000
ln $(\overset{\approx}{Y}_t)$	0.369	55.435	0.000
AR(1)	0.701	41.049	0.000

D.W. = 1.861

The estimated equation (19) can be written, using estimates from table 3.9, as:

$$\frac{\overset{\approx}{D}_t}{\overset{\approx}{Y}_t} = \frac{2.6}{10^4} (\overset{\approx}{Y}_t)^{0.369}$$

The estimated equation (19) has a lower standard errors and higher R^2 compared to equation (25). Therefore chances of committing type I error is small in case of equation (19) compared to equation (25). However, since the difference is not much, we may use either of the models for estimation. We make the decision on the basis of a statistical analysis as will be explained later. From the estimated demand equation we can obtain estimates of learning rate and rate of progress.

We now turn to the results obtained from estimating equations (30) and (31). The estimation results pertaining to equation (30) on applying OLS show that the explanatory variables have a fairly high goodness of fit but the D.W. statistic shows the existence of autocorrelation in the model. As a consequence an AR(1) correction procedure was carried out under the assumption that the OLS residuals and their lagged values are linearly related. This yields us more than satisfactory results showing that our assumption of a linear relationship between lagged residuals is valid. The results for estimates are tabulated in Tables 3.10 and 3.11 for without and with corrected AR(1) respectively. As is observed the coefficient estimates are significant at 5% level of significance.

Table 3.10

Regression Results

Dependent Variable = ln (d_t/y_t)

$\bar{R}^2 = 0.9668$

Variable	Coefficients	t-statistics	2 tail significance
Constant	-6.750	-50.494	0.000
ln $(\overset{\approx}{y}_t)$	0.398	29.591	0.000

D.W. = 0.483

Table 3.11

Regression Results

Dependent Variable = ln (d_t/y_t)

$\bar{R}^2 = 0.9917$

Variable	Coefficients	t-statistics	2 tail significance
Constant	-7.661	-28.538	0.000
ln $(\overset{\approx}{y}_t)$	0.487	18.602	0.000
AR(1)	0.559	7.5799	0.000

D.W. = 2.439

The results obtained from estimating equation (31) by applying OLS to the equation shows that the explanatory variables explain about 95% of the total variation in the dependent variable. However, the D-W test statistic shows that we cannot reject the null hypothesis of non-existence of autocorrelation; even though, the parameter estimates obtained are significant at 5% level of significance. These results are tabulated in Table 3.12.

Table 3.12

Regression Results

Dependent Variable = ln $(\overset{\approx}{d}_t/\overset{\approx}{y}_t)$

$\bar{R}^2 = 0.9487$

Variable	Coefficients	t-statistics	2 tail significance
Constant	-5.935	-48.967	0.000
ln $(\overset{\approx}{y}_t)$	0.288	23.584	0.000

D.W. = 0.226

Thus, on assuming a linear relationship between the OLS residual and their lagged values we carry out the AR(1) correction procedure. This improves the results considerably showing that our assumption of OLS residual and their lagged values being linearly related is valid. The goodness of fit, R^2, considerably improves, with the D-W statistic showing that the existence of first order autocorrelation is corrected. Moreover, the coefficient estimates are significant at 5% level of significance. The results are tabulated in Table 3.13.

Table 3.13

Regression Results

Dependent Variable = ln $(\overset{\approx}{d}_t/\overset{\approx}{y}_t)$

$\bar{R}^2 = 0.9996$

Variable	Coefficients	t-statistics	2 tail significance
Constant	-7.299	-74.694	0.000
ln $(\overset{\approx}{y}_t)$	0.419	45.096	0.000
AR(1)	0.716	49.037	0.000

D.W. = 1.671

The estimated equation (3) may be written as:

$$\frac{d_t}{y_t} = \frac{4.7}{10^4} \cdot (\overset{\approx}{y}_t)^{0.48} \qquad (32)$$

and estimated equation (31) may be written as:

$$\frac{\overset{\approx}{d}_t}{\overset{\approx}{y}_t} = \frac{6.8}{10^4} (\overset{\approx}{y}_t)^{0.419} \qquad (33)$$

Even though both equations (30) and (31) yield high R^2 on estimation, the estimated standard error of the coefficients is lower in case of equation (31) compared to equation (30). The T-statistics of the coefficients of equation (31) are larger than those of equation (30) showing that chances of committing type I error in case of equation (31) are less. Since both the equations exhibit a very high $\bar{R}^2$, we employ both the estimated equations to carry out forecasting for the terminal years of the Plan periods.

The per capita demand equation has been estimated as given in equation (32). From equation (33) also the demand function may be obtained by first order differencing. The learning rates may be estimated from the estimates of the coefficients.

By changing our assumption of the disturbance terms and assuming it to be additive, we have also carried out Non Linear Least Square (NLS) estimation procedure to the above models. But results did not improve for any of the equations estimated. So we are not mentioning these results here.

The learning model shows the adaptability of the economy to increasing electricity requirement through the process of learning. The results obtained from the estimation of the models confirms our belief that the intensity of electricity consumption in the economy and GDP are quite strongly related and GDP is a major determinant in deciding the future consumption requirement and pattern of the economy. The estimates also reveal that cumulative GDP has its impact at the margin on the consumption of electricity as there exists a less than proportional relationship between intensity of consumption and cumulative GDP.

Now that we have strong reasons to believe that there might exist a strong relationship between intensity of consumption and GDP, we formulate a model which incorporates intensity of consumption and GDP.

3.3 Translog Form Model

For long term forecasting it would be appropriate to use a technique that relates consumption in physical terms to some basic determinants, such as GDP, population etc. So intensity of electricity consumption may be used within this framework. Now, for quite some time we have been using the term 'Intensity' of consumption without formally defining it. 'Intensity' of electricity consumption is defined as the ratio of consumption of electricity in physical units to GDP in value terms.

For long run forecasting GDP seems to favour the intensity as a forecasting tool, since we are essentially examining macroeconomic trends with time series data for electricity requirement.

Malenbaum (1973)[10] showed that intensity of energy consumption plotted against per capita income exhibits a skewed bell shaped pattern for the industrialized economies. Thus, one can possibly think of intensity as a function of per capita income where the function is a log normal functional form.

In an attempt to preserve the robustness of this log normal type pattern, Harris and Jeon (1987)[11] showed that representing the intensity pattern by a log normal functional form model implies a demand model in which income elasticity of demand varies with the income level. This is based upon the equivalence of log normal and translog form models. Such models may be applied to study the electricity demand behaviour in Indian economy. Studying the pattern of the movement of intensity against per capita income for the last three decades, we observe that there is a tendency for intensity to behave the way described above. So for long term projection we may consider this phenomenon and incorporate this in a model for projection.

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[10] W. Malenbaum, "Material Requirements in the United States and Abroad in the year 2000", University of Pensylvania Press, Philadelphia, PA; 1973.

[11] D.P. Harris and G.J. Jeon, "Improved Methods for Long Range Forecasting", Tucson, Mineral Economics, Department of Mining and Geological Engineering, College of Engineering and Mines, University of Arizona, Research Project, 1987.

3.3.1 Model

According to Malenbaum (1973), intensity of energy usage, IE, is a function of per capita income, y, and is given as:

$$IE = \frac{K}{y\sigma\surd(2\pi)} \cdot \exp\left[- \frac{1}{2\sigma^2} (\ln y-\mu)^2 \right] \qquad (34)$$

where, K, μ and σ^2 are lognormal functional form parameters.

By logarithmic transformation to equation (34) we obtain,

$$\ln IE = \ln K - \ln \sigma \surd(2\pi) - \ln y - \left(\frac{1}{2\sigma^2} (\ln y-\mu)^2 \right) \qquad (35)$$

or,

$$\ln IE = \ln K - \ln \sigma\surd 2\pi - \frac{\mu^2}{2\sigma^2} - \ln y \left(1- \frac{\mu}{\sigma^2} \right) - \frac{1}{2\sigma^2} (\ln y)^2 \qquad (35')$$

Let,

$$\ln A = \ln K - \ln \sigma \surd 2\pi - \frac{\mu^2}{2\sigma^2} \qquad (36)$$

$$\beta_0 = - (1 - \mu/\sigma^2) \qquad (37)$$

$$\beta_1 = - 1/2\sigma^2 \qquad (38)$$

Now, substituting (36) to (38) in equation (35') we obtain,

$$\ln IE = \ln A + \beta_0 \ln y + \beta_1 (\ln y)^2 \qquad (39)$$

therefore,

$$IE = A(y)^{\beta_0+\beta_1 \ln y} \tag{40}$$

Equation (41) is analogous to a simple income-demand model, where elasticity varies with the level of income. Thus, demand takes a flexible functional form. But this function is based on the equivalence of lognormal and translog forms. Now, accepting this demand function, the income-elasticity of demand and income elasticity of intensity may be obtained as:

Income elasticity of per capita demand = $1+\beta_0+2\beta_1 \ln y$ (42)

Income elasticity of intensity = $\beta_0+2\beta_1 \ln y$ (43)

Now, the functional form (40) may be represented by,

$$IE = T(y;\beta) \;,, \text{ where } \beta = (A,\ \beta_0,\beta_1).$$

The derived demand theory suggests that a more complete and comprehensive description of IE would include own price, substitute price and other parameters.

We consider here two such forms:

(a) $IE = T\ (y,\ P,\ P_s;\ \Omega)$

and

(b) $IE = T\ (y,\ P,\ P_s,\ t;\ \Omega)$

where, Ω = vector of parameters.

These two cases may be written as:

(a) $$\ln IE = \alpha_0 + \alpha_1 \ln y + \alpha_2 \ln P + \alpha_3 \ln P_s + \beta_1 (\ln y)^2 + \beta_2 (\ln y)(\ln P) + \beta_3 (\ln y)(\ln P_s) + \beta_4 (\ln P)^2 + \beta_5 (\ln P)(\ln P_s) + \beta_6 (\ln P_s)^2 \quad (44)$$

(b) $$\ln IE = \alpha_0 + \alpha_1 \ln y + \alpha_2 \ln P + \alpha_3 \ln P_s + \alpha_4 \ln t + \beta_1 (\ln y)^2 + \beta_2 (\ln y)(\ln P) + \beta_3 (\ln y)(\ln P_s) + \beta_4 (\ln y)(\ln t) + \beta_5 (\ln P)^2 + \beta_6 (\ln P)(\ln P_s) + \beta_7 (\ln P)(\ln t) + \beta_8 (\ln P_s)^2 + \beta_9 (\ln P_s)(\ln t) + \beta_{10} (\ln t)^2 \quad (45)$$

Before we discuss the estimation techniques and results it would appropriate to discuss the data used to estimate the above two cases.

3.3.2 Data and Variables

For estimation of the above two cases, we have used time series data for the period 1960-61 to 1990-91. Data is required for per capita GDP, per capita consumption of electricity, price of electricity and price of substitute.

The data for per capita aggregate consumption of electricity and per capita GDP have been taken from same sources and generated in the same way as described in sections 3.1.2 and 3.2.2.

Since we are considering aggregate or macro demand models, so for price variables (both own and substitute prices) we have considered wholesale price indices of electricity and mineral oil. these indices are taken from India Database. The Economy, vol. I (1990) and RBI Bulletin (various years). Price indices between 1960-61 and 1988-89 had base 1970-71 as 100 and another series was available which was for 1981-82 to 1990-91 with base

1981-82 as 100. But we needed a complete series from 1960-61 to 1990-91. In order to combine the two series we changed the base of first series (1960-61 to 1988-89) from 1970-71 as 100 to 1981-82 as 100. Then we combined the two series to obtain a complete time series. But for the sake of simplicity we have ignored the fact that both the series had different weighting diagram. After combining the two series to obtain a complete series of wholesale price indices between 1960-61 and 1990-91 we changed the base to 1980-81 as 100. It is always suggestible that we use relative pries in demand models. So we proceed to obtain relative prices using GDP deflator at '80-'81 prices implicit in CSO data. Such provided by CSO. It is common practice to use relative prices in demand models reveal whether commodities have become expensive or cheap. Thus, here GDP is taken as the numeraire. The time variable is generated manually (refer Annexure Table S2).

3.3.3 Estimation and Results

In order to carry out estimation and make it simple we have considered an additive disturbance term to both the cases, represented by equations (44) and (45).

Carrying out OLS to both equations (44) and (45) we observe that equation (44) can be estimated but there is existence of strong multicollinearity in the model. The symptoms for multicollinearity being very high R^2 and highly insignificant T-statistics for most of the coefficient estimates. Besides, this the multiple correlation coefficients are also very high between the explanatory variables. The OLS result is tabulated in Table 3.14.

Since the D-W statistics lies in the zone of ignorance, we had to carry out a non-parametric runs test for the randomness of disturbance term. The hypothesis did not get rejected. But the problem is that existence of multicollinearity invalidates OLS estimation of the model.

Table 3.14

Regression Results

Dependent Variable = lnIE

$\bar{R}^2 = 0.9415$

Variable	Coefficients	2 tail significance
Constant	214.56	0.185
lny	-39.21	0.232
lnP	-27.33	0.312
$\ln P_s$	-5.16	0.647
$(\ln y)^2$	-0.06	0.971
(lny)(lnP)	9.38	0.014
$(\ln y)(\ln P_s)$	-0.43	0.829
$(\ln P)^2$	-6.68	0.011
$(\ln P)(\ln P_s)$	4.11	0.063
$(\ln P_s)^2$	-1.16	0.210

D.W. = 1.1857 (zone of ignorance at 1% level of significance).

In the case of equation (45), OLS estimation could not be carried because of the presence of a near singular matrix of explanatory variables. This again is a problem of the existence of multicollinearity in the model.

So we carried out stepwise regression[12] to the above two cases, to take account of multicollinearity (refer Appendix 3.A.2), in the data and estimate the coefficients of the best set of explanatory variables. But to our dismay, the estimated model is left with just one or two explanatory variables besides the intercept term. Thus, a lot of information is lost in this procedure. As an illustration we tabulate the result of the stepwise regression applied to equation (45), given in Table 3.15.

Table 3.15

Regression Results

Dependent Variable = lnIE

$\bar{R}^2 = 0.9943$

Variable	Coefficients	2 tail significance
Constant	-3.06	0.000
$(\ln t)^2$	0.11	0.000
$(\ln P_s)(\ln y)$	-0.02	0.000

Besides this loss of information, most econometricians criticize stepwise procedure on grounds that it yields results which give unnecessary importance to few variables and often rejects some important explanatory variables on grounds of high R_i^2 and R^2. Thus, variables accepted or rejected are not on the basis of any economic theory. So, we have finally dropped considering stepwise regression estimates for our analysis. Moreover, since most of the variables are dropped, through

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[12] A. S. Golberg and D.B. Jochems, "Note on Stepwise Least Squares", Journal of American Statistical Association, March 1961, pgs. 105-110.

application of this technique, the model no more retains its original form and the relationship becomes difficult to be explained.

Rejecting stepwise regression procedure, we once again went back to the position where we started; OLS estimation is invalidated by the presence of multicollinearity and have to use some estimation technique which can be applied to both the models and which will retain most, if not all, the variables thereby retaining maximum information, at the same time explaining most of the variation in the dependent variable.

So finally, we took recourse to the application of principal component method of estimation (refer appendix 3.A.3). But in this context it should be mentioned that application of this method has been questioned by many on the grounds that it uses less information from the sample than the OLS method. Moreover, it requires construction of artificial orthogonal variables (from the explanatory variables) to which specific economic meaning cannot be attached. But given the inability of OLS technique in presence of multicollinearity, we do not have any other choice. At least it utilizes all the variables. Hence it contains more information than stepwise procedure and it retains the model in its original form.

Now applying principal component method to the model represented by equation (44) and applying Kaiser's decision rule, we get principal components P_1 and P_2 where P_1 and P_2 explain together 90.3% of the total variation .

So, equation (44) may be now written as,

$$\ln IE = b_0 + b_1 P_1 + b_2 P_2 + u_1 \qquad (46)$$

where u_1 = error term.

Eigenvalue of P_1 = 6.4955

Eigenvalue of P_2 = 1.6294

Now, OLS estimation technique is applied to equation (46) to obtain the results tabulated in Table 3.16.

Table 3.16

Regression Results

Dependent Variable = ln IE

$\bar{R}^2 = 0.8269$

Variable	Coefficients	T-statistics	2 tail significance
Constant	-2.810	-102.396	0.000
P_1	0.333	11.916	0.000
P_2	-0.051	-1.812	0.081

D.W. = 0.739.

But this shows inspite of high R^2 and fairly significant coefficient estimates, there is existence of autocorrelation. So carrying out AR(1) correction procedure to this model on the assumption of a linear relationship between OLS residuals and their lagged values, we observe the results to improve considerably. The results are given in Table 3.17.

We have carried out the principal component analysis in SPSS/PC+^{TM} V2.0, which provides with the factor coefficient matrix. Therefore, with the help of this, mean and standard deviation of each variable, and the estimates tabulated in Table 3.17 we derive the coefficient estimates of the equation 44 as:

Table 3.17

Regression Results

Dependent Variable = ln IE

$\bar{R}^2 = 0.9297$

Variable	Coefficients	T-statistics	2 tail significance
Constant	-2.732	-3.592	0.001
P_1	0.186	2.672	0.013
P_2	0.079	2.713	0.012
AR(1)	0.974	13.140	0.000

D.W. = 1.523 (no autocorrelation at 1% level of significance).

$$\begin{aligned} \ln(IE) = {} & -7.850 - 0.054(\ln y) + 0.364(\ln P) - 0.019(\ln P_s) \\ & - 0.014(\ln y)^2 + 0.015(\ln y)(\ln P) - 0.003(\ln y)(\ln P_s) \\ & + 0.04(\ln P)^2 + 0.005(\ln P)(\ln P_s) \\ & - 0.002(\ln P_s)^2 \end{aligned} \tag{47}$$

Then we obtain the elasticities from the estimated equation (47), given in Table 3.18.

Table 3.18

Elasticities Estimated

	$\delta \ln IE/\delta \ln y$	$\delta \ln IE/\delta \ln P$	$\delta \ln IE/\delta l P_s$
1960-61	-0.055	1.047	-0.034
1970-71	-0.058	0.853	-0.035
1980-81	-0.059	0.536	-0.036
1990-91	-0.060	0.869	-0.036

The elasticities so obtained are not too encouraging as can be seen from the above table. So to check for the stability of the model, we go to estimate the model with a deliberately restrictive sample, only to find insignificant estimates for P_1 and P_2. Using just P_1 in the model and carrying out regression we again obtained insignificant estimate with a restricted sample (1960-1975), at 5% level of significance. As we won't be using this, we are not stating the result here. So, considering the inherent instability in the model we reject this model and move on to estimate equation (45) with principal component method.

Applying Kaiser's test we observe that only two principal components are retained, say, P_3 and P_4

Eigen value of $P_3 = 9.7979$
Eigen value of $P_4 = 3.0239$

Together they explain 91.6 per cent of the total variation. Using P_3 and P_4 we transform equation (45) to obtain:

$$\ln IE = b + b_3 P_3 + b_4 P_4 + u, \quad \text{where } u = \text{error term} \qquad (48)$$

The results obtained on applying OLS to equation (48), we observe significant at 5% level of significance, with a high $\bar{R}^2=0.9725$ and no autocorrelation in the model as D.W.=1.166. The result given in Appendix 3.A.4.

But faced with the problem of instability in the first case, we deliberately restrict the sample, 1960-1975 and find that coefficient of P_4 is insignificant at 5% level of significance. The model does not seem to yield stable coefficient estimates.

So in an attempt to obtain better results we used just the principal component P_3 which explains 70% of the total variation. The equation (45) may be alternatively written as:

$$\ln IE = m_0 + m_1 P_3 + u, \quad \text{where } u = \text{error term} \qquad (49)$$

On carrying out OLS to equation (49) we obtain significant estimate of the coefficient with a high $\bar{R}^2$ but model exhibiting autocorrelation in the residuals. The result is tabulated in Table 3.19.

Table 3.19

Regression Results

Dependent Variable = lnIE

$\bar{R}^2$ = 0.9624

Variable	Coefficients	t-statistics	2 tail significance
Constant	-2.810	-219.769	0.000
P_3	0.361	27.734	0.000

D.W. = 0.933

Assuming a linear relationship between the OLS residuals and their lagged values, we carry out AR(1) correction procedure to obtain quite satisfactory results. Thus, our assumption is validated and we obtain significant estimates. The result is tabulated in Table 3.20.

To check for the stability of the model, if we use this principal component, we deliberately withheld the sample and used the sample 1960-61 to 1975-76 to obtain estimates. It turned out that the model estimates are stable as the results of the restricted sample are quite encouraging. The result is tabulated in Table 3.21.

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Table 3.20

Regression Results

Dependent Variable = lnIE

$\bar{R}^2 = 0.9664$

Variable	Coefficients	t-statistics	2 tail significance
Constant	-2.810	-116.928	0.000
P_3	0.352	12.459	0.000
AR(1)	0.517	3.180	0.004

D.W. = 1.853

Table 3.21

Regression Results

Dependent Variable = lnIE

$\bar{R}^2 = 0.9673$

Variable	Coefficients	t-statistics	2 tail significance
Constant	-2.874	-177.141	0.000
P_3	0.305	21.101	0.000

D.W. = 1.597

Therefore, we have enough good reasons to accept this particular case, for the model represented by equation (45), where we operate with only the first of the two principal components satisfying Kaiser's test.

From the estimated Coefficients of the transformed model given in Table 3.20, we can estimate the coefficient of the original equation (45) as:

$$\begin{aligned} \ln IE = & -3.936 + 0.206 \ln y - 0.376 \ln P + 0.071 \ln P_s \\ & + 0.061 \ln t + 0.014 (\ln y)^2 - 0.002 (\ln y)(\ln P) \\ & + 0.009 (\ln y)(\ln P_s) + 0.008 (\ln y)(\ln t) \\ & - 0.042(\ln P)^2 + 0.003 (\ln P)(\ln P_s) + 0.013 (\ln P)(\ln t) \\ & + 0.009(\ln P_s)^2 + 0.012 (\ln P_s)(\ln t) \\ & + 0.013 (\ln t)^2 \end{aligned} \qquad (50)$$

Now that we have obtained estimates of the original equation we can easily obtain the elasticities of intensity of consumption with respect to income, price of electricity, price of substitute and time. Here time variable is used as a proxy for all those variables not considered explicitly in model but which have its impact over time, including the trend factor involved. Factors such as technological change, extent of rural electrification, structural change of the economy, population, urbanization etc., all involve time trend. Such factors are captured in the time variable. Since, we have used time series data, the elasticities so obtained should be short run elasticities. This case represented by equation (45) has the advantage over equation (44) that, this is a more general case compared to the case represented by equation (44); in addition to the fact that this is a more stable case.

However, it suffers from the severe criticism that the principal component used accounts for only 70% of the total variation, which implies that a lot of information is lost if we use this model; besides the usual criticisms of principal components. But, since we do not have much of an alternative we accept this particular case, represented by equation (4), for projection.

The elasticities obtained from equation (50) is tabulated in Table 3.22. The interesting fact is that the elasticities conform to the usual economic theory. And as these elasticities are flexible, it can be observed from the table as to how elasticities have changed over the decades. As the table shows, intensity of consumption of electricity has become more and more elastic with respect to per capita GDP over the decades, though still less than unity. Intensity has become more and more inelastic with respect to prices over the decades and confirms the insensitivity of consumption of electricity to price changes. This obviously, requires reassessment of tariff policy in the economy. Cross price elasticities though less than unity are increasing over the decades, showing more and more substitution being taking place in the economy over the decades. It also shows that the rising oil prices over the decades have a positive impact on the intensity of electricity consumption in the economy. But because of the existing technology and the oil intensiveness of some sectors such as the transport sector, oil prices have a less than proportional impact on the intensity. The less than proportional relationship may also be accounted for, by the highly efficient form of energy provided by the electricity. The most interesting revelation is provided by the elasticity with respect to trend factors. The trend factors not only have a positive impact on intensity of consumption of electricity but have a more than proportionate relationship in 1990-91. It has been increasing throughout over the decades showing that with development and industrialization of the economy, the economy has become more and more electricity intensive. This could be a result of increased pace of rural electrification, increasing population and increased urbanization mainly. Increasing mechanization in agricultural sector and fast replacement of commercial energy for non-commercial energy, with increasing per capita income both in rural and urban sectors could also explain this behaviour partially. A combined impact of all trend factors have a strong influence on the electricity intensiveness of the economy.

Table 3.22

Elasticities Estimated

	$\delta lnlE/\delta lny$	$\delta lnlE/\delta lnP$	$\delta lnlE/\delta lnPs$	$\delta lnlE/\delta lnt$
1960-61	0.445	-0.757	0.236	0.254
1970-71	0.528	-0.614	0.353	0.511
1980-81	0.616	-0.486	0.485	0.780
1990-91	0.703	-0.362	0.605	1.04

Having discussed the models to be considered for the purpose of projection in detail, we now move on to our next section where we discuss the macro assumptions made for the purpose of projection. We also forecast future electricity demand on the basis of that model which best satisfies the statistical and economic requirements among the models considered for the purpose of forecasting.

3.4 Projections

Now that we have estimated all the models, the obvious question that arises is that, which model is most suitable for the purpose of projection of future consumption of electricity. The choice of the model should have both an 'Economic' as well as a 'Statistical' basis. Of the three models considered - simple expectation models, learning models and translog form models - there is no economic basis to reject any one of them. As already explained, in quite detail, all three are quite plausible and are basically alternative ways of looking at the demand, which are not mutually contradictory. Besides having strong economic rationale, the regression results of all the models are quite acceptable. Among the various alternatives of the models we have considered those corresponding equations (28) to (31), (50), (7) and (12), because these yields us with the most optimistic results. Since there is no economic basis to choose among these models and their variants, we employ statistical technique to choose the most suitable one from the above mentioned models.

Several statistical measures have been proposed for assessing the predictive accuracy of forecasting models.[13] Such measures involve evaluation of 'ex post forecasts', i.e., forecasting for dependent variables whose actual values are known and then compare between the actual and forecasted values. Such a measure involves finding the 'Average Absolute Errors' (AAE), also called 'Mean Absolute Error' method.

$$AAE = 1/n_o \left(\Sigma_i \mid y_i - \hat{y}_i \mid \right) \qquad (51)$$

where,

y_i = dependent variable of ith observation (actual observed value).

$\hat{y}_i$ = forecasted value of y_i

n_o = number of periods being forecasted.

According to the test, we choose that model which has the highest forecasting accuracy or the minimum average absolute error. It should be noted here that since our models involve different dependent variables; so to make them comparable, by some simple manipulation with forecasts of dependent variables we obtain

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[13] W.H. Greene, "Econometric Analysis", MacMillan Publishing Company, New Yark, 1991, pgs. 197-198.

forecasts of total consumption of electricity, for each model separately. Then compare the average absolute error of the total consumption, obtained through each model.

To carry out expost projections we deliberately restrict the sample to 1960-61 and 1975-76. Then we employ the same estimation techniques, as employed in the unrestricted sample, to each of the models and their variants. It was observed that the estimates still obtain satisfactory results, with significant coefficient estimates and a high R^2. Then using the estimates of the respective models we make forecasts for 1976-77 to 1990-91. Using equation (5) we obtain the AAE corresponding to each model. Finally, on the basis of minimum AAE we choose the model with highest predictive accuracy. Having isolated the model with minimum AAE, we use the model to carry out ex ante projection. In this context it should be mentioned that all the learning model variants have autocorrelated error terms and we carry out AR(1) corrections to obtain the estimates. Now, we use estimates from the model which takes into consideration the first order autocorrelation and these estimates are taken as in the final stage of iteration. In order to increase the accuracy of the projections we should take the estimated autocorrelation coefficient and the error term of the final model into consideration (refer Appendix 3.A.5).

The AAE corresponding to the various models and their variables are given in Table 3.23.

Now, the observed actual average total consumption of electricity between the period 1976-77 and 199-91 is 125045.91 MKWh.

Table 3.23

Model	AAE of total consumption
I.	
i. Represented by equation 7	5203.91 MKWh
ii. Represented by equation 12	14908.36 MKWh
II.	
i. Represented by equation 28	6177.76 MKWh
ii. Represented by equation 29	10833.97 MKWh
iii. Represented by equation 30	8962.33 MKWh
iv. Represented by equation 31	15163.67 MKWh
III.	
i. Represented by equation 50	21673.25 MKWh

Notes: I : Simple expectation models.
II : Learning models.
III : Translog form models.

Among the models we have considered here the simple expectation model represented by equation (7) yields the minimum average absolute error 5203.91 MKWh which is 4.16% of the average total consumption. So we accept this model as having the highest projective accuracy. Moreover, our estimation results with restrictive samples also were quite satisfactory which shows that the model is not really unstable. Moreover, we have also considered equations (28) and (30) of learning models for the purpose of projections. As given in Table 3.23, equation (28) yields an average absolute error of 6177.76 MKWh which is 4.93% of the average actual total consumption, and equation (30) yields an AAE of 8962.33 MKWh which is 7.16% of average actual total consumption. All these three cases yield an error less than 10% of actual average. Even though we have considered these three cases forex ante' projection for the terminal years of future plan periods, we finally take the projections made by the simple expectation model on the grounds of stability of the model[14] and

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[14] It is widely criticised, by many scholars, that dynamic adjustment models are quite unstable, besides having fixed adjustment factor. But in our case, probably because we are

minimum AAE. Projections with the two equations of learning model may be considered as sensitivity results i.e. compared to the projections made with equation (7), how the projected values differ when different methodologies are adopted. As the expectation model faces the criticism of a fixed adjustment factor, so does the learning model face the criticism of having a fixed learning rate.

In order to obtain forecasted values for total consumption for the terminal years of the 8th, 9th and 10th Plans respectively we make some assumption on macro aggregates, such as GDP, and demographic factors. Keeping in view the long term goals of the society and taking into account policies directed toward long run, the government has worked out a path of growth for the future, which is given in the 8th Plan Document, Government of India. For our projections we assumed these GDP growth rates for the 8th, 9th and 10th Plans to arrive at the GDP values in the terminal years of successive plans. We have assumed the actual growth rate between 1990-91 and 1991-92 as given in Economic Survey (1992-93).[15] The growth rates assumed for GDP are:

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considering a macro model, the model does not seem to be unstable. We have used various restricted samples to estimate the model, to find that this model still yields satisfactory results.

[15] The Economic Survey (1993-94) was published some time after we carried out our projections, so between 1991-92 and 1992-93 we could not assume their quick estimates and we had to somewhat arbitrarily assume a GDP growth rate of 5%, reasoning that, because of low growth rate of 1% between 1990-91 and 1991-92, the assumed 5-6% will never be achieved between 1991-92 and 1992-93. But later when Economic Survey (1993-94) came out we found the quick estimates of GDP growth rate to be 4% between 1991-92 and 1992-93. So, in that respect our projections of electricity consumption will be slightly on the higher side, than what it would have been if we considered the quick estimate between 1991-92 and 1992-93. However, for sectoral analysis we considered this quick estimate. It would have been better if we could have assumed this and reassessed the macro projections but paucity of time did not permit this.

Period	1992-93 to 1996-97	1996-97 to 2001-02	2001-02 to 2006-07
GDP growth rates (% p.a.)	5.6	6.05	6.51

Source: 8th Plan Document.

The 8th Plan document states that the envisaged population growth rate during the 8th Plan period will be 1.78%. We assume the population projections for terminal years, as given in the 8th Plan document and we tabulated in Table 3.24 below:

Table 3.24

Population Projections

(millions)

Year	1991-92	1996-97	2001-02	2006-07
Population	844	925	1006	1086

Source: 8th Plan Document.

The 8th, 9th and 10th Plans populations are obtained using the compounded growth rates, when terminal year populations are assumed as in Table 3.24.

On the basis of our assumptions on GDP and population therefore we make the forecasts of demand for electricity using estimated equations (7), (28) and (30), which are given in Table 3.25.

Table 3.25

Projections of Aggregate Consumption of Electricity (MKWh)

Year	Projections of aggregate consumption with		
	Learning model (eqn. 28)	Learning model (eqn. 30)	Expectation model (eqn.7)
1960-97	310413.2	281879.8	351578.9
2001-02	467853.5	418963.0	530643.7
2006-07	721950.5	637055.2	794309.9

Compared to the expectation model,[16] the learning model yields projections which are considerably on the lower side. A probable reason for the gap in projections is that they correspond to different approaches to modelling demand for electricity. The expectations model yields estimates that incorporate both short run and long run impacts as dynamics is explicitly build in the model. Since these estimates are used to make the projections, quite obviously such long run and short run features will be reflected in the projections too. Another probable reason for the difference could be the assumptions on which the learning model is formulated. The estimated fixed learning rate is quite high and is reflected in electricity consumption at the margins, causing

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[16] Even with expectations model we have tried two alternative ways of carrying out projections. First we carried out projection with the intercept term included and then again without the intercept term of equation (7). In order to make projections without intercept term, we projected the first differences and then from that we calculated the total consumption. But since the presence of the intercept term do not make much of difference, we preferred to retain the model in its original form and accepted the projection's made taking intercept term into account. Refer Appendix 3.A.6 for the projections.

projections to be on the lower side. Thus, essentially it is the difference in methodology which results in the divergence of projections. Moreover, unlike ex post projections in ex ante projections we have not taken residents and estimated correlation coefficients into account for projection with learning model. So the projections are not efficient enough. So we choose the projection made by expectation model.

Now, that we have made the alternate set of projections and decided which one to consider as the plausible future projection set refer Table 3.26, it would be appropriate to compare the projections of our study with some other study.

Table 3.26

Final Aggregate Projections of Present Study (MKWh)

Year	1990-91	1996-97	2001-02	2006-07
Projections	211568.4	351578.9	530643.7	794309.9

Note: These projections corresponding to simple expectation model are more consistent and stable compared to those corresponding to learning model.

As far as short term projections are concerned, comparing our final projections, i.e. those made with the expectation model, with those of CEA[17] it is evident that our projections are different from theirs. Whatever discrepancy is there may be explained by the fact that they have used a 'partial end use' method for projection and have taken a disaggregated approach by carrying out projections sector wise; besides taking a number of other factors, such as number of households, number of consumers per household, growth in connected load, consumption per

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[17] 14th Electric Power Survey of India, CEA, Government of India, March 1991.

KW of connected load, energisation of pumpsets, specification of pumpsets etc., into consideration. As a result the CEA projection is slightly higher than ours. The power requirements on a long term basis was made by CEA employing the trend approach. Thus, trend in overall energy requirement in a State and Union territories formed a basis of their projections. Long term forecasts were made by extrapolating the overall requirements for electricity for States and Union territories with 1994-95 as the base year. Therefore, compared to our projections the CEA projection are quite high for the terminal years of the 8th, 9th and 10th Plans. The method of interpolation on the basis of past trend, using 1994-95 as base year, adopted by CEA, caused the hiatus between our study projections and CEA's to keep on increasing. Also, the state level projections is a disaggregated approach taken by CEA, whereas we have adopted a completely aggregative approach here to make forecasts. The comparative figures are given in Table 3.27.

Table 3.27

Comparative Table (MKWh)

Year	1994-95	1996-97	2001-02	2006-07
Projections (CEA)	307355	416274	594520	824076
Projections (present study)	297233	351579	530644	794310

However, it should be pointed out that CEA considers only projection of utilities but our projections include both utilities and non utilities. So CEA's projection will be even higher if consumption of non utilities is included. The gap in the projections of the two studies are a consequence of the different methodology adopted and assumptions made.

Using the projections of aggregate consumption of electricity given in Table 3.26 we obtain the intensity of consumption of electricity and per capita consumption of electricity for the terminal years of the plans. They are given in Table 3.28.

Table 3.28

Year	Per capita consumption (KWh/person)	Intensity of consumption (KWh/Rs)
1996-97	380.09	0.126
2001-02	527.48	0.142
2006-07	731.41	0.155

The prognosticated figures show that intensity of consumption of electricity will go on increasing till 2006-07 but at a decreasing rate. Per capita consumption will be increasing too. Thus, per capita consumption is expected to grow at 6.77% p.a. between 1996-97 and 2001-02, and at 6.76% p.a. between 2001-02 and 2006-07.

3.5 Concluding Comments

The forecasted electricity requirements should be viewed as a normative demand for electricity in the terminal years of the Plan periods. So, what is really important is to take account of the direction of the change. As is quite evident from our projections, which has been conducted under fairly simplistic assumptions that the consumption requirements of electricity by the terminal year of the 10th Plan would be very large. The growth rate in electricity consumption during the 9th Plan is expected to be 8.58% p.a. and during the 10th Plan 8.40% p.a..

But the interesting factor is that the rate of growth of electricity consumption is much larger than the rate of growth of GDP over the entire projection period till 2006-07, even by our conservative estimates. This is bound to create pressures unless policy measures are taken, to meet the requirements, now. Even per capita consumption growth rates are much higher than the per capita GDP. In fact given the income elastic nature of per capita consumption, increased industrialization and improved standard of living will further increase consumption. The electricity intensity of the economy is very high and will increase further by 2006-07, as is evident from Table 3.28.

Even though we agree that GDP is an important long range forecasting tool for consumption of electricity, there are other factors which affect future consumption of electricity. We have not, till now, considered these factors in any of our models. While forecasting electricity requirements at the macro level. These factors have been implicitly assumed in our macro models but an explicit discussion of these other factors would make it clear, as how strongly these factors affect the consumption of electricity and shape the future pattern of consumption.

These factors include proportion of villages electrified, number of rural households having access to electricity and using electricity, ratio of urban population to total population, urbanization, development of rural non agricultural sector, etc.

As per the prediction of the 8th Plan, urban population is expected to be 224 million, i.e., 26.04% of total population in 1992. Urban population for the next decade represents the long term trend of urbanization. However, after 2001 the urban population is assumed to gradually decline in line with the assumed reduction in rate of natural increase. The share of urban population is expected to increase continuously and number of cities are also expected to increase. These cities happens to be the 'main hubs' of economic activity. Thus a fast pace of urbanization seems to be inevitable. This will create pressure to raise future electricity requirements.

With the continued development process, rural development will be encouraged too. This will cause the rural non-agricultural sector to develop and raise the rural income. More and more rural households then will be in a position to bear the costs of wiring etc., to have access to electricity. The development of rural non-agricultural sector will also require electricity. Moreover, the number of households having access to electricity will increase considerably by 2001-02, so that the number of rural consumers of electricity will increase. There is a very high possibility that by 2001-02 the number of households electrified will increase considerably. If our expectations are true then the electricity requirements in 2001-02 will be higher than our forecasts and even higher in 2006-07.

We have discussed in this chapter the various aggregative demand models considered with the objective of carrying out projections of electricity requirements in terminal years of the 8th, 9th and 10th Plan. However, the models used have their own drawbacks. Of the three models considered we have used two of them to make ex ante projections. The expectation model is often criticised for having a fixed adjustment rate. But, in order to incorporate dynamics into the model we ignored this. As far as stability of the model is concerned, our model fortunately survived the test. Learning models, on the other hand, have a fixed learning rate, which is also quite strongly criticised.

However, the use of cumulative variables in the model, causes disturbance terms to be autocorrelated. This cause projections to be inefficient.

But, the biggest advantage of our models is their simplicity. Moreover, while carrying out projections we have made very few assumption, which make the projections indicative. Some might argue that prices were not incorporated into the models. But as pointed out earlier, prices being administered in our economy do not have any strong influence on consumption. Thus, consumption of electricity is rather insensitive to prices of electricity. The two models considered may be viewed as providing a sensitivity test. The projections with the aid of learning model shows how electricity requirement change when the learning process is in operation in the economy. Whereas the projections with the aid of the expectation model reveals what the electricity requirements may be if expectations of economic activity is incorporated in the model.

To conclude then it is quite clear that with the increasing growth of GDP and development of the economy the aggregate electricity consumption of the economy will increase considerably over the next two plans. This is clearly indicative of the fact that judicious planning, to meet this future requirements, should be carried out now. Otherwise, the future electricity requirement might pose as an effective constraint to the development process of the economy.

From the next chapter onwards, we discuss the sectoral electricity requirements in the terminal years of the 8th, 9th and 10th Plans. Such a disaggregated analysis and projection would better highlight the economy's electricity requirement in the terminal years.

CHAPTER IV

RESIDENTIAL SECTOR

The residential sector is fast coming up as an important consumer of electricity. The growth in consumption of electricity in this sector depends on a number of factors, which include growth in population, growth in urban population, changes in the levels of private final consumption expenditure (PFCE) of the households, degree of urbanization, improvements in standard of living.

Considering that large sections of the population still live in rural areas, access to electricity still remains limited. According to the 8th Plan Document, only 27% of the rural households, approximately, are electrified, when more than 80% of the villages are electrified. The relationship between urbanization and access to electricity cannot be overstated. Even though government is taking proactive efforts to intensify rural electrification programmes and on pen and paper the number of villages electrified looks promising, actual number of households having access to electricity is quite small. This is so because income is a major determinant of electricity.

Income increases are now gradually taking place with an increased pace in rural areas than what it used to be in the past. Infrastructure such as transport, telecommunications, education, etc., are now gradually moving into rural areas. On top of that, deliberate effort is taken by government to improve the distribution and transmission system in the rural areas. Also, efforts are being made to develop the rural non-agricultural sector. All these together will cause the rural population to increase the demand for electricity by large amounts in the not too distant future. Therefore, increased income and spending ability of the people are bound to increase the demand for electricity by the residential sector, in future. Moreover, because of rising kerosene prices and more efficient energy provided by electricity, electricity is fast replacing kerosene for lighting purposes. In fact, with traditional fuels being fast replaced by commercial fuels, kerosene is more and more being used for cooking purposes and electricity for lighting. Though still kerosene accounts for a large share of lighting purposes, specially in rural areas, still electricity is fast getting introduced in many households.

According to the EPD study (1991),[1] the share of electricity in total energy consumption increased from 0.2% in 1960-61 to 1.5% in 1987-88. This share in total commercial energy consumption increased from 8.7% in 1960-61 to 13.9% in 1987-88. This steady increase is mainly due to an increase in income level and urbanization leading to an increase in the use of household electrical appliances. Besides variations in electricity demands in rural and urban areas, there are variations among different income classes. Even though a small percentage of total PFCE is spend on fuel & light, still a regular amount have to be incurred, because such an expenditure is a necessity in most cases. Cooking accounts for the largest share of energy consumption in the household sector. But with income increase the share of lighting and other uses of energy also increases. The Table 4.1 shows the enduse pattern of household energy consumption for different income groups in rural and urban areas in percentage terms.

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[1] "Sectoral Energy Demand in India", Government of India in cooperation with ESCAP, UNDP and Government of France, 1991.

Table 4.1

End Use Pattern of Household Energy Consumption

Annual income class (Rs)	Rural in (%)			Urban in (%)		
	Cooking	Lighting	Other uses	Cooking	Lighting	Other uses
< 3000	90.3	6.1	3.6	87.2	7.2	5.6
3000-6000	89.5	6.5	3.9	85.2	8.3	6.7
6000-12000	88.7	6.5	4.8	82.2	8.6	8.7
12000-18000	88.2	6.4	5.4	80.2	9.0	10.6
> 18000	88.0	6.3	4.0	77.0	10.2	12.8

Source: NCAER (1985), "Domestic Fuel Survey with Special Reference to Kerosene".

Electricity for lighting in both rural and urban areas increases with the income level. The share of kerosene seems to decline slightly in the rural areas as the income level increases. In the urban areas, share of kerosene is more significant and seems to remain more or less the same with changes in income levels. However, kerosene is also used for cooking. But data does not provide us with the exact proportion in which kerosene is used for cooking and lighting. Table 4.2 gives the percentage share of kerosene and electricity in total energy consumption in the household sector for different income classes in rural and urban areas.

Table 4.2

Percentage Share of Kerosene and Electricity Consumption in Total Energy Consumption

Annual income classes (Rs)	Rural		Urban	
	Kerosene	Electricity	Kerosene	Electricity
< 3000	3.77	0.15	8.36	0.87
3000-6000	3.74	0.36	11.17	2.35
6000-12000	3.21	0.57	11.11	4.17
12000-18000	2.70	0.81	11.76	6.52
> 18000	2.65	0.92	11.30	10.60

Source: NCAER (1985), "Domestic Fuel Survey with Special Reference to Kerosene".

According to NSSO sources, the percentage of households reporting consumption of electricity is increasing both in rural and urban areas. The Table 4.3 below shows this.

Therefore, with the influence of several factors that affect consumption of electricity and various policies undertaken at the official level, the consumption of electricity has increased from 8.8% in 1970-71 to 11.2% in 1980-81 and further to 15.5% in 1988-89 in the total consumption of electricity (utilities). The demand for electricity by the domestic sector grew from 1492.29 MKWh in 1960-61 to 3839.76 MKWh in 1970-71 and then again from 9246.43 MKWh in 1980-81 to 24767.67 MKWh in 1988-89. Thus, the growth rate in the decade of '70's was 9.2% p.a. and in the decade of the 80's it was 13.2% p.a. compounded. Thus, the importance that domestic sector is assuming as a consumer of electricity cannot be overstated. We expect that in future the demand will be quite high.

Table 4.3

Shares of Electricity And Kerosene in Total Monthly Expenditure Per Person on Fuel and Light and Percentage of Households Reporting Consumption

Sector and NSSO rounds	Share of electricity in total mpce on fuel & light	% of HHS reporting consumption	Share of kerosene in total mpce on fuel & light	% of HHS reporting consumption
Rural				
27th	0.012	4	0.21	96
32nd	0.024	7	0.10	96
38th	0.040	14	0.09	95
Urban				
27th	0.17	38	0.18	86
32nd	0.17	42	0.23	88
38th	0.20	54	0.22	88

Note: mpcc = monthly per capita consumption expenditure.
Source: Report NSSO 38th Round, Number 358, CSO, 1989.

Therefore, in this chapter we forecast the demand for electricity by the residential sector in the terminal years of the 8th, 9th and 10th Plan. For this purpose we employ two alternative models to carry out projections, where both the models estimate demand for electricity in two stages. In the first stage total expenditure on fuel and light is estimated and in the second stage demand for electricity is estiamted. However, in the second model we incorporate the influence of expenditure class distribution on the demand for electricity. The spending ability of the people affects consumption and this is captured in this model through the assumptions on poverty ratio. As the consumption pattern is different for rural and urban, we have worked out the models for each of the sectors and made projections separately for the two sectors. Finally, by summing them up we arrived at the total demand for electricity for the domestic sector. After the projections have been made, we adopt a different set of assumptions, where the initial assumptions take alternative values, but use the same models to carry out a sensitivity analysis to check for the robustness of the results.

4.1 Projections and Analysis with Model I

This section is divided into several subsections dealing with methodology and data, assumptions to be made for projection, results of estimation and projection, and finally, the sensitivity analysis of the projections made with this model. The model employs both regression technique and norms to make the projections.

4.1.1 Methodology and Data

We have made projections for the terminal years of 8th, 9th and 10th Plan (1996-97, 2001-02, 2006-07) on the basis of assumptions on GDP growth rate scenarios, urbanization factor, share of electricity in total monthly PFCE, the implicit price of electricity and rural urban population. Corresponding to the GDP growth rates we have growth rates for PFCE.

First, given the data on monthly per capita PFCE and monthly per capita PFCE on fuel and light, we estimate the Engel's function, relating monthly per capita expenditure on fuel and light with monthly per capita expenditure total, in double-log form. This estimation is carried out for rural and urban sectors separately. After obtaining the estimates of the Engel's function, these estimates have then been used along with the assumptions on

PFCE and population (rural and urban separately) for the terminal years of the plans to make the projections separately for per capita monthly expenditure on fuel and light.

In stage two we obtain the share of expenditure on electricity in total monthly per capita expenditure on fuel and light from the same data. Then using the historical growth rates and future norms[2] we obtain shares for the terminal years. Finally, along with these shares and implicit electricity prices we obtain the projections of demand for electricity in the terminal years, separately for rural and urban sectors, in physical units.

In order to estimate the Engel's function in the first stage of the model, we have used a pooled time series of cross sectional (18 states and three rounds) data. Since, we use the estimates to make long range projections, such pooling of data is an useful technique, as the estimates obtained incorporates both short run and long run features. The estimation procedure followed is the one proposed by Kmenta (1971).[3] This procedure assumes same autocorrelatin coefficients for the cross sections. The Stochastic specification is such that the model is cross sectionally heteroscedastic and time wise autoregressive. The assumption of same autocorrelation coefficient for the cross sections is made for the ease of estimation. The details of the Stochastic specification are given in Appendix 4.A.1. Thus a feasible generalized least square estimation technique is applied to the Engel's function given as:

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[2] These future shares have been estimated taking past growth rates and norms, and decided upon only after discussion with Professor R.P. Sengupta.

[3] J. Kmenta (1971), "Elements of Econometrics", MacMillan, New York.

$$\ln y_{it} = \alpha_0 + \alpha_1 \ln x_{it} + e_{it}, \text{ for all } i,t \qquad (1)$$

where,

y_{it} = per capita monthly expenditure on fuel and light, for ith state in round t.

x_{it} = per capita total monthly consumption expenditure, for ith state in the round t.

e_{it} = error term for the ith state in round t.

This model is applied for rural and urban sectors separately.

For the estimation of the model represented by equation (1) we have used data from the NSSO 27th, 32nd and 38th rounds.[4] The entire analysis has been carried out in 1983-84 prices as the NSSO data of 38th round are in 1983 prices and this was the latest round made available to us. These rounds provide data for monthly PFCE per capita and per capita monthly consumption expenditure on fuel and light. But since these figures in value terms were in current prices, we had to convert these in 1983-84 prices. In order to obtain the figures in 1983-84 prices, we deflated them using consumer price indices. But since Statewise indices were not available, we used All India Consumer price indices taken from India Database (1990). In order to generate variable in 1983-84 prices for rural and urban sectors separately we have taken consumer price indices for agricultural labourers and industrial workers. We obtained for agricultural labourers both the general index and index for fuel and light. But for the industrial workers we obtained only the general index. So we had to generate the price index for fuel and light for the urban sector. Now, all the rounds (27th, 32nd and 38th) provide both

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[4] NSSO 27th round (1972-73), 32nd round (1977-78), 38th round (1983). These are the only rounds, made available to us, which provide data in disaggregated form for all the sources of fuels both in values and quantities.

quantity and value data for individual items of fuels, for urban and rural sectors separately. From these value and quantity figures we obtained the implicit prices of the specific items of fuel. Using these implicit prices and quantity figures we obtained the Laspeyer's Price Index[5] for fuel and light for the urban sector. The price indices are given below in Table 4.4.

Thus, using these price indices we obtained the consumption expenditure figures for all rounds in 1983-84 prices.

The GDP at factor cost and PFCE figures were obtained for the economy as a whole from National Accounts Statistics (CSO). But these figures are in 1980-81 prices. So the deflator implicit in CSO's data for GDP at factor cost and PFCE, in constant '80-81 prices, have been used to obtain the data in 1983-84 prices.

Table 4.4

Price Indices (1983-84 Base)

Rounds	General index	Index for fuel & light
	Agricultural Labourers (for Rural)	
27th	41.73	67.25
32nd	62.31	83.33
38th	100	100
	Industrial Workers (for Urban)	
27th	37.84	40.65
32nd	59.23	81.3
38th	100	100

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[5] Laspeyer's Price Index = $\Sigma P_n q_n / \Sigma P_o q_o$ where n=current period and o = base period.

The urban and rural population figures are taken from Census of India, 1991, 'Series 1', Paper 2 of 1992. Final Population Totals, for the census years.[6]

The data for share of expenditure on electricity in total monthly consumption expenditure per capita have been obtained from the NSSO rounds.

4.1.2 Assumptions

In order to make the projections we require target growth rates for PFCE, urbanization factor (i.e., ratio of urban per capita consumption to rural per capita consumption), demographic projections, projections on share of expenditure on electricity in total expenditure on fuel and light, and implicit price of electricity in 1983-84 (as the entire analysis and projections have been conducted in 1983-84 prices). Target GDP growth rates for the 8th, 9th and 10th Plans are given in the 8th Plan Document and we take these figures as the target growth rates for our projections. However, 8th Plan Document provides growth rate for PFCE only for the 8th Plan. So we take historical data (1960-61 to 1990-91) for Private Final Consumption expenditure and GDP at factor cost and obtain the elasticity factor by regression techniques using a double log functional form. Then, using this elasticity factor, which is 0.92 we obtain the growth rates for PFCE corresponding to the target growth rates for GDP at factor cost;[7] refer Table 4.5.

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[6] The population figures between two census years have been interpolated using decadal growth rates, as suggested by Prof. M.K. Premi (CSRD/JNU).

[7] $\ln(\text{PFCE}) = \alpha_0+\alpha_1 \ln(\text{GDP})$
Then, gr. rate of PFCE = α_1* (gr. rate of GDP),
α_1 = elasticity factor.

Table 4.5

Target Growth Rates

Period	GDP % (p.a.)	PFCE (%) p.a.
1990-91 to 1991-92	1.0	0.92
1991-92 to 1992-93	4.0	3.68
1992-93 to 1993-94	5.0	4.6
1993-94 to 1996-97	5.6	5.3
1996-97 to 2001-02	6.0	5.52
2001-02 to 2006-07	6.5	5.98

Note: PFCE = Private final consumption expenditure, obtained using elasticity factor 0.92.
GDP = Gross domestic product.

The demographic projections are taken from the 8th Plan Document and are given in Tables 4.6 and 4.7.

Tables 4.6

Urban Population (Target)

Year	Urban population as percentage of total population
1991	25.72
1996	27.82
2001	30.50
2006	33.38

Tables 4.7

Target Growth Rates for Urban Population

Period	Urban population
1991-92 to 1996-97	3.4
1996-97 to 2001-02	3.6
2001-02 to 2006-07	3.4

Thus, it is assumed that percentage share of urban population will increase over the next two plans.

The urbanization factor is assumed to remain the same till 1996-97 as it was in 1983-84, but thereafter it is assumed to decline. Through this we assume that from the 9th Plan onwards the standard of living in rural sector will considerably improve, considering the conscious effort being taken by government to increase the pace of development of the rural sector, e.g., through the development of rural non-agricultural sector.

The urbanization factor is used along with the share of urban population in total population and monthly PFCE in the terminal years to obtain the per capita monthly PFCE in rural and urban sectors separately, in the following way:

If,

b = urbanization factor.

C_u = per capita monthly private final consumption expenditure (mpce) in urban sector.

C_r = mpce in rural sector

C = mpce in rural and urban sectors together.

then,

$$b = C_u / C_r \tag{2}$$

Now.

$$C = C_r \cdot \frac{P_r}{P} + C_u \cdot \frac{P_u}{P} \tag{3}$$

where

P = total population

P_u = urban population

P_r = rural population

Therefore using equation (2) and (3) we obtain

$$C = C_r \cdot \frac{P_r}{P} + b \cdot C_r \cdot \frac{P_u}{P}$$

$$C = C_r \left(\frac{P_r}{P} + b \cdot \frac{P_u}{P} \right)$$

Therefore,

$$C_r = C / \left(\frac{P_r}{P} + b \cdot \frac{P_u}{P} \right) \tag{4}$$

and $C_u = b \cdot C_r$ (5)

The share of electricity in total expenditure on fuel and light are assumed for the terminal years on the basis of growth rates of shares over the 27th, 32nd and 38th NSSO rounds, and on the basis of the expectations about the consumption patterns in future. It is expected that this share will grow both in urban and rural sectors but faster in rural sectors. This is assumed keeping in view the active effort undertaken to increase the pace of electrification of rural areas and also to improve the non agricultural rural sector. With increase in income level and accessibility to electricity the share of expenditure in rural sector should increase at a faster rate compared to urban areas where already the share is high. Additionally, through this assumption it is also assumed that more and more electricity will be used for the purpose of lighting, by replacing kerosene. The increase in share in the urban sector is viewed mainly to be caused by increase in urban population and improved urban lifestyle.

As the entire analysis is carried out in 1983-84 prices, so we consider the implicit price of electricity for 1983-84 prevailing throughout the projection. It is assumed to be 0.43 Rs per Kwh for rural sector and 0.49 Rs per Kwh for urban sector.

The base case assumptions are summarized in Table 4.8 below.

With the help of the estimates of the Engel's function and these assumptions we can make projections for the terminal years for the base case separately for rural and urban. The results of estimation and projections are given in the next subsection.

Table 4.8

Base Case Assumptions
(in 1983-84 Prices)

	1990-91	1996-97	2001-02	2006-07
Rural				
GDP (Rs crore)	271310	352372	471554	646069
PFCE (Rs crore)	201093	256972	336170	449447
Population (millions)	837	925	1006	1086
Rural population (millions)	619	668	699	723
Urbanization factor	1.57	1.57	1.5	1.45
Share of expenditure on electricity in total consumption expenditure on fuel and light	0.10	0.15	0.20	0.22
Implicit price of electricity (Rs/KWh)	0.43	0.43	0.43	0.43
Urban				
GDP (Rs crore)	271310	352372	471554	646069
PFCE (Rs crore)	201093	256972	336170	449447
Population (millions)	837	925	1006	1086
Rural population (millions)	218	257	307	363
Urbanization factor	1.57	1.57	1.5	1.45
Share of expenditure on electricity in total consumption expenditure on fuel and light	0.22	0.25	0.27	0.29
Implicit price of electricity (Rs/KWh)	0.49	0.49	0.49	0.49

Note: Population figures are for all India.

4.1.3 Estimation Results and Projections

The estimated Engel's function given by equation (1) on the basis of NSSO data has yielded an elasticity of 1.537 for the rural sector and 1.08 for the urban sector.

The estimation results for rural and urban sectors, separately are given below in Tables 4.9 and 4.10 below:

Table 4.9

Estimation Result for Rural Sector

Dependent Variable = ln y_{it}

Variable	Coefficient	t-ratios
Constant	-5.513	-7.1647
ln x_{it}	1.537	9.3104

Estimated autocorrelation coefficient = 0.7970

D-W Statistic = 0.9143

R^2 = 0.7970

Buse R^2 = 0.6250

The result shows that the estimated coefficient is significant at 5% level of significance. Both R^2 and Buse[8] R^2 is high enough to show that considering we are pooling the sample the explanatory variable explains more than 62% of the total variation. But the D.W. statistics shows the existence of autocorrelation in the disturbance terms. So either our assumption of a linear first order autocorrelation of disturbance term is not true or that of same autocorrelation coefficient across cross sections is false. This yields us estimates which are unbiased

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[8] For Buse R^2 see Appendix 4.A.2.

but inefficient. Nevertheless, we still use this estimate of elasticity as it has the right sign and is significant. Also it is the case that R^2 and Buse R^2 are both high enough. However, when these estimates were used for projection, there are other inaccuracies of projected values involved which we have already discussed in Appendix 3.A.5; here we did not consider the disturbance terms and autocorrelation coefficient into account while forecasting.

Table 4.10

Estimation Result for Urban Sector

Dependent Variable = ln y_{it}

Variable	Coefficient	t-ratios
Constant	-3.262	-6.171
ln x_{it}	1.08	10.336

Estimated autocorrelation coefficient = -0.151
D-W Statistic = 1.7896
R^2 = 0.9906
Buse R^2 = 0.6726

The result in Table 4.10 shows that the estimates are significant at 5% level of significance. The explanatory variables explains more than 67% of the total variation. Unlike the case for rural sector, here our assumption of a linear relationship between the residual and its lagged value holds true. This estimated elasticity is both unbiased and efficient and we have used it for the purpose of projection. But, as we have not taken into consideration the estimated autocorrelation coefficient and the residual into consideration while projecting, there is scope for inaccuracy of the forecasts to prevail.

Now, these elasticity estimates along with our base case assumptions were used to forecast the per capita monthly expenditure on fuel and light, for rural and urban sectors separately. then, the assumption on share of electricity in total expenditure on fuel and light is used to obtain the monthly expenditure on electricity. Finally, implicit prices were used to arrive at the demand for electricity in physical units. However, the forecast made on the basis of assumptions made in Tables 4.8, 4.9 and 4.10, may diverge from the actual demand; so in that sense the projections are indicative.

The projections for monthly per capita expenditure for the household sector is given in Table 4.11.

Table 4.11

Projections for Monthly Per Capita Expenditure (in 1983-84 prices)

	1990-91	1996-97	2001-02	2006-07
Rural				
(a) C_r	174.36	199.65	241.10	300.29
(b) C_{rf}	11.2	13.82	18.46	25.87
(c) C_{re}	1.12	2.07	3.69	5.69
(d) C_{rf}/C_r	0.06	0.07	0.08	0.09
Urban				
(a) C_u	273.7	313.45	361.65	435.42
(b) C_{uf}	16.42	19.01	22.19	27.12
(c) C_{ue}	3.61	4.75	5.99	7.86
(d) C_{uf}/Cu	0.06	0.06	0.06	0.06

Notes:

C_r = Monthly per capita consumption expenditure in rural sector (Rs/person/month)

C_u = Monthly per capita consumption expenditure in urban sector (Rs/person/month).

C_{re}, C_{ue} = Monthly per capita expenditure on electricity in rural and urban sectors respectively (Rs/person/month).

C_{rf}, C_{uf} = Monthly per capita expenditure on fuel and light in rural and urban sector respectively (Rs/person/month).

C_{rf}/C_r, C_uf/C_r = Share of expenditure on fuel and light in total expenditure for rural and urban sector respectively.

The projections bring out that share of expenditure on fuel and light in total expenditure per capita will increase for the rural sector; but for urban sector this will remain more or less constant. This incorporates the assumption that in the rural sector more and more traditional forms of fuel will be replaced by commercial fuels. This is also supported by the implementation of policies which arise from environmental consciousness.

The per capita monthly expenditure on electricity is projected to be much higher in the urban areas compared to the rural areas. But this is increasing in both the sectors and at a faster rate in rural areas. This is based on the assumption that the share of expenditure on electricity in total expenditure on fuel and light will increase at a faster rate in rural areas during the initial years but slowly taper off after some years.

Table 4.12 below provides the projection of demand for electricity for the household sector, for the base case.

Table 4.12(i)

Projections of Monthly Per Capita Demand for Electricity for the Household Sector (in KWh) - Base Case

	1990-91	1996-97	2001-02	2006-07
Rural	2.60	4.81	8.58	13.23
Urban	7.37	9.69	12.22	16.04

The demand for electricity per person is projected to increase both in rural and urban sectors over the 8th, 9th and 10th Plans, but faster for the rural sector. This is so because it is assumed that more number of people will use electricity in the rural sectors with increase in level of income and accessibility to electricity in the rural sector.

Table 4.12 (ii) below tabulates the overall demand for electricity for the household sector in MKWh (million kwh).

Table 4.12(ii)

Projections of Demand for Electricity (in KWh) - Base Case

	1990-91	1996-97	2001-02	2006-07
Rural	19312.80	38644.47	72019.81	114825.77
Urban	19279.92	29895.92	45035.02	69873.80
Total	38592.72	68540.39	117054.83	184699.57

Now that we have made the projections for the base case, we propose a sensitivity analysis in the next subsection.

4.1.4 Sensitivity Analysis

Here we propose an analysis of the robustness of the projections. the base case projections are based on certain assumption of growth rates, demographic projections, urbanization factor etc. Now, it is quite possible that the future scenario may turn out to be different from what we have visualized. Here we carry out projections for alternative set of assumption to see how the demand for electricity gets altered in the terminal years. To keep the analysis simple we have two different sets of assumptions where all the previous assumptions of base case remain same, as given in Section 4.1.2, but only the GDP growth rates are different. Thus, we make projections of demand for electricity for alternative GDP growth rates. GDP being an important determinant for demand in the long run and electricity being an important input for the development process, such an analysis would be quite helpful.

Here we consider two cases, which we name Case 2 and Case 3, with a lower growth rates and higher growth rates of GDP respectively. The assumptions for GDP growth rates are given in Table 4.13.

Table 4.13

Alternative Target GDP Growth Rates (% p.a.)

Period	Case 2	Case 3
1990-91 to 1991-92	1	1
1991-92 to 1992-93	4	4
1992-93 to 1996-97	5	5.6
1996-97 to 2001-02	5.6	6.5
2001-02 to 2006-07	6.0	7.0

Corresponding to these GDP growth rates we obtain the growth rates for the PFCE using the elasticity factor 0.92 as before. these growth rates are tabulated below in Table 4.14.

Table 4.14

Alternative Target Growth Rates for PFCE (% p.a.)

Period	Case 2	Case 3
1990-91 to 1991-92	0.92	0.92
1991-92 to 1992-93	3.68	3.68
1992-93 to 1996-97	4.60	5.30
1996-97 to 2001-02	5.20	5.98
2001-02 to 2006-07	5.52	6.44

Note: PFCE implies private final consumption expenditure.

The rest of the assumptions remain as it is in Section 4.1.2. We then use the assumptions on demographic projections and urbanization factor to obtain the monthly per capita expenditure. Then using equations (4) and (5) we obtain the projections for monthly per capita expenditure for rural and urban sectors separately. Using the same elasticities obtained from estimating equation (1) we project the monthly per capita expenditure on fuel and light for the terminal years for rural and urban sectors. Finally, using share of expenditure on electricity in total expenditure on fuel and light and implicit prices for 1983-84, we arrive at the demand for electricity in the terminal years.

The details of the assumptions for case 2 and case 3, for rural and urban sectors are tabulated in appendix 4.A.3.

Table 4.15 (i)

Projections for Rural Monthly Per Capita Expenditures (in 1983-84 prices)

	1990-91	1996-97	2001-02	2006-07
Base Case				
C_r	174.36	199.65	241.10	300.29
C_{rf}	11.22	13.82	18.46	25.87
C_{re}	1.12	2.07	3.69	5.69
Case 2				
C_r	174.36	195.69	232.76	283.67
C_{rf}	11.22	13.40	17.49	23.70
C_{re}	1.12	2.01	3.50	5.21
Case 3				
C_r	174.36	200.97	248.05	315.71
C_{rf}	11.22	13.96	19.29	27.94
C_{re}	1.12	2.09	3.86	6.15

Notes: C_r = Rural monthly expenditure per person (in Rs).
C_{rf} = Rural monthly expenditure per capita on fuel & light (in Rs).
C_{re} = Rural monthly expenditure per capita on electricity (in Rs).

Table 4.15 (ii)

Projections for Urban Monthly Per Capita Expenditures (in 1983-84 prices)

	1990-91	1996-97	2001-02	2006-07
Base Case				
C_u	273.7	313.45	361.65	435.42
C_{uf}	16.42	19.01	22.19	27.12
C_{ue}	3.61	4.75	5.99	7.86
Case 2				
C_u	273.7	307.23	349.14	411.32
C_{uf}	16.42	18.61	21.36	25.50
C_{ue}	3.61	4.65	5.77	7.40
Case 3				
C_u	273.7	315.52	372.08	457.78
C_{uf}	16.42	19.15	22.88	28.62
C_{ue}	3.61	4.79	6.18	8.30

Notes: C_u = Urban monthly expenditure per person (in Rs).
C_{uf} = Urban monthly expenditure per capita on fuel & light (in Rs).
C_{ue} = Urban monthly expenditure per capita on electricity (in Rs).

Neither expenditure on fuel and light nor expenditure on electricity per person is very sensitive to GDP growth rate hence PFCE growth rates, as is evident from the above tables. Thus even though expenditure on fuel and light and specially electricity goes up as PFCE increases, still the increase is not of any great dimension.

Table 4.16 provides projections of demand for electricity for the terminal years in physical units.

Table 4.16

Projections of Demand for Electricity for Alternative Scenarios (in MKWh)

	1990-91	1996-97	2001-02	2006-07
(i) Rural				
Base case	19312.80	38644.47	72019.81	114825.77
Case 2	19312.80	37470.14	68235.35	105201.49
Case 3	19312.80	39036.00	75257.86	124026.42
(ii) Urban				
Base case	19279.92	29895.92	45035.02	69873.80
Case 2	19279.92	29266.53	43380.98	65784.49
Case 3	19279.92	30147.67	46463.51	73785.31
(iii) Total				
Base case	38592.72	68540.39	117054.83	184699.57
Case 2	38592.72	66736.67	111616.33	170985.98
Case 3	38592.72	69183.67	121721.37	197811.73

The above projections strongly reveal that even though there is a substantial increase in demand for electricity between the terminal years of the successive plans, still the demand does not vary much with alternative scenarios; particularly compared to our base case scenario. So, the choice of target growth rate should not matter and may be achieved if we can project the demand properly and plan the supply in order to meet that requirement.

But the projections obtained with this model seem to be somewhat erroneous as the rural demand for electricity is very high. This is spurious in the face of the evidence that in 1990-91 less than 25% of the rural household were electrified and a vast majority of the rural population had a very low spending ability, implying impossibility for every person in the rural sector to have had access to electricity. This abnormality in the projection arises from the nature of the model. The model considered in this section actually projects the monthly per capita expenditure on fuel and light from which monthly per capita demand for electricity is obtained for the terminal years of the target plans. Thus, the estimated projections are for a typical rural and urban household. Then, when we use demographic projections to project the overall demand, we tend to over estimate the rural and urban demand. This is so, because we do not take into consideration the expenditure class distribution for rural and urban sectors into consideration while projecting. It is very important that we take into consideration the ability to spend of the rural and urban sectors. Besides this, the elasticity for the rural sector is not very efficient. All these together does not make the model very attractive.

So we propose in the next section an alternative model, similar to the models of this section but tries to overcome the shortcomings discussed above.

4.2 Projections and Analysis With Model-II

In this section we make projections for the terminal years of the target plans based on a model and various assumptions, which not only take into consideration a consistent rate of growth of PFCE, but also the expenditure class distribution of the rural and urban sectors separately. Thus, the marginal spending ability of the people and the proportion of the population living below the poverty line is taken into consideration while carrying out projections.

4.2.1 Methodology and Data

Based on the assumptions on target growth rates, urbanization factor, demographic projections, monthly consumption expenditure distribution etc., for the terminal years of the target plans, we make the projections for the terminal years of 8th, 9th and 10th Plans, for the rural and urban sector separately. Here in this model we would assume consistent growth rates for GDP and PFCE and also some targets of poverty alleviation. This is so because we believe that removal of poverty and the fact that more and more households are getting electrified, with nearly all households getting electrified by the 9th Plan, will have a strong influence on the future consumption of electricity. Thus, based on various assumptions, same as those made in Section 4.1.2 and others such as poverty lines and poverty ratios we may obtain the monthly personal consumption expenditure distribution of the population for the terminal years of the target plans, for rural and urban separately.

The entire analysis has been conducted at 1983-84 prices as we have used the NSSO 38th round data on monthly consumption expenditure per person. On the basis of this data we have estimated the Engel's function relating monthly consumption expenditure per person to the monthly expenditure per person on fuel and light in double log form for rural and urban sector separately. Thus the functional relation takes the form:

$$\ln y = \alpha + \beta \ln x + u \qquad (6)$$

where

y = monthly per capita expenditure on fuel and light.

x = average monthly per capita expenditure.

u = disturbance term.

In order to analyse and take into consideration the spending ability of the people we need to forecast the monthly expenditure distribution for the terminal years. We have chosen the log normal distribution as an appropriate analytical tool for fitting these distributions.[9] Thus, we assume that the monthly personal consumption expenditure distribution takes log normal distribution and we can obtain the proportion of the population in each expenditure class for the terminal years. By doing this we explicitly take into consideration the fact that two different poverty ratios would give two different projections of consumption for the same per capita consumption level.

The attractiveness of choosing a lognormal distribution is two fold. First, it is as positively skewed distribution and, secondly, the random values take a range between zero and infinity. Given our targets for personal consumption expenditure and demographic projections we can obtain the monthly personal consumption expenditure for rural and urban sectors separately, using equations (4) and (5). The details of obtaining the distribution are furnished below.

Let us assume that the rural and urban sector's monthly personal consumption expenditure as the mean of the expenditure class distribution. Now, given the poverty line in value terms and the poverty ratio or proportion of population living below the poverty line we can obtain the distribution.

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9. This procedure was followed by Planning Commission as given in the "Report of the Task Force on Projections of Minimum Needs and Effective Consumption Demand", 1979.

Let x be the variate of per capita monthly expenditure and α the poverty ratio. Then, x takes lognormal distribution as follows:

$$dF(x) = f(x)\ dx \quad , o < x < \infty$$

Therefore,

$$dF(x) = \frac{1}{x\ \sigma\sqrt{(2\pi)}} \exp \left[\frac{-1/2\ (\log x-\mu)^2}{\sigma^2} \right] . dx \qquad (7)$$

Now, suppose mean personal consumption expenditure = $\bar{C}$

Then,

$$\text{mean} = E(x) = \exp (\mu + ½\ \sigma^2) = \bar{C} \qquad (8)$$

$$\text{variance} = V(x) = \exp (2\mu+2\sigma^2) - \exp (2\mu+\sigma^2) \qquad (9)$$

Also, $E\ (\log x) = \mu$ and $V\ (\log x) = \sigma^2$

Now, if Z_α be the value of the standard normal value for which the cumulative integral is α, then

$$\frac{\log x_\alpha - \mu}{\sigma} = Z_\alpha \qquad (10)$$

If α = poverty ratio then, x_α = poverty line in value terms.

Now solving (8) and (10) for μ and σ^2 we can obtain the distribution $\log x \sim N\ (\mu,\sigma^2)$.

It should be noted that in order to obtain μ, σ^2 we solve a quadratic equation in σ. We take the minimum positive value for σ by solving the quadratic equation in σ. By choosing the minimum value for σ we minimise the lorenz inequality.

Now,

$$Z = \frac{\log x - \mu}{\sigma} \sim N(0,1)$$

both for rural and urban sector. Let the range of the monthly personal expenditure variable be defined by the classes: 1,..,n.

Then,

Class	Average value of class	Standard normal value of upper class	Proportion of population	Population in the class
1	W^1	Z_1	$\Phi\ (Z_1)$	$P.\ [\Phi\ (Z_1)]$
2	W^2	Z_2	$\Phi\ (Z_2)-\Phi(Z_1)$	$P.\ [\Phi\ (Z_2)-\Phi(Z_1)]$
3	W^3	Z_3	$\Phi\ (Z_3)-\Phi(Z_2)$	$P.\ [\Phi\ (Z_3)-\Phi(Z_2)]$
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
n	W^n	Z_n	$\Phi(Z_n)-\Phi(Z_{n-1})$	$P.\ [\Phi(Z_n)-\Phi(Z_{n-1})]$

where P = total population (rural or urban).

Here Z_i is the standard normal value for the upper limit of the class whose average value is W_i. Φ is the cumulative integral of normal distribution. This is how the distribution of consumption expenditure is projected.

In order to obtain the monthly personal expenditure on fuel and light and its distribution we use the estimate of elasticity form the Engel's function given by equation (6). Once we obtain the monthly personal expenditure on fuel and light for each expenditure class, we take the weighted average of the monthly personal consumption expenditure on fuel and light. Now, share of electricity in total expenditure on fuel and light is used to obtain average expenditure on electricity. Finally, with the help of demographic projections and implicit price of electricity we forecast the demand for electricity in physical units for the terminal years of the target plans.

The data used for the analysis are more or less the same, with same sources, as explained in Section 4.1.1. The NSSO 38th round data is used so the entire analysis was conducted in 1983-84 prices. We have used the CSO data for PFCE to obtain the per capita monthly PFCE for the base year 1990-91. The deflator implicit in CSO's data in constant 1980-81 prices have been used to convert the PFCE of 1990-91 to 1983-84 prices. Besides this the estimates of poverty line for rural and urban sectors are taken from the study of EPD, Planning Commission (1991), which is taken from the technical note of the 7th Plan. These poverty lines are then converted to 1983-84 prices using consumer price index for industrial workers and agricultural labourers.

We have used ordinary least squares technique to estimate the Engel's function given by equation (6).[10]

Now, on the basis of this technique and data we forecast demand for electricity by making certain assumptions for the various scenarios expected in the terminal years of the target plans.

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[10] For the sake of simplicity and ease of estimation we have ignored the presence of existence of heteroscedasticity and spatial autocorrelation.

4.2.2 Assumptions and Estimation Result

In order to make projections we require target growth rates for PFCE, urbanization factor, demographic projections, projections on share of expenditure on electricity in total expenditure on fuel and light, implicit price of electricity in 1983-84, expected poverty ratios in the terminal years of the target plans and estimates of poverty line. Excepting for the estimates of poverty ratio and poverty line, all other assumption for the base case remain the same as that given in Section 4.1.2. The assumptions regarding the poverty line and poverty ratios are given below in Table 4.17.

Table 4.17

Assumptions on Poverty Ratio for Base Case

	1990-91	1996-97	2001-02	2006-07
Poverty ratio	27%	10%	5%	1%

These assumptions of poverty ratio take into consideration the poverty alleviation programs followed by government.

The poverty lines assumed for rural and urban sectors separately at 1983-84 prices are taken as:

Rural (Rs/person/month) = 105.28
Urban (Rs/person/month) = 125.92

The elasticities to be used for projection are obtained on estimating the Engel's function given by equation (6), the results of which are are given below in Tables 4.18 and 4.19.

Table 4.18

Estimation Result for Rural Sector
Dependent Variable = ln y

Variable	Coefficient	t-ratios
Constant	-0.629	-13.3475
ln x	0.577	56.9087

$\bar{R}^2 = 0.9963$

The estimates are all significant at 5% level of significance with a very high R^2. But it is to be noted that the elasticity is smaller than that given in Table 6.5. This is so because we have taken here the class distribution into account explicitly.

Table 4.19

Estimation Result for Urban Sector
Dependent Variable = ln y

Variable	Coefficient	t-ratios
Constant	-1.0463	-12.1209
ln x	0.688	37.0893

$\bar{R}^2 = 0.9913$

The above table shows that both the estimates are significant at 5% level of significance with a very high R^2.

Thus, the NSSO data has yielded us an estimate of elasticity of 0.58 for the rural and 0.68 for the urban sectors. These elasticities are smaller than those of model I. We next use these elasticities along with the other assumptions to forecast the demand for electricity.

4.2.3 Projections of Demand for Electricity for Base Case

The projections for the PFCE distribution per month are given in the Appendix 4.A.4 and 4.A.7, for rural and urban sectors respectively, for the years 1990-91, 1996-97, 2001-02 and 2006-07. We have obtained forecasted figures for average per capita monthly expenditure on fuel and light, average per capita expenditure on electricity for rural and urban sectors. The table 4.20 below shows these figures for rural and urban sectors separately.

Table 4.20

Projections for Monthly Per Capita Expenditure (in 1983-84 Prices) - Base Case

	1990-91	1996-97	2001-02	2006-07
Rural				
C_r	174.36	199.65	241.10	300.29
C_{rf}	10.13	11.27	12.65	14.23
C_{re}	1.01	1.69	2.53	3.13
Urban				
C_u	273.7	313.45	361.65	435.42
C_{uf}	15.01	17.50	19.02	21.14
C_{ue}	3.30	4.38	5.14	6.13

Notes:

C_r, C_u = Mean monthly per capita consumption expenditure for rural and urban sectors respectively (Rs).

C_{rf}, C_{uf} = Average monthly per capita expenditure on fuel and light for rural and urban sectors respectively (Rs).
C_{re}, C_{ue} = Average monthly per capita expenditure on electricity for rural and urban sectors respectively (Rs).

After projecting the monthly personal consumption expenditures per person which is expected to be higher for the urban sector compared to the rural sector for the terminal years of the target plans, we make projections for demand for electricity in physical units.

Table 4.21

Base Case Projections of Monthly Per Capita Demand for Electricity (KWh)

	1990–91	1996-97	2001-02	2006-07
Rural	2.35	3.93	5.88	7.28
Urban	6.73	8.93	10.48	12.51

These projections show that the per capita demands for electricity are lower if we take expenditure class distribution into account. Thus, compared to the projections of per capita demand, for base case with model I, the above 4.21 table shows that the forecasted consumption is much lower for the rural sector. This could be because of the concentration of poor in the rural areas, with a lower ability to spend. So, even though the demand for electricity is expected to increase, it won't increase to the extent projected by the previous model.

By incorporating the policy of removal of poverty and rise in rural income per capita we have assumed that more and more people will be able to afford electricity over the next two plans.

And, as potentiality for rural demand improves, rural accessibility for electricity will also increase. Hence, demand for electricity is expected to increase considerably over the next two plans.

Table 4.22

Base Case Projections of Demand for Electricity (KWh)

	1990-91	1996-97	2001-02	2006-07
Rural	17455.8	31506.23	49350.62	63182.36
Urban	17605.68	27536.53	38624.39	54502.87
Total	35061.48	59042.76	87975.02	117685.20

The overall demand for electricity is expected to increase approximately three and a half time from 1990-91 to 2006-07 and two fold from 1990-91 to 2001-02.

As we have carried out for model I, here too we propose to carry out for model II a sensitivity analysis to look for the robustness in the results.

4.2.4 Sensitivity Analysis

In the last subsection we carried out projections for the base case. Now, it is quite possible that the assumptions regarding the poverty ratios may not actually be achieved through various alleviation programme. It is also possible to achieve a better situation in the future target plans. The question that arises is that how does these alternate scenarios affect the demand for electricity in future. In order to answer this question we carry out a sensitivity analysis of the projections with alternative poverty ratio scenario.

We consider two alternative cases with case 2 corresponding to lower poverty ratios and case 3 to higher poverty ratios compared to the base case. These alternative scenarios for future target plans for terminal years are tabulated in Table 4.22.

Table 4.22

Alternative Targets for Poverty Ratios

	1996-97	2001-02	2006-07
Case 2	5%	1%	0.1%
Case 3	20%	10%	5%

The projections of distribution of monthly consumption expenditure per person for different terminal years of future plans, for the targets specified in Table 4.22 are given in Appendix 4.A.5, 4.A.6, 4.A.8 and 4.A.9 for rural and urban sectors. While carrying out the projections for the distribution and hence demand for electricity it's assumed that besides the alternative scenarios for poverty ratio, all other assumptions for the base case remain the same in case 2 and case 3.

The projections for consumption expenditures for rural and urban sectors, for alternative scenarios may be obtained using the elasticities estimated from the Engel's function, the projected distribution and assumptions of share of expenditure on electricity in total expenditure on fuel and light in the terminal years of the target plans.

Table 4.23

Comparative Projections

	1990-91	1996-97	2001-02	2006-07
Rural				
Base case				
C_r	174.36	199.65	241.10	300.29
C_{rf}	10.13	11.27	12.65	14.23
C_{re}	1.01	1.69	2.53	3.13
Case 2				
C_r	174.36	199.65	241.10	300.29
C_{rf}	10.13	11.26	12.77	14.56
C_{re}	1.01	1.69	2.55	3.20
Case 3				
C_r	174.36	199.65	241.10	300.29
C_{rf}	10.13	10.99	12.33	13.66
C_{re}	1.01	1.65	2.47	3.00
Urban				
Base case				
C_u	273.7	313.45	361.65	435.42
C_{uf}	16.42	17.5	19.03	21.14
C_{ue}	3.61	4.38	5.14	6.13
Case 2				
C_u	273.7	313.45	361.65	435.42
C_{uf}	16.42	18.19	20.12	22.05
C_{ue}	3.61	4.55	5.43	6.39
Case 3				
C_u	273.7	313.45	361.65	435.42
C_{uf}	16.42	16.30	18.24	19.86
C_{ue}	3.61	4.08	4.92	5.76

Note: The definitions of C_r, C_{re}, C_{rf} and C_u, C_{uf}, C_{ue} are same as those in Table 4.20.

As the table shows, that the results are quite robust for average per capita expenditure and do not change much for the alternative scenarios.

Using implicit price of electricity for rural and urban sectors the demand for electricity are obtained (refer Table 4.24).

Table 4.24

Projections of Demand for Electricity for Alternative (MKWh)

	1990-91	1996-97	2001-02	2006-07
Rural				
Base case	17455.8	31506.23	49350.62	63182.36
Case 2	17455.8	31484.20	49839.19	64647.68
Case 3	17455.8	30754.79	48109.51	60627.78
Urban				
Base case	17605.68	27536.53	38624.39	54502.87
Case 2	17605.68	28620.99	40836.56	56841.39
Case 3	17605.68	25652.31	37024.42	51193.44
Total				
Base case	35061.48	59042.76	87975.02	117685.20
Case 2	35061.48	60105.19	90675.76	121489.0
Case 3	35061.48	56407.11	85133.93	111821.20

Thus, from the above table it is quite clear that the projections do not change to any great extent for the alternative scenarios of poverty ratio. Among the rural and urban sectors the change in rural sector is even less.

We have carried out sensitivity analysis with alternative GDP target growth rates for the last model and the results were found to be rather insensitive. Thus, even though we have not carried out sensitivity test for alternative target GDP growth rates in this model, still we believe that here also the results for projections would be rather insensitive. This is so because majority of the poor are situated ind the rural sector. This is evident from our projections of distribution for alternative poverty ratios. So, with rise in income, they instead would be of spending the marginal income increase on other things besides fuel and light, which is consumed as a necessity.

But one thing is quite clear from our sensitivity analysis, that is electricity won't be an effective constraint to the development process if the requirement for electricity is properly projected and supply planned to meet the requirement. It is also true that the household sector will exhert a lot of pressure on overall electricity consumption over the next two plans.

4.3 Concluding Comments

The projections that we finally accept are those made with the help of the second model, which explicitly take the expenditure class distribution into consideration. It is only in this model where we take the spending ability of the people into consideration. We also incorporate the policy of poverty alleviation into this model, through our assumptions on the poverty ratios. In all these aspects the second model is a superior model over the first model to be considered for projections of electricity demand. However, the non availability of expenditure class wise distribution of consumption of electricity in the 38th round NSSO data has seriously constrained our estimation of demand. Moreover, due to paucity of time we could not carry out sensitivity analysis for each of the assumptions, made to carry out projections. As far as estimation techniques are concerned, ignoring presence of heteroscedasticity and spatial autocorrelation was a rather restrictive simplification because their presence may yield us inefficient and inconsistent estimates of elasticity, which in turn may yield us erroneous projections.

Some might object to the fact that the demand functions were not made functions of price and the effect of substitution was not considered. But this we believe are not constraining factors as far as long run projections of demand are concerned. Prices of electricity and kerosene have not been playing their usual role of eliminating demand supply imbalances. These prices are administered and that these fuels have been receiving heavy subsidies on a regular basis. It is because of this that the demand for electricity is rather insensitive to price changes. There are other constraints to incorporating prices also. The price data published by CEA in Bulletin of Average Electricity Supply Rates and Duties in India, usually refer to the price per unit of electricity charged according to the load used by consumers. The revenue collected for electricity consumption is actually based on a kind of two part tariff. The variable part of the tariff rates are in different categories according to the load used by the consumer. Since we do not have the means to distinguish the different consumers according to the load they draw we are seriously constrained in our choice of price. In addition, the existence of a two part tariff impose additional problems to modelling demand. So, as we are more concerned with long range projection we chose to leave out price variable in our analysis and took the implicit price of electricity from the NSSO data.

The use of NSSO data does not allow us to take into consideration the unsatisfied demand and so the usual identification kind of problems remain. Finally, taking appliance stocks and prices of appliances into consideration while modelling and projecting demand for electricity would have been more appropriate. But due to problem of availability of data we had to leave these out from our analysis, while modelling demand for electricity.

But, inspite of its short comings and limitations the second model is quite an useful model, which yields us quite reasonable projections given the assumptions on target growth rates and target poverty ratios, along with the other assumptions. Thus, according to our projections, the demand for electricity is expected to grow at the rate of 8.3% p.a. compounded between 1996-97 and 2001-02 and again at the rate approximately 6% p.a. compounded. That is over the next two successive plans the growth rate is anticipated to remain quite high, with a slight decline after the 9th Plan. This will considerably contribute to the power intensiveness of the economy over the next two plans.

CHAPTER V

INDUSTRIAL SECTOR

The importance of industrial sector in the economy cannot be overstated, with a considerable increase in growth rate over the last four decades. Value added in industry has increased to 7.22% in the decade of 1980's. Even though the elasticity of value added in industry with respect to GDP declined slightly, still it is greater than unity and was 1.32 during the decade of 1980's. The share of industry in total GDP has increased from 15.2% in 1960-61 to 22.3% in 1989-90. The industrial sector comprises of the registered sector and the unregistered sector. The unregistered sector consists of unregistered industrial establishments and household industries. The registered sector consists of registered factories.[1] However, not only has the importance of industry gone up but it has also undergone structural changes. As a consequence of the change in the product mix, due to structural change, the energy intensity and pattern of energy consumption of the industry has also changed.

The industrial sector is the largest consumer of commercial energy in India, consuming nearly half of the commercial energy available in the country. The industrial sector

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[1] According to ASI (CSO), a Registered factory is one which is registered under section 2m(i) and 2m(ii) of the Factory Act, 1948. These sections refer to any premises including the precincts thereof whereon ten or more workers are working on any day of the year, in any part of which a manufacturing process is carried on with the aid of power or with twenty or more workers working on any part where the manufacturing process is carried on without the aid of power.

consumes more than 40% of the total electricity consumption and also a substantial amount of coal and petroleum products. Even though in percentage terms the consumption of electricity in total consumption of economy has declined from 69.4% in 1960-61 to 42.0% in 1991-92. Still it is very high. The consumption of electricity in total consumption of commercial energy increased from 8.2% in 1960-61 to 15.8% in 1987-88. From the seventies the consumption of oil has declined. The consumption of coal is very high but has gradually declined over the decades. Thus, coal is getting replaced by electricity and petroleum products. The increase in importance of power has made the industry quite power intensive. But, lately the consumption elasticities with respect to value added in industries for commercial energy, electricity and oil have declined. The intensity of consumption of electricity is also growing at a slower rate and declined after the 1980's. This could be caused by the increasing use of the energy efficient technology. Also, the fact that power provides more efficient energy may account for the declining intensity. But, there is no doubt that the overall electricity consumption of the economy is to a great extent influenced by the requirement of electricity by the industrial sector.

Within the industry itself, there are a few industries which account for nearly half of the total energy consumption in this sector. These are iron and steel, aluminium, paper, sugar, chemicals, fertilizers and cement. These energy intensive industries account for nearly half of the total electricity requirement in the industry. As these sectors have grown rapidly over the last two decades, so they have contributed to a substantial increase in electricity and other fuels consumption by the industrial sector.

Therefore, industry being the major consumer of electricity shall, to a great extent, influence the future overall requirement of electricity. In consonance with this, we make the future projections of electricity demand by the industrial sector, for the terminal years of 8th, 9th and 10th Plans.

5.1 Methodology

Forecast of electricity demand for the industrial sector is made separately for registered and unregistered sector. The projections for the registered sector is carried out first and then using a proportionality constant, based on historical observations, the projections for the unregistered sector are made. The projections for registered sector are based on a two stage model, where in the first stage we use a cost function approach to estimate the share of the cost of fuel in total cost incurred by the industry. In the second stage we relate the total expenditure on electricity to total expenditure on all fuels obtained from the first stage, to obtain the total expenditure on electricity borne by the registered sector. Then on the basis of the assumptions of the price in the terminal years, along with the assumptions on other variables required to project the total cost, fuel cost shares and expenditure on electricity in the terminal years, we obtain the projections of the demand for electricity in the terminal years of the target Plans. We have used an econometric model here to forecast the demand for electricity. Let us now describe the model for registered sector in detail.

Demand for inputs by the industry is essentially a derived demand, from its output. Since the objective, of the firms, is to minimise the total cost of production for a given level of output, hence the derived demand for inputs depend on their substitution possibilities. By the application of the duality theory, the specification of a production function implies a particular cost function. Recent developments in duality theory have enhanced the appeal of the cost function approach. Functional forms for cost functions have been developed which have two attractive features. First, they imply derived demand equations which are linear in parameters, and at the same time they represent very general production structures, even though explicit production functions are not considered.

For the first stage of our model, we have chosen the translog cost function.[2] What we assume is that there exists in the Indian registered manufacturing sector a production function, which is of a very general form and is weakly separable in material inputs. This condition is necessary because of the lack of reasonable data on material inputs and its prices.[3] Assuming factor prices and output is exogenously determined, by applying duality theory, given cost minimising objective of the firms we have a cost function of the form:

$$\phi = \phi\ (Y,\ C\ (P,Y),\ P_M) \qquad (1)$$

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[2] The translog cost function is due to Christensen, Johgenson and Lau (1973). A large body of literature is now available on the specification and estimation of translog cost functions which provide estimates of derived demand elasticities for inputs. Some of these studies have used aggregative translog models while others disaggregative, we will use here an aggregative model where we treat energy as an aggregative input rather than treating different energy inputs as separate inputs.

[3] This assumption of not considering material inputs will seriously constraint our analysis. But it is believed that material inputs will not be substitutable with capital, labour and energy, in order to minimise the total cost of production. So we proceed as if the objective of the firm is to minimise the cost function represented by equation (2) for a given level of output, in order to minimise total cost given by equation (1).

where

Y = output

$C(.)$ = non homothetic aggregate consisting of capital labour and energy.

P_M = price of material inputs

P = price vector of inputs weakly separable from material inputs.

Say,

$$C = C\ (P,Y) \qquad (2)$$

where

$P = (P_k, P_L, P_E)$, is a vector of input prices i.e, capital, labour, and energy prices. Equations (1) and (2) corresponds to a non homothetic and non homogeneous production function.[4] By assuming that both equations (1) and (2) corresponds to a non homothetic production function, we assume a general functional form for equations (1) and (2) which involve few, if any, a priori restrictions on parameters.

In order to make the cost function, given by equation (2), quite flexible with no a priori restrictions on substitution possibilities, we assume that it takes the translog form. Therefore, we assume that the cost function, given by equation (2), satisfies the usual properties of cost function[5], is twice continuously differentiable, and provides a second order local

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[4] By assuming a non homothetic and non homogenous production function, we make the production function quite general for the registered manufacturing sector. There is no a priori reason to believe that the cost function will be separable in input prices and output i.e., the case for homothetic production functions (Refer Appendix 5.A.1).

[5] The usual properties of a cost function are that the cost functions should be monotonic, linear homogenous in prices, and concave.

approximation.

Then equation (2) may be written in translog form as:

$$\ln C = \alpha_0 + \alpha_Y \ln Y + 1/2\, \beta_{YY} (\ln Y)^2 + \Sigma_i\, \alpha_i \ln P_i + 1/2\, \Sigma_i \Sigma_j\, \beta_{ij} \ln P_i \ln P_j + \Sigma_i\, \beta_{Yi} \ln Y \ln P_i \quad (4)$$

where,

C = total expenditure on capital, labour and energy
i,j = k,L,E
$\beta_{ij} = \beta_{ji}$
P_i = price of the ith input
Y = value added output
k = capital
L = labour
E = energy

Since by Shephard's Lemma (Varian, 1984)

$$\delta C / \delta P_i = X_i \quad (5)$$

where X_i is the cost minimising quantity demanded of the ith input.

Then, using (5),conveniently,in a logarithmic form for the translog cost function we obtain:

$$\frac{\delta \ln C}{\delta \ln P_i} = \frac{P_i}{C} \cdot \frac{\delta C}{\delta P_i} \quad (6)$$

or,

$$\frac{\delta \ln C}{\delta \ln P_i} = \frac{P_i X_i}{C} = S_i \quad (7)$$

where

S_i = share of expenditure on ith input in total expenditure on all inputs.

Then from equation (7) and equation (4) we obtain,

$$S_i = \alpha_i + \Sigma_j \ \beta_{ij} \ \ln P_j + \beta_Y \ \ln Y, \text{ for all } i \qquad (8)$$

where,

$i,j = k,L,E$

Since the shares add up to unity,

or $\Sigma_i \ S_i = 1 \quad , \quad i = k,L,E$

Therefore, we need to impose the following parameter restrictions:

$$\left.\begin{array}{ll} \text{i.} & \Sigma_i \ \alpha_i = 1 \\ \text{ii.} & \Sigma_j \ \beta_{ij} = \Sigma_i \ \beta_{ij} = 0 \\ \text{iii.} & \Sigma_i \beta_{Yi} = 0 \end{array}\right] \qquad (8')$$

and

Now, the Allen Partial Elasticities of Substitution (AES) may be written as (Griffin and Gregory, 1976, pg. 849):

$$\sigma_{ii} = \frac{\beta_{ii} + S_i^2 - S_i}{S_i^2} \quad , \ i=k,L,E \qquad (9)$$

and

$$\sigma_{ij} = \frac{\beta_{ij} + S_i \ S_j}{S_i S_j} \quad , \ i \neq j \ \& \ i,j=k,L,E \qquad (10)$$

Again, the price elasticities of demand for inputs are given as:

$$\mu_{ij} = S_j \, \sigma_{ij} \quad , \; i,j=k,L,E \tag{11}$$

Thus, the equation (4) and the system of equations (8) together explain the first stage of our model. But in order to make the model estimable, it has to be embedded in a stochastic framework. Therefore, the econometric model corresponding to the translog cost function is given by adding random disturbances to the equations (4) and (8). We, therefore, have:

$$\begin{aligned} \ln C = {} & \alpha_0 + \alpha_Y \ln Y + 1/2 \, \beta_{YY} \, (\ln Y)^2 + \Sigma_i \, \alpha_i \ln P_i \\ & + 1/2 \, \Sigma_i \, \Sigma_j \, \beta_{ij} \ln P_i \ln P_j + \Sigma_i \, \beta_{Yi} \ln Y \ln P_i + v \end{aligned} \tag{12}$$

where v is the disturbance term for the translog cost equation (4) and

$$S_i = \alpha_i + \Sigma_j \, \beta_{ij} \ln P_j + \beta_{Yi} \ln Y + u_i \text{ for all } i \tag{13}$$

where u_i is the random error term which accounts for the divergence between estimated and actual shares.

Now,

$$\Sigma_i \, u_i = 0 \text{ as } \Sigma_i \, S_i = 1$$

So these disturbances, u_i, are not distributed independently, therefore yielding a singular covariance matrix. The standard procedure, in such a case, is to drop one of the share equations and jointly estimate the remaining share equations. Then the estimates of the dropped equation may be obtained from the parametric restrictions given in (8'). The share equations estimate most of the parameters of cost equation excepting a few. However, an optimal procedure for estimation, according to Christensen and Greene (1976), would be to jointly estimate the cost function and cost share equations as a multivariate regression system.[6] However, if we include all the share equations along with the cost equation, the singularity of the covariance matrix remains because of $\Sigma u_i = 0$. So, we jointly estimate the cost equation and the share equations, deleting one share equation. As, there is no a priori reason to believe that covariances of disturbance between equations should be zero and, the disturbance variances should be homoscedastic and same for all the equations, so an appropriate estimation technique would be to use Zellner's Seemingly Unrelated Regression (SUR) technique of estimation.[7] But a more appropriate technique would be to use iterative Zellner's SUR technique, as Kmenta and Gilbert (1968) and Dhrymes (1970) have shown.[8] This estimation technique ensures the invariance of parameter estimates to which share equation is dropped.[9] Thus, we adopt the iterative Zellner's procedure for the estimation of our model. The details of the technique is explained

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[6] The inclusion of all the share equations of the model to the cost equation has the effect of adding many additional degree of freedom without adding any new unrestricted regression coefficients. However, u_i are not obtained from the disturbance term v of the cost equation.

[7] Zellner's SUR technique or seemingly unrelated regression estimation technique is a type of generalised least square technique.

[8] Christensen and Greene, 1976, pg. 663.

[9] Barten (1969) has shown that the maximum likelihood estimates of a system of share equations with one equation dropped are invariant to which equation is dropped. Kmenta and Gilbert (1968) and later Dhrymes (1970) have shown that iteration of Zellner's estimation procedure until convergence results in maximum likelihood estimates.

in appendix 5.A.2. The test for homotheticity and homogeneity restrictions are carried out using a likelihood ratio (LR) test (refer appendix 5.A.3). The test statistic is given by:

$$- 2 \ln \pi = T [\ln | \hat{\Omega}_R | - \ln | \hat{\Omega}_u |] \qquad (14)$$

is distributed as chi square with h degrees of freedom.
where,

π is the likelihood ratio

h is the number of restrictions

$|\hat{\Omega}_R|$ = determinant of the restricted estimates of disturbance covariance matrix.

$|\hat{\Omega}_u|$ = determinant of the unrestricted estimates of disturbance covariance matrix.

This test ensures the validity of our assumption of a most general form of production function.

In the second stage of our model, we estimate the elasticity of total expenditure on electricity with respect to total expenditure on all fuels, by the registered manufacturing sector. The idea is that, once we have obtained the share of expenditure on all fuels in the total expenditure incurred by the registered manufacturing, taking into consideration the substitution possibilities with the non-energy inputs, we want to find out the share of expenditure on electricity among the fuels.[10]

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[10] Because of the lack of reasonable data, consistent with the first stage of the model, we could not frame a more elaborate model which takes into consideration interfuel substitution possibilities.

The basis of the second stage of the model given by equation (15) is that, we assume a proportional relationship between expenditure on electricity in total expenditure on all fuels, given the existing technology. Thus, the second stage of the model may be written as:

$$\ln EL = \alpha_0 + \alpha_1 \ln EF + u \qquad (15)$$

where,

EL = expenditure on electricity
EF = total expenditure on all fuels
u = disturbances terms.

Therefore, with the aid of estimates of equations (12) and (13) and the assumptions, for the terminal years, regarding the value added output and prices we forecast the expected total cost and share of energy in total cost for the terminal years of the target plans. Then using the elasticity estimated from (15) and our assumption on price of electricity, we make projections of demand for electricity for the terminal years of the target plans. This we take as the prognosticated demand for electricity by the registered manufacturing sector, in the terminal years of the future plans.

On the basis of the past data we observe that, the ratio of the moving average of electricity demanded by unregistered manufacturing sector to that by the registered manufacturing sector has remained fairly constant. So we use this proportionately constant to project the demand for electricity by the unregistered sector, once we have made the projections for the registered manufacturing sector.

5.2 Data And Variables

We have estimated the above model for the registered manufacturing sector in India using a time series data, for the period 1968-69 to 1988-89. In order to estimate the model data is required on shares of expenditure on various inputs in total expenditure on all inputs; total expenditure on capital, labour, and energy inputs; prices of capital, labour and energy; value added output; consumption of electricity in registered and unregistered manufacturing sector; and price of electricity.

The data for value added output, fuels consumed (total purchase value), total emoluments paid to all employees, total persons engaged, value of stock of fixed capital at current prices are taken from the Annual Survey of Industries (ASI) reports for the factory sector (Summary Results) for various years. Data for 1972-73 was missing, but was interpolated using appropriate growth rates. We had to use data for value added output instead of data on industrial output (in value terms). Since deflator implicit in CSO data was available for value added output for the registered sector, we could use that to obtain value added output by the registered manufacturing sector in constant prices. On the other hand due to non availability of deflator for industrial output we could not obtain data for industrial output in constant prices.

Fuels consumed data represent total purchase value of all items of fuels, lubricants, electricity, water etc., consumed by the registered sector.

Total emoluments to all employees are defined in the same way as wages i.e., all remunerations capable of being expressed in monetary terms and also payable more or less regularly in each pay period to workers. But total emoluments refer remuneration to all employees plus imputed value of benefits in kind i.e., the net cost to the employer on those goods and services provided to employees free of charge or at markedly reduced cost which are clearly and primarily of benefits to the employees as consumers.

Total persons engaged relate to all persons engaged by the factory whether for wages or not, in work connected directly or indirectly with the manufacturing process and include all administrative, technical, clerical staff, as also labour engaged in production of capital assets for factory's own use. It also includes all working proprietors and their family members who are actively engaged in the work of the factory even without any pay and the unpaid members of the cooperative societies who worked in or for the factor in any direct and productive capacity.

Fixed capital covers all type of assets, new or used or own constructed deployed for production, tansportation,living and recreational facilities, hospitals, schools etc., for factory personnel. It includes the fixed assets of the head office allocable to the factory and also the full value of assets taken on hire purchase basis.

In order to estimate the total cost of capital services, we use the technique adopted by Murty (1986). As suggested by Jorgenson and Griliches (1967), in the absence of direct taxation the price of capital services may be estimated as follows:

$$P_k = q_k(r + m_k - \dot{q}_k/q_k) \qquad (16)$$

where

P_k = price of capital services

q_k = price of investment good

r = rate of return on capital

m_k = rate of replacement of investment good

$\dot{q}_k/q_k$ = rate of capital gain on that good

Neglecting capital gains, we have obtained price of capital services as $P_k=q_k\ (m+r)$.

Now, one rupee worth of capital may be estimated as (m+r) worth of capital services. The interest rate r is taken from H.L. Chandhok, India Database. Due to lack of uniformity in the interest rates at which capital is loaned out, we have taken the bank rate as r. To arrive at the rate of replacement, we have taken the book value of depreciation from ASI and book value of fixed capital from ASI. The ratio of depreciation and fixed capital is taken as the rate of replacement, m_k. The value of fixed capital stock at current prices is multiplied by (m_k+r) to obtain the annual cost of capital services for the registered manufacturing sector. The price of investment good is taken as the deflator implicit in gross fixed capital formation data obtained from CSO (National Accounts Statistics). The price of capital services is taken as price of this deflator multiplied by (m_k+r). By ignoring capital gains, however, we tend to overestimate price of capital services.

Thus, annual cost of capital services, total emoluments and cost of fuels together gives the total cost we use in the estimation of the model. Next, the shares of individual inputs in this total cost is generated.

Value added output taken from ASI has been converted to constant 1980-81 prices using the deflator implicit in CSO data for registered manufacturing sector.

On dividing total emoluments by total number of employees we obtain the implicit price of labour. This we take as our data on price of labour.[11]

ASI publishes aggregate electricity consumption data for the registered manufacturing sector from 1981-82 onwards. The aggregate electricity consumption data for the industry is published by CEA in the General Review. However, from the ASI source we have taken the purchased consumption figures only, so as not to include consumption of non utilities. These consumption figures are subtracted from those obtained from General Review to obtain consumption of electricity by the unregistered sector.

For the data on fuel we have taken the wholesale price index for fuel and light at 1980-81 prices from the India Data Base.

The price data on electricity are taken from the Annual Report on the working of State Electricity Boards and Electricity Departments (Planning Commission), for various years. In order to generate an aggregative price index for the industrial sector we have taken the weighted average of prices given according to industry size for each State. We have used consumption figures for the same as weights, thereby generating an average price index for electricity for industrial sector.

In estimation of the second stage of the model we had to restrict ourselves between the period 1981-82 to 1988-89, because this was the period for which ASI data on consumption of electricity was made available to us. For data on expenditures and price, refer Annexure Tables S3 and S4.

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[11] The way price of labour is defined, they may have either an upward or a downward bias.

5.3 Estimation Results

Having discussed the variables and data used to estimate the model given in Section 5.1, we now discuss the results of estimation in this section.

On estimating the first stage of model given by equations (12) and (13) jointly by the procedure mentioned in Section 5.1, we obtain the estimates of the parameters of the equation (12). In doing so, we have imposed the restrictions given by (8'), which correspond to condition of linear homogeneity in factor prices. The other regularity conditions which the cost functions need to satisfy in order to correspond to well behaved production structures are montonicity and concavity in factor prices.[12] These additional conditions are needed to be satisfied at each and every observations. Monotonicity is satisfied if the fitted cost shares at each and every observations are positive. This condition is satisfied in our model. Concavity requires that the principle minors of the Hessian matrix should alternate in sign with the first principle minor being negative.[13] Concavity is a sufficient condition for a cost function to be well behaved. However due to lack of time such a test was not carried out here. A necessary condition for the cost functions to be well behaved is that all own price elasticities should be negative. This condition however is satisfied in our model. We have tested for the symmetry restriction, but one at a time, i.e., each time deleting a different share equation. The hypothesis of symmetry restriction doesn't get rejected. But this in no way ensures that all the symmetry conditions hold simultaneously. The additive restrictions

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[12] The translog cost function is a local approximation and may not satisfy the conditions of monotonicity and concavity globally.

[13] An alternative test is that all the characteristics roots of the Hessian matrix should be negative.

were tested, using Likelihood Ratio test and were not rejected in our model at 5 per cent level of significance. However, following most of the studies, we assume linear homogeneity in input prices, by simply imposing the restrictions (8'), without really establishing its validity in our model. The estimated parameters of equation (12) are given in Table 5.1

As is evident from the Table 5.1, all the coefficients, excepting those corresponding to log of price of capital ($\ln P_k$) and square of log price of capital [$(\ln P_k)^2$] are significant at 5% level of significance. The system R^2 or pseudo R^2 is very high, explaining 99% of the total variation.[14] While estimating the model, we dropped the first share equation i.e., S_k for convenience. As already mentioned in Section 5.1, it does not matter which equation we drop, if we carry out iterative Zellner's SUR estimation procedure. By employing such an estimation procedure, we obtained the estimates. For the equations jointly estimated, the individual equations R^2 are also very high.

Thus,

R^2 for equation $\ln C = 0.9966$
R^2 for equation $S_E = 0.9128$
R^2 for equation $S_L = 0.9021$

Moreover, a non-parametric runs test show that the hypothesis of randomness of disturbance term for equations $\ln C$ and S_E does not get rejected at 1% level of significance. But for equation S_L there is existence of autocorrelation at 1% level of significance.

Using these parameters estimates we can easily obtain the Allen Partial elasticities of substitution and the price elasticities of demand for the factor capital, labour and energy

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[14] Pseudo $R^2 = 1 - (\det E'E / \det Y'Y)$, where det = determinant.

(refer Tables 5.2 and 5.3). It is evident from the Tables 5.2 and 5.3 that the performance of the model explaining substitution between energy and non-energy inputs is not so good. However, within non-energy inputs substitution possibility seems to be quite strong. Since we have used time series data to estimate the model, the elasticities estimated are essentially short run elasticities.

We have used the LR test statistic given by (14) to test for homogeneity and homotheticity. Since all β_{yi} are significantly different from zero, as is evident from Table 5.1, so the assumption of homotheticity is rejected.

Table 5.1

Parameter Estimates for Trans-log Model

Parameters	Estimates	Standard errors	t-ratios
α_0	-61.336	11.373	-5.393
α_y	8.215	1.719	4.779
β_{YY}	-0.421	0.124	-3.372
α_k	-0.367	0.246	-1.492
α_L	2.288	0.356	6.415
α_E	-0.921	0.321	-2.860
β_{kk}	0.021	0.029	0.724
β_{kL}	0.042	0.016	2.480
β_{kE}	-0.063	0.025	-2.473
β_{LL}	0.048	0.023	2.055
β_{LE}	-0.090	0.022	-4.094
β_{EE}	0.153	0.0043	4.576
β_{Yk}	0.024	0.0043	5.581
β_{YL}	-0.16	0.013	-11.597
β_{YE}	0.136	0.012	10.845

Table 5.2

Estimated Partial Elasticities of Substitution

	Estimates	Standard errors
σ_{kk}	-2.19	0.293
σ_{kL}	1.313	0.119
σ_{kE}	0.232	0.304
σ_{LL}	-1.088	0.127
σ_{LE}	0.182	0.2
σ_{EE}	-0.597	0.492

Notes: 1. Standard errors are estimated at the mean of the shares.
2. σ_{ij} are estimated at mean of the shares.

Table 5.3

Estimated Price Elasticities of Demand for Factors

	Estimates	Standard errors
μ_{kk}	-0.625	0.092
μ_{kL}	0.557	0.046
μ_{kE}	0.06	0.079
μ_{LL}	-0.461	0.053
μ_{LE}	0.047	0.052
μ_{EE}	-0.155	0.127
μ_{Lk}	0.415	0.037
μ_{Ek}	0.073	0.096
μ_{EL}	0.077	0.084

Notes: 1. μ_{ij} are estimated at the mean of the shares.
2. Standard errors are estimated at the mean of the shares.

For homogeneity it is required that $ß_{yy}=0$ and $ß_{yi}=0$ for all i. With and without these restrictions we estimate the model to obtain the likelihood ratio statistic as:

$- 2 \ln\pi = 31.79$ with d.f.3.

Comparing with critical chi square value with 3.d.f we reject the hypothesis of homogeneity restriction, at 5 per cent level of significance. Thus, our assumption of a general form of the model doesn't get rejected.

Now that we have the estimates for the first stage of the model, we illustrate the result of the second stage of the model. The result of estimation of equation (I5) is tabulated in Table 5.4

Table 5.4

Estimation Results for Second Stage

Dependent Variable lnEL

$\bar{R}^2 = 0.9296$ D.W. = 1.464

Variable	Coefficients	t Statistic	2 tail significance
Constant	-6.423	-3.272	0.017
lnEF	1.375	9.664	0.000

It is evident from the Table 5.4 that all the coefficients are highly significant. The explanatory powers of the model is also very high, as $\bar{R}^2 = 0.9296$ and there is no autocorrelation in the model given by equation (15). The estimated elasticity of expenditure on electricity with respect to expenditure on all fuels is 1.38 approximately.

We also obtain the proportionality constant between consumption of electricity in unregistered and registered sector. The ratio of the 3 yearly moving average is found to be fairly constant, in and around 0.29. So, we accept this as the estimated proportionality constant which we use for the purpose of projections.

5.4 Assumptions And Projections

The entire projection for the terminal years of target plans have been carried out on the assumption that during the projection period prices of capital, labour, energy and electricity do not change. Whatever increase in electricity consumption takes place, it is due to a change in real value added. In order to make the projections of demand for electricity using the estimates in Tables 5.1 and 5.4, we make certain assumptions of the growth rates anticipated for the 8th, 9th and 10th Plans. The target growth rates for GDP and gross value added (GVA) in the registered sector is given in Table 5.5. Given the target growth rates for GDP (taken from 8th Plan document), the target growth rates for GVA for registered sector was obtained using an estimated elasticity factor of 1.4.[15]

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[15] To estimate the elasticity factor, CSO data on GVA for SIC 20-29, 30-38, 40-42, 74, 97 was taken into consideration, so as to make it consistent with ASI data.

Table 5.5

Target Growth Rates

Period	GDP(%)	RGVA(%)
1990-91 to 1991-92	1	1.4
1992-92 to 1992-93	4	5.6
1992-93 to 1993-94	5	7
1993-94 to 1996-97	5.6	7.8
1996-97 to 2001-02	6.0	8.4
2001-02 to 2006-07	6.5	9.1

Note: RGVA = GVA in registered sector.

Using these growth rate we obtain the value added output of the registered sector in the terminal years of the target plans.

For the entire projection the price of capital services, price of labour and price of energy are taken as those prevailed in 1988-89. The price of electricity is also taken as that of 1988-89, for the entire projection period.

Using target RGVA; prices of capital services, labour and energy at 1988-89 prices; and the estimates from Table 5.1 alongwith equations (12) and (13) projections for total cost and share of energy in total cost are forecasted for the terminal years 1996-97, 2001-02 and 2006-07. From these estimates then the estimated projections for total expenditure on fuels consumed are projected for the registered sector for the terminal years. Projections for share of expenditure on fuels consumed by registered sector in total cost on capital, labour and energy; total expenditure on fuels are given in Appendix 5.A.4. Once we have forecasted the total expenditure on fuel for the terminal years, we then obtained the growth rates of the total expenditure on fuel. The growth rates for total expenditure on electricity are obtained using the elasticity factor 1.38, estimated in the second stage of the model, for the 8th, 9th and 10th Plans.

Table 5.6

Target Growth Rates for Total Expenditure on Electricity Between 1991-92 And 2006-07

Period	Total expenditure on electricity (%)
1991-92 to 1996-97	6.4
1996-97 to 2001-02	5.2
2001-02 to 2006-07	2.9

Using the target growth rates for the three successive plans we forecast the total expenditure on electricity for the terminal years 1996-97, 2001-02 and 2006-07 as tabulated below in Table 5.7.

Table 5.7

Total Expenditure on Electricity - Projections

(Rs. lakh)

Period	Expenditure on electricity
1990-91	969387.2
1996-97	1789880
2001-02	2306230
2006-07	2660600

Now, since the projections for expenditure on electricity have been carried out in 1998-89 prices, so using the price of electricity for 1988-89 we forecast the demand for electricity by the registered manufacturing sector, in the terminal years of the target plans. These projections are tabulated in Table 5.8.

Table 5.8

Projections of Demand for Electricity by Registered Manufacturing Sector (Mkwh)

Year	Demand for electricity
1990-91	103677.7
1996-97	191431.0
2001-02	246655.7
2006-07	284556.2

Thus, demand for electricity is expected to grow at the rate of 6.5% per annum between 1990-91 and 2006-07, for the registered manufacturing sector. But the growth rate is assumed to decline over the successive plan period, given the existing technology prevails over successive plans, with 10.7% per annum between 1990-91 and 1996-97, 5.2% per annum between 1996-97 and 2001-02, and finally 2.9% per annum between 2001-02 and 2006-07. This growth in electricity demand is due to growth in gross value added per se as prices are not allowed to change over the projection horizon. As is evident from Table 5.8, the increase is quite substantial even though the growth rate is expected to decline, given the existing technology to prevail over the forecasting horizon.

From the projections of demand for electricity by the registered sector we make projections for the unregistered sector using the proportionality constant 0.29, assuming that this constant will prevail over the entire forecasting horizon. These forecasts are given in Table 5.9.

Table 5.9

Forecasts of Demand for Electricity By the Unregistered Sector (Mkwh)

Year	Projections
1990-91	30066.55
1996-97	55515.01
2001-02	71530.15
2006-07	82521.29

The demand for electricity in unregistered sector is also expected to grow in a similar fashion, as the registered sector.

The demand for electricity by the industrial sector as, a whole, as forecasted for the terminal years of target plans are given in Table 5.10.

Table 5.10

Projections of Demand for Electricity By the Industrial Sector (Mkwh)

Year	Projections
1990-91	133744.25
1996-97	246946.0
2001-02	318185.8
2006-07	367077.4

Thus, between 1990-91 and 2006-07 the demand for electricity is expected to grow at the rate of 6.5% per annum for the industry as a whole. The growth rate will gradually fall with time, with growth in industrial production with no change in the existing technology. But by 2001-02 the increase in demand will be quite significant. It will be even higher still in 2006-07. The growth rate, however, will fall to 2.9% per annum between 2001-02 and 2006-07 from 5.2% per annum in the previous Plan. Even though technological advancement is not explicitly considered in the model, but efficiency of the existing technology will cause the growth rates to decline. The growth rates, however, can be further brought down through technological innovations and energy conservation.

The model considered for the purpose of projection does not consider substitution possibilities between electricity and non-electricity forms of energy, e.g., oil and coal. Here we consider another simplistic model for the purpose of sensitivity analysis.

5.5 Sensitivity Analysis

In this model we try to incorporate substitution possibilities between electricity and other forms of energy in the production process. For this a very simple model is considered, which assumes that over the planning horizon more and more power operated technology will be replacing non-electrical technology. But in doing so the electrical tecnnology maintains the same standard of efficiency of use of electricity i.e., assumption on improvement in technology is not explicitly made. Thus the objective is to observe, how demand for electricity is affected due to production increases and replacement of non-electrical form of energy by electricity within the framework of the present technology.

In order to do so, we consider a simple model which assumes that over time the share expenditure on electricity in total expenditure on all fuels gradually increases and asymptotically tends towards unity. Thus, the share of electricity in total expenditure on all fuels takes a logistic functional form.

The model, therefore, is in two stages. In the first stage share of fuels in total cost on fuels, capital and labour are estimated using a translog function, the same way we did in Section 5.1. However, in the second stage, we assume that the share of electricity in total expenditure on all fuels takes a logistic function of time, asymptotically approaching unity.

Since the first stage of the model remains the same as that in Section 5.1, we describe here only the second stage of the model. In the first stage equations (12) and (13) are jointly estimated to obtain estimates of the parameters. In the second stage we consider the model:

$$Z = \frac{1}{1+a\ \exp(-bt)} \tag{17}$$

where,

Z = share of expenditure on electricity in total expenditure on all fuels.

t = time.

Hence, $Z \longrightarrow 1$ as $t \longrightarrow \infty$; so that 1 is the upper asymptote.

Therefore,

$$\ln\ (1-Z/Z) = a_0 - bt \quad , \text{ where } a_0 = \ln a \tag{18}$$

In order to estimate equation (18) for a_0 and b we add a disturbance term u to equatin (18).

Therefore,

$$\ln\ (1-Z/Z) = a_0 - bt + u \tag{19}$$

To estimate we use the procedure of iterative SUR to the first stage. To the second stage we carry out OLS estimation of equation (19).[16] The model considered here is for the registered manufacturing sector. For the unregistered sector, as in the previous model, it is assumed that consumption of electricity is proportional to that of the registered manufacturing sector. This proportion is observed to be fairly constant and so is assumed to remain for the entire forecasting horizon. Thus, once the projections for the registered manufacturing sector's demand for electricity is made, we obtain the demand for electricity for the unregistered sector using the proportionality constant 0.29. The data used for estimation are same as those given in Section 5.2, both for first stage and second stage of this model.

The estimates for the first stage of the model are same as those given in Tables 5.1, 5.2 and 5.3. Even though not all estimates are significant, but there exists substitution possibilities between the inputs. Substitution possibility between energy and non energy inputs is, however, slightly poor. The results of the second stage given by equation (19) are tabulated in Table 5.11.

The results show that the coefficients are significant at 5% level of significance, with a reasonably high explanatory power of independent variables. Moreover, there is no autocorrelation present in the model.

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[16] We have considered an additive disturbance term to equation (17) and carried out NLS estimation procedure to the equation. But since OLS gave us better result, so we accept the OLS estimates.

Table 5.11

Regression Results

Dependent Variable ln (1-Z/Z)

R^2 = 0.7766 D.W. Statistic = 1.541

Variable	Coefficients	t Statistic	2 tail significance
Constant	1.328	13.930	0.000
t	-0.095	-5.033	0.002

Using the estimates in Table 5.11 we obtain the growth rate of share of electricity in total expenditure on all fuels.

Now, since, $\ln(1-Z/Z) = a_0 - bt$

Therefore,

$$\frac{d}{dt}\left[\ln\left(\frac{(1-Z)}{Z}\right)\right] = -b$$

or

$$\frac{dZ/dt}{Z^2} = \frac{b(1-Z)}{Z}$$

or

$$\frac{dZ/dt}{Z} = b(1-Z)$$

Thus,

$$\frac{Z_t - Z_{t-1}}{Z_{t-1}} = b\ (1-Z_{t-1}) \qquad (20)$$

therefore, as is evident from equation (20) the growth rate of the share is variable. Share thus depends on the estimated coefficient, b, and share with a one period lag.

The assumptions made for the purpose of projection are more or less the same as those given in Section 5.4. The growth rates for gross value added in the registered sector are obtained using the elasticity factor 1.4, when growth rates on GDP are assumed as those in Table 5.5. These growth rates along with the growth rates of GDP are given in Table 5.5. The GDP growth rates are taken from the 8th Plan document. For the entire projection we make a very simplistic assumption that the prices do not change any further but remain at those of 1988-89. By assuming this we do away with the price effect on the demand and expenditure, thereby making our projections of demand entirely dependent on the target value added by the industrial sector.

Now, using the parameter estimates given in Table 5.1 and equations (12) and (13), along with our assumptions on gross value added and prices we project the share of fuels in total cost on fuels, capital and labour, and total cost. From these two projections, we obtain the projections for the consumption expenditure on fuels for the terminal years of the target plans.

On the other hand, using estimate in Table 5.11 and the equation (20), we obtain the growth rates for the share of expenditure on electricity in total expenditure on all fuels.

These growth rates are given in Appendix 5.A.5. Using these growth rates the shares are projected for the terminal years of the target plans.

Now, using the projections of total expenditure on all fuels and those of shares for the terminal years of the target plans, we obtain the forecast of total expenditure on electricity. Since we have assumed that the price of electricity will remain the same as in 1988-89; so using this price we forecast the demand for electricity, in the terminal years of target plans, for the registered sector. Then using the proportionality constant 0.29 we obtain the demand forecast of electricity for the unregistered sector. These forecasts are given in Table 5.12 below.

If we compare the results in Table 5.12 with those in Table 5.10, the difference is not insignificant.

Table 5.12

Alternative Projections for Demand for Electricity (Mkwh)

Year	Registered sector	Unregistered sector	Total
1990-91	122709.7	35585.82	158295.52
1996-97	204949.8	59435.45	264385.25
2001-02	294197.2	85317.19	379514.39
2006-07	374212.7	108521.6	482734.3

The projections obtained with the aid of the model considered in this section are definitely higher than those given in Table 5.10. This is mainly because of the assumption of interfuel substitution of other form of fuels, such as coal and oil, by electricity. The implications of the sensitivity analysis is that if we allow for interfuel substitution along with the fuel and non fuel substitutions, then demand for electricity in future are not insensitive to such substitution. Thus, given the existing technology to prevail in future, demand for electricity will increase considerably, if electricity replaces other fuels in the production process. Therefore, unless and until technological advancement takes place, with more power efficient machines replacing older vintages, along with conservation measures, it would increase the power requirements of the industry considerably thereby imposing pressures on the economy.

Thus, in the face of interfuel substitution possibilities with cheap and efficient energy provided by electricity, technological advancement and electricity conservation measures are the needs of the hour.

5.6 Concluding Comments

Since the entire analysis and projections have been made at an aggregative level, for the industry as a whole, the projections should not be taken as the precise estimates of demand in the terminal years of the target plans. Rather, they should be treated as indicative of the power intensiveness of the industry over the entire projection horizon. As the industrial sector comprises of diverse production structures producing heterogeneous commodities, with different energy and power intensiveness; it is not appropriate to estimate the demand at such an aggregative level. A more appropriate method would be to make an analysis at a disaggregated level, with a separate analysis for each of the energy intensive industries and for the rest of the industry.

The energy intensive industries account for more than half of the total energy consumed within the industrial sector. The aluminium industry is a very large consumer of electricity along with other fuels. With rapid development expected in electrical and transport sectors, this industry is expected to receive considerable pressure from the other sectors using this product. Thus, until appropriate policy measures are taken the industrial demand for electricity will be higher than expected.

Another sector that will face a lot of demand with the on-going development strategy of the economy is the cement industry. This industry in turn will demand a considerable amount of electricity. Unless policy measures are taken to conserve the use of electricity through technological innovations, the industrial sector won't be able to bring down its power intensiveness.

The iron and steel industry also accounts for a major share in the total industrial demand for electricity. Even though they consume a lot of non utilities, their demand for utilities are expected to go up with the development strategy adopted by the economy.

With the increasing demand for agricultural produce, the demand for fertilisers also go up. Thus, this sector would also be an important contributor in the increase in demand for electricity.

The primary energy inputs required by the textile industry are steam and electricity. Their requirements, however, vary with product mix, capacity utilisation and overall operating efficiency of the plants. This sector also raises the demand for electricity considerably for the industrial sector.

The power intensiveness of these sectors and others, such as those dealing with electroplating etc., cannot be understated. With special importance being attached to all of them and heavy dependence on some of them for the achievement of development targets, improvement in the availability of power is an absolute necessity. These sectors will demand a major portion of the total industrial demand for electricity.

Our analysis could have been made far more interesting, by incorporating structural changes, technological changes, interfuel substitution possibilities. The estimates of our models would have been far more efficient if we used time series of cross sectional data rather than just time series data. But due to lack of time we could not use such data. A detailed study at the disaggregated level is required to make electricity demand forecasts for the industrial sector.

However, inspite of the limitations of the model and its estimates, it is evident from our projections that the industrial demand for electricity will increase. If the plan targets are to be achieved then appropriate measures should be taken to improve the power situation and meet the industrial requirements of electricity.

CHAPTER VI

AGRICULTURAL SECTOR

The Indian economy remains predominantly an agricultural economy, even though its share in GDP declined over the years. With the increase in demand for agricultural produce over the years, this sector is under a continuous pressure to increase its productivity. Inspite of its excessive dependence on monsoon and nearly stagnant agricultural land area, agricultural output has growth considerably over the years. The major break through in agricultural production may be attributed to three factors. First, besides gradual increase in net sown area, a steady increase in the intensity of cropping is observed over the last four decades, thereby increasing the gross sown area from 147.3 mha. in the first Plan to 176.9 in 1986. Second, due to modernization of agriculture and use of fertilizers, HYV seeds, pesticides etc., there has been a steep increase in the productivity levels in agriculture. Thirdly, increase in production have been largely realised not only through an assumed supply of water owing to expansion of irrigation facilities but also through a steady increase in the intensity of irrigation. The intensity of irrigation has increased from 1.14 in 1955 to 1.32 in 1986. All this has contributed to the increase in direct and indirect use of energy in the agricultural sector.

Agricultural sector is an important consumer of electricity and diesel, required for land preparation and lift irrigation. Electricity consumption in the agricultural sector, over the period 1960 to 1989, have registered an average annual growth rate of 14.6% whereas the corresponding rate of growth of diesel was 10.4%. As a consequence the relative share of electricity in total energy consumption in agriculture increased from 18.5% in 1960 to 40.3% in 1989, whereas that of diesel declined.[1] Thus, the share of electricity consumption in total electricity consumption of the economy has increased from 6% in 1960 to 26.4% in 1990.

The important feature of the electricity consumption in the agricultural sector is that, the extensive rural electrification programme taken up in all States has led to the gradual replacement of diesel by electricity for operating agricultural pumpsets. But for a large number of areas, which has no ready access to electricity, diesel still continues to be an important fuel for lift irrigation. The number of electrified pumpsets have increased from 0.19 million in 1960 to 8.3 million in 1989 against the increase in diesel operated pumpsets from 0.28 million in 1960 to 4.35 million in 1989. The rate of utilisation in electrified pumpsets have also increased steadily over the last two decades. The major cause for such an increase is the increased multicropping pattern adopted in recent years. Besides this, inefficient pump system design and lowering of ground water tables has also contributed towards increase in the rate of utilisation. As a consequence of all these, the electricity intensity of agriculture have increased steeply over the years, from 0.25 in 1960 to 6.39 in 1989. The electricity consumption to value added elasticity in agriculture in 1989 was as high as 5.23.[2] However, the rapid rise in intensity of electricity in agriculture over the last decade or so may be, to some extent, accounted for by the

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[1] The statistical figures are taken from "Sectoral Energy Demand in India" - study conducted by Government of India in cooperation with ESCAP, UNDP and Government of France, 1991.

[2] Some fluctuation in the elasticities are observed over the years, which is mainly due to the seasonal fluctuations in the level of agricultural output which still largely depend on rainfall conditions. ibid. pgs. 76-77.

increasing use of electricity in non irrigation activities. Such activities include threshing, cutting, chopping etc., which are now carried out with the use of mechanised instruments.

The increasing demand for electricity for the economy as a whole, in the face of declining share of electricity demand by industry, is mainly accounted for by the increases in relative share of agriculture and the domestic sector due to extensive rural electrification programme adopted. But, such programme involves a certain lag before electricity demand considerably increases. Thus it is expected that the agricultural demand for electricity will continue to increase in the future. In this chapter we try to forecast the demand for electricity for pumping water in agricultural sector for the terminal years of 8th, 9th and 10th Plans. Let us now discuss the methodology adopted for this purpose.

6.1 Methodology And Data

A disaggregated approach of cropwise and areawise or regionwise analysis would have been ideal. But due to time constraint we could not take such an approach. Instead, we have used a very simple econometric model relating gross value added in agriculture with consumption of energy and electricity required for pumping water. Irrigation pumpsets (energised - diesel and electrified) constitute a major source of demand for direct commercial energy. Keeping in view the importance of irrigation in raising the productivity in agriculture and exploiting the increasing ground water potential and proactive efforts towards rural electrification, it is expected that the number of energised pumpsets would increase considerably in future, and electrified pumpsets will be replacing diesel pumpsets in the years to come.

The model that we propose here is in two stages. In the first stage we relate the total energy required, in calorific units, for irrigational purposes, ie,.to operate both diesel and electrified pumpsets together, to the gross value added in agriculture. We have taken three yearly moving averages of these two variables to iron out the random fluctuations, if any, in these variables over time. The first stage of the model is considered in double log linear form as given below:

$$\ln(TE) = \alpha_0 + \alpha_1 \ln(VA) \qquad (1)$$

where,

TE = 3 yearly moving average of energy consumed for irrigational purpose in calorific units.

VA = 3 yearly moving average of value added in agriculture.

In the second stage of the model, we assume that electrified pumpsets will be replacing diesel pumpsets, and at some point in future, may be, all pumpsets in operation will be electrified. Thus, the share of energy consumed by electrified pumpsets, in calorific units, is assumed to increase over time and approach unity asymptotically. Thus, the share of energy consumed by electrified pumpsets to total energy consumed for irrigation purpose takes a logistic function of time. It may be written as:

$$k = \frac{1}{1+b \exp(-at)} \qquad (2)$$

where,

k = Ratio of 3 yearly moving average of energy consumed by electrified pumpsets in calorific value to 3 yearly moving average of total energy consumed by all pumpsets in calorific value.

t = Time.

We estimate the model to obtain estimates of parameters of both the stages. Then, using the assumptions on macroaggregates for the terminal years of target plans we project the total energy required for irrigation in the terminal years of the target plans.

Then, we project the shares in the terminal years of target plans, using the estimated growth rates from second stage of the model. Using these two projections we estimate the energy required by agriculture in operating electrified pumpsets for irrigation. Finally, using the conversion norms we obtain the projections of demand for electricity in the agricultural sector. Implicit in the growth rates estimated from second stage are the substitution possibilities of diesel pumpsets by electrified pumpsets.

The data required for estimation of the model are on value added in agriculture, total energy consumed by pumpsets (both diesel and electrified), and total energy consumed by electrified pumpsets. We have used time series data for the period 1971-72 to 1990-91 to estimate, the model, for the parameters.

The value added data has been taken from National Accounts Statistics (CSO) at 1980-81 prices. The data on number of electrified and diesel pumpsets are taken from Statistical Abstract published by CSO. Planning Commission norms on utilisation rate were combined with number of pumpsets (both diesel and electrified) to obtain the fuel required for operating these pumpsets. Finally, using the conversion table taken from Indian Petroleum and Natural Gas Statistics, these diesel and electricity requirements were converted to their calorific equivalents. The energy requirements in calorific units were added together to obtain total energy requirement. Electricity requirement in calorific units was divided by total energy requirement in calorific units to arrive at the share. The Planning Commission norms on average utilisation rate are:

i. Utilization rate of electric pump = 4423 Kwh/year/pumpset.

ii. Consumption of diesel pump = 883 lts/year/pumpset.

This, however, will somewhat overestimate the total energy requirement for the earlier years, as past years had lower utilization rates.[3]

The data for number of pumpsets is given in Annexure Table S5. The conversion table used is given below:

i., 1 kg. of HSD = 10,000 Kcals of energy.
ii. 1 Kwh. of electricity = 860 Kcals of energy.
iii. 1210 litres of HSD = 1 metric ton by weight of HSD.

Finally, to iron out random fluctuations, three yearly moving averages for the variables were taken. The share variable was obtained from the ratio of the moving averages.

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[3] An obvious consequence of this is that the elasticity factor estimated from the model may be somewhat biased. The norms are taken from the "Sectoral Energy Demand in India", 1991.

Now that we have discussed the methodology, variables and data, we may move on to illustrate the results obtained, on estimating equations (1) and (2), before we put forward the projections.

6.2 Estimation Results

On carrying out OLS to equation (1) the estimates of the parameters obtained are found to be quite significant at 5% level of significance. The explanatory variable explains more than 95% of the total variation. But there is existence of autocorrelation in the model. The result is tabulated in Table 6.1

Table 6.1

Regression Result

Dependent Variable = ln(TE)

Variable	Coefficient	t-Statistic	2 Tail significance
Constant	3.742	2.516	0.024
ln(VA)	2.572	18.458	0.000

$\bar{R}^2 = 0.9550$; D.W. = 1.077

So, we carry out AR(1) correction procedure, where we assume a linear relationship between the disturbance term and its lagged value. The result is given in Table 6.2

Table 6.2

Regression Result

Dependent Variable = ln(TE)

Variable	Coefficient	T-Statistic	2 Tail significance
Constant	12.687	1.736	0.106
ln(VA)	1.744	2.606	0.022
AR(1)	0.791	4.271	0.001

$\bar{R}^2 = 0.9711$; D.W. = 1.276

As is clearly evident from Table 6.2, our assumption of linear relationship between the disturbance term and its lagged value is not rejected at 1% level of significance. The explanatory power has improved with $\bar{R}^2$=0.9711 and the coefficient of logarithm of value added is significantly different from zero. However, the intercept term is not significant at 5% level of significance. But, since we are interested in the elasticity factor only, it does not affect our analysis. The elasticity obtained from the estimation is 1.74, shows an elastic demand for energy, for irrigation, in the agricultural sector.

For the second stage of the model, we have carried out two procedures of estimation. First by assuming a product disturbance term, we log linearised the equation (2) to obtain a semi log function and carried out OLS to the transformed equation. Again, by assuming an additive disturbance term we carried out NLS (Non linear least square) estimation to equation (2).

The NLS estimation results turned out to be superior to the OLS estimates with higher R^2, larger log likelihood value, larger F-statistics, larger t-statistics for both coefficients. So we choose the estimates obtained from carrying out NLS to equation (2). These estimates are tabulated in Table 6.3.

Table 6.3

Regression Result

Dependent Variable = K

Variable	Estimates	t-Statistic	2 Tail significance
b	1.735	20.965	0.000
a	0.029	-6.249	0.000

$\bar{R}^2 = 0.7065$; $R^2 = 0.7248$; D.W. = 1.472

As is evident from Table 6.3, both the coefficients are significant at 5% level of significance. There doesn't exist any autocorrelation at both 5% and 1% level of significance. The explanatory variables explain more than 70% of the total variation. These estimates of the model are then used to forecast the demand for electricity for the agricultural sector.

6.3 Assumptions And Projections

For the projection of demand for electricity we make certain assumptions on the growth rates of value added and use the norms regarding pumpsets.

In order to obtain the target growth rates for the value added in agriculture, we assume the target growth rates of GDP as given in the 8th Plan document. Then using the elasticity factor 0.68 we obtain the target growth rates for gross value added (GVA). These target growth rates are tabulated in Table 6.4 below, for the projection horizon.

Table 6.4

Target Growth Rates (% per annum)

Period	GDP	GVA	Total energy
1990-91 to 1991-92	1	0.68	1.15
1991-92 to 1992-93	4	2.72	4.62
1992-93 to 1993-94	5	3.4	5.78
1993-94 to 1996-97	5.6	3.80	6.46
1996-97 to 2001-02	6.0	4.1	6.97
2001-02 to 2006-07	6.5	4.42	7.48

Now, in order to obtain the target growth rates for total energy requirements for irrigation purposes in the terminal years of target plans, we use the target growth rates for GVA and the estimated elasticity factor, from equation (1), 1.74,(Refer Table 6.4). These growth rates are then used to project the total energy requirements in the terminal years of the target plans. These projections are tabulated in Table 6.5

Table 6.5

Projections for Total Energy Demand for Operating Pumpsets ('10^{14} Kcals)

Year	1990-91	1996-97	2001-02	2006-07
Total energy	0.67	0.90	1.3	1.8

Since we already have the estimates for equation (2) we can easily obtain the estimated growth rates for the shares, using the relation:

$$\frac{K_t - K_{t-1}}{K_{t-1}} = 0.028\ (1-K_{t-1})$$

These estimated target growth rates are used to obtain the shares in the terminal years of the target plans (refer Table 6.6).

Table 6.6

Projections for Shares of Energy Consumption By Electrified Pumps in Total Energy Requirement

Year	1990-91	1996-97	2001-02	2006-07
Share	0.507	0.549	0.583	0.617

Finally, these two projections on shares and total energy required for irrigation are used along with the conversion table, given in Section 6.1, to obtain forecasts of the electricity demand in the agricultural sector for the terminal years of the target plans. These are tabulated in Table 6.7.

Table 6.7

Forecasts of Electricity Demand (Mkwh)

Year	1990-91	1996-97	2001-02	2006-07
Forecast	39546.55	57643.56	85518.68	129256.2

It is evident from Table 6.7 that the demand for electricity shall increase considerably over the next two plans, with more than two hundred per cent increase over the base year. The expected growth rate between 1996-97 and 2001-02 is 8% per annum and that between 2001-02 and 2006-07 is 8.6% per annum.

The requirement of electricity in 2006-07 is likely to increase 3.27 times the consumption level of 1990-91 with an average annual growth rate of 7.68%. This increase may be accounted for by an increase in the share of electric pumpsets in the economy, due to our assumption of diesel pumpsets getting replaced by electric pumpsets. After having discussed with Professor R.P. Sengupta, we arrive at the conclusion that this projection is more or less consistent with the expected ground water potential in the terminal years of the target plans.

Even though our projections may have a bias, because of the assumption of uniform utilisation rate made during estimation, we accept these forecasts as the target forecasts of electricity demand for the terminal years of the target plans. But before we conclude our discussion of the demand for electricity in agricultural sector, let us very briefly describe an alternative model of projection. However, we reject the projections made with the alternative model, for the terminal years of target plans, for being over ambitious and infeasible.

6.4 Alternative Model And Projection

This model may be considered as an indirect method of forecasting the demand for electricity, if we view the last model as a more direct method of projection.

6.4.1 Methodology, Data And Estimation Results

This model, similar to the previous one, employs a two stage method. In the first stage total energy required for irrigation is estimated and in the second stage energy required by electrified pumpsets in total energy requirement is estimated.

Thus, in the first stage, three yearly moving average of gross irrigated area is related to three yearly moving average of agricultural output, in double-log form. Again, three yearly moving average of irrigated area is related to the three yearly moving average of total energy required for operating pumpsets, both diesel and electrified, in a double-log form. Thus, instead of directly relating value added in agriculture to total energy required for irrigation, we indirectly link up, first agricultural output to irrigated area and then irrigated area to total energy required for irrigation. The moving averages are taken to iron out the random fluctuations in the variables.

The first stage of the model in equation form may be written as:

$$\ln(IA) = a_0 + a_1 \ln(IO) \tag{3}$$

again,

$$\ln(TE) = b_0 + b_1 \ln(IA) \tag{4}$$

where,

IA = 3 yearly moving average of gross irrigated area.

IO = 3 yearly moving average of Index of agricultural output.

TE = 3 yearly moving average of total energy required for irrigation.

The second stage of the model is similar to that of the previous model, where share of energy consumption by electrified pumpsets in total energy consumption for irrigation takes a logistic function of time. The equational form is same as that of equation (2).

Thus, by considering gross irrigated area we are taking explicit consideration of multicropping patterns which are increasing with the objective of increasing productivity. Again, through the second stage of the model, we are considering substitution possibilities between diesel and electrified pumpsets.

The basic principle underlying the projections is that, given certain assumptions on gross value added for the target plans, we obtain target growth rates of the index of agricultural output. Using these growth rates and the estimated elasticity factor we obtain target growth rates for gross irrigated area. Finally, using the estimates of elasticity factor from equation (4) we obtain the target growth rates for the total energy requirement for irrigation.

Now, once we obtain the total energy requirements, using the target growth rates, for the terminal years of the target plans, we employ a similar procedure as the previous model in Section 6.1 to obtain the forecasts of demand for electricity for the target plans. This model, thus, differs from the first model only in the first stage, i.e., estimation of target growth rates of total energy requirement for irrigation. But the second stage in both the models are identical.

The data required to carry out estimation is more or less the same as described in Section 6.1, except that we require data on two new variables - index of agricultural output and gross irrigated area. Data on both the variables are taken from Economic Survey. Then, three yearly moving averages were taken for these variables.

The same Planning Commission norm for pumpsets and conversion table, as given in Section 6.1, are used to obtain the data on total energy. Three yearly moving average is taken for this. The same way, data for energy required by electrified pumpsets are generated and three yearly moving averages are taken to arrive at the share of energy required by electrified pumpsets to total energy requirements for irrigation.

Both to equations (3) and (4) OLS estimation procedure is applied to obtain the estimates of the parameters. The regression results are given below in Tables 6.8 and 6.9

Table 6.8

Regression Results

Dependent Variable = ln(IA)

Variable	Coefficient	t-Statistic	2 Tail significance
Constant	-1.461	-6.065	0.000
ln(IO)	1.107	22.582	0.000

$\bar{R}^2$ = 0.9695 ; D.W. = 1.391 (no autocorrelation at 1% level of significance.

Table 6.9

Regression Regulsts

Dependent Variable = ln(TE)

Variable	Coefficient	t-Statistic	2 Tail significance
Constant	21.904	165.227	0.000
ln(IA)	2.336	70.139	0.000

$\bar{R}^2$ = 0.9968 ; D.W. = 1.103 (no autocorrelation at 1% level of significance).

The coefficients are highly significant and the model has a very high explanatory power.

From Tables 6.8 we observe that the elasticity factor between irrigated area and agricultural output is 1.107. Again, from Table 6.9 we observe that the elasticity factor between total energy and irrigated area is 2.336. Both the elasticities being highly elastic, the impact of an increase in agricultural output on the total energy requirement is quite severe.

The growth rate for share estimated from the second stage of the model is given by:

$$\frac{K_t - K_{t-1}}{K_{t-1}} = 0.028\ (1-K_{t-1})$$

The results for the estimation of second stage of the model are given in Table 6.3, obtained by using NLS technique to the second stage. These first and second stage estimates along with the assumptions on GDP growth rates and value added growth rates are used to make the projections of demand for electricity.

6.4.2 Assumptions And Projections

The assumptions for GDP and gross value added growth rates for target plans are taken the same as those in Section 6.3. According to the 8th Plan Document the projected growth rates between 1992-93 and 1996-97, in per cent per annum, for the agricultural sector gross value added and value of gross output are given as:

for GVA = 3.1% per annum

and for value of gross output = 4.1% per annum.

From these two growth rates we obtain the elasticity factor of agricultural output with respect to value added as (4.1/3.1) or 1.32.

We have assumed that this elasticity factor shall prevail over the entire projection horizon. Therefore, given our target growth rates for value added we can easily obtain the target growth rates of agricultural output. Using the estimated elasticity factor 1.107 we also obtain the target growth rates for gross irrigated area. Finally, using the estimated elasticity factor 2.336 we estimate the target growth rates for total energy requirement for irrigation in the agricultural sector. These growth rates are tabulated below in Table 6.10. On using these growth rates we can easily forecast the total energy requirement for irrigation in the terminal years of the target plans.

Table 6.10

Target Growth Rates (% per annum)

Period	GDP	GVA	IO	IA	TE
1990-91 to 1991-92	1	0.68	0.89	0.98	2.28
1991-92 to 1992-93	4	2.72	3.59	3.98	9.27
1992-93 to 1993-94	5	3.4	4.48	4.97	11.58
1993-94 to 1996-97	5.6	3.8	5.01	5.56	12.95
1996-97 to 2001-02	6.0	4.1	5.41	6.0	13.98
2001-02 to 2006-07	6.5	4.4	5.8	6.43	14.98

Notes: IO : agricultural output ; IA : irrigated area
TE : total energy requirement for irrigation.

Again using growth rates, estimated from second stage of this model we can forecast the shares of energy required to operate electrified pumpsets to total energy requirements, for the terminal years of the target plans. These shares are tabulated in Table 6.6.

Using these two projections, the norms on pumpsets, and the conversion table we obtain the forecasts of electricity requirement to operate electrified pumpsets, for the terminal years of the target plans. These projections are given in Table 6.11 below.

Table 6.11

Projections for Electricity Requirement in Agriculture Using Alternative Model (Mkwh)

Year	1990-91	1996-97	2001-02	2006-07
Electricity demand forecast	41645.70	81015.18	165627.0	352056.2

Now, according to this forecast consumption requirement is expected to increase 8.45 times over 1990-91, registering an annual growth rate of 14.3%, in 2006-07.

Compared to the projections in Table 6.7 these forecasts are rather over ambitious. According to Sengupta (1993), as per the assumptions on the current estimates of ground water potential of the country and assessment of the minor irrigation potential in the country, the implied electricity requirement for irrigational purposes is at the level of 85 billion Kwh. in 1994-95, which would increase to 106 Bkwh in 2004-05.[4] So the projections given in Table 6.11 are far too much to be actually feasible. The ground water potential for minor irrigation have to be much higher if these projections have to be valid. But our projections in Table 6.7 are comparable to those of Sengupta's (1993) and are more consistent with the estimate 60 million acreage for minor irrigation in 2004-05. On these feasibility grounds we accept the projections given in Table 6.7 as the expected demand for electricity in the terminal years of the target plans.

6.5 Concluding Comments

Now that we have obtained the projections of demand for electricity for the terminal years of the target plans, the substantial increase in consumption expected is quite evident. However, we rejected the projections made with the alternative model for being infeasible. This abnormally high projection obtained from the second model is a consequence of the indirect approach taken to estimate the total energy requirements for irrigation. As the agricultural output was related to the irrigated area, the target growth rates of agricultural output, obtained through elasticity factor and target growth rates of value added, pushed up the growth rates of gross irrigated area to abnormal heights. Even though the target growth in gross irrigated area is needed to achieve the level of agricultural output in target plans, it is not feasible given the estimated ground water potential over the forecasting horizon. This was the main causal

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[4] These figures were arrived at by R.P. Sengupta after consultation with the experts and after reconsidering the possible under estimation of ground water potential made by the Advisory Board on Energy (refer Sengupta, 1993, p. 22).

variable for our abnormally high projections in case of the alternative model. So we reject the projections with the alternative model and accept those tabulated in Table 6.7.

It is, however, clear from the above projections of electrical energy requirements for agriculture that, the supply side constraint of water availability for minor irrigation is a binding constraints, for the agricultural growth, for all the terminal years. Therefore, if the agricultural growth have to be sustained, then the shortfall will have to be met by the extension of surface irrigation programmes of major and minor kinds. Therefore, as more and more electrified pumpsets replace diesel pumpsets, the potential electricity requirements increase but supply side constraint restricts the requirement.

In our models, we have assumed that electrified pumpsets will be replacing diesel pumpsets and at some time in the future all pumpsets for irrigation will be electrified. Increasing use of electricity for agriculture is most welcome in as much as it replaces the diesel pump sets by electric pumpsets. However, the extremely unreliable power supply and its failure at the nick of the time is the harsh reality which the farmer has to face very day. This is so much the case that those who can afford have started installing a diesel engine as standby in addition to the electric pump. Thus, unless the power situation in the Indian agriculture improves it is difficult even to think about diesel pumps being completely replaced by electrical pumps.

On the basis of the projections made we may define two types of demand. On the one hand there is, what we may term as, the feasible demand, and on the other hand we have the potential demand. For example, the projections made with the use of the alternative model may be infeasible but we cannot totally deny the demand potential. The extension of electricity grids and power lines does not immediately lead to increased demand for electricity. The lag in the process of rural electrification and increase in demand for electricity in rural area are strongly correlated. Actually, what happens is that, in the initial stages it is the richer farmers and those with other advantages that essentially benefit from the supply of electricity. The low income and small farmers, generally, come on stream subsequently, when credit facilities, with which to make the initial investment necessary to use electricity, are made available to them. Therefore, the potential demand for electricity in future is actually much higher than what our projections given in Table 6.7 are. Besides this, the potential demand to sustain an increase in demand for agricultural output, required to feed an increasing population, is much higher than the feasible demand for electricity.

Electricity demand in agriculture is, however, not entirely for the purpose of irrigation. Electricity demand for non irrigational purposes also exist. This demand is in fact gradually increasing in importance. Electricity is required for threshing, cutting, chopping etc. Mechanical and power operated threshers and choppers are fast getting introduced in the agricultural sector. Often due to lack of proper manning of meters and inefficient meters, these do not get recorded or incorrectly recorded. It is also the case that sometimes the farmers connect these mechanical instruments used for agricultural purposes to their domestic connections. The demand for electricity for these operations are growing at a moderately fast speed. But by the end of the 9th and 10th Plans their importance as means of electricity consumption shall no longer be insignificant. If some how this can be accounted for, it will be observed that the agricultural demand for electricity in the terminal years of the target plans will be higher than our projections.

However, taking the projections as normative it is quite clearly evident that the demand for electricity in the agricultural sector will be substantial over the next two plans. Looking at the pathetically poor performance on the supply side and the financial mess of the State Electricity Board, we may infer that the future of the agricultural sector is quite critical.

To conclude, we may add that our projections and the models employed have certain drawbacks. First, the use of calorific value to obtain the total energy requirements may give rise to some conceptual questions, as Professor R.P. Sengupta pointed out. Second, the use of a uniform utilisation rate of electric pumps and consumption per diesel pumpsets, through out the analysis, may somewhat bias the estimates and projections. It would have been better, if we could take account of the improvement in utilisation rates for our analysis and projection. Besides these, we should have carried out a sensitivity analysis; which due to time constraint we could not. Morecver, for a proper demand analysis for electricity in agriculture, it would have been better to take a total system approach of analysis taking choice of irrigation strategy into consideration. A disaggregated demand analysis based on agroclimatic variations, would have been better.

CHAPTER VII

COMMERCIAL & SERVICES SECTOR AND TRANSPORT SECTOR

7.1 Commercial & Services Sector

The commercial and services sector comprises of a plethora of activities, such as communication, trade, hotels and restaurants, banking and insurance, real estate, ownership of dwelling houses and business services, public administration etc. While other fuels are also used, electricity is the most important form of energy used in this sector. It is relatively simple to analyse and forecast the demand for electricity for this sector because of the ready availability of data, compared to other fuels.

The consumption of electricity in the commercial sector increased from 2572.66 MKWh. in 1970-71 to 4681.84 MKWh in 1980-81. In 1990-91 the consumption demand for electricity was as high as 11180.99 MKWh. Thus, in the decade of the '70's it registered a growth of 6.2% p.a., which increased to 9.1% p. a. in the decade of the '80's.[1] The average annual growth rate between 1971-72 and 1990-91 was 7.6%. On the other hand the growth rate in gross value added in commercial sector registered a growth of about 4% p.a. between 1971-72 and 1980-81, which increased to 6.2% in the decade of the 1980's. This shows that the consumption demand for electricity is growing faster than the value added in this sector. Thus, the power intensity in this sector has been continuously rising.

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[1] These figures are obtained from the General Review, CEA.

According to the study conducted by Energy Policy Division of Planning Commission (1991), the growth rate in commercial and services sector has been greater than the growth rate of GDP in the decades of 1970 's and 1980's. This is an evidence of the growing importance of this sector in the economy as a whole. The elasticities of electricity consumption with respect to value added in this sector has been fairly constant, at 1.6 approximately, over the decades of 1970's and 1980's. The elasticity is fairly constant and slightly less than that of the economy as a whole.

The increasing consumption of electricity in this sector has been the result of more number of buildings using airconditioners and elevators, greater installation of various office equipments like computers, electronic typewriters etc. It is expected that, with the development of the economy , this sector will assume greater importance. An obvious consequence of this would be, substantial rise in the demand for electricity over the future successive plans. We, thus propose to forecast the demand for electricity in this sector for the terminal years of the 8th, 9th and 10th Plans.

7.1.1 Methodology, Data And Estimation Results

Electricity demand is essentially a derived demand for the commercial sector. It is required in order to carry out various activities and also to enjoy the services of various electricity using appliances. It would have been better if data on these were available, to carry out demand analysis for electricity. But as data on these are not readily available, we carry out the analysis at an aggregative level by assuming the gross value added in this sector to be the main determinant of demand for electricity. Value added is considered to be an important forecasting tool for long range projections.

The methodology adopted for the purpose of projection is quite simple. It is assumed that demand varies with the value added in the commercial and services sector. An analysis of the historical trend shows that electricity consumption in this sector should be positively related to value added. In order to estimate this functional relationship we choose both a linear and double-log linear functional form. In equation form they may be written as:

$$ECON = a_0 + a_1(VA) \qquad (1)$$

and

$$\ln(ECON) = b_0 + b_1 \ln(VA) \qquad (2)$$

where,

ECON = Consumption of electricity in the commercial sector.

VA = Value added in commercial sector.

A time series data is used for estimating these two functional forms. The period 1971-72 to 1990-91 is considered as the sample range for estimation. The data on consumption for electricity was taken from the General Review, CEA and the data on gross value added was taken from National Accounts Statistics, CSO.

The functional forms (1) and (2) were estimated using ordinary least squares technique. The results are tabulated in Tables 7.1 and 7.2 respectively for equations (1) and (2).

Table 7.1

Regression Result

Dependent Variable = ECON

Variable	Coefficient	t-Statistic	2 Tail significance
Constant	-2375.399	-10.201	0.000
VA	0.219	36.821	0.000

$\bar{R}^2 = 0.9861$; D.W. = 2.396

Table 7.2

Regression Result

Dependent Variable = ln(ECON)

Variable	Coefficient	t-Statistic	2 Tail significance
Constant	-6.566	-15.553	0.000
ln(VA)	1.445	35.892	0.000

$\bar{R}^2 = 0.9854$; D.W. = 1.584

In both the equations (1) and (2) the $\bar{R}^2$ is very high, the estimated coefficients are significant and there is no autocorrelation present. Although in every aspect the linear equation yields results which are slightly better than log linear equation, still we have used the log linear equation estimates for projection. The reason for doing so is that, we can completely get rid of the intercept term and simply use the elasticity estimated for obtaining electricity consumption growth rates, for target growth rates of value added. This, however, assumes the elasticity factor to remain fixed over the entire projection horizon.

7.1.2 Assumptions And Projections

To forecast the demand for electricity for the terminal years of the target plans, we need to make assumptions of the target growth rates for gross value added in the commercial sector.

In order to obtain the growth rates for the target plans, we assume that the value added for this sector along with the value added by agricultural and industrial sectors together constitute the total GDP. Thus, gross value added for this sector may be calculated as a residual after growth rates for industrial and agricultural sectors have been accounted for in total GDP. Now, given the value added growth rates for the agricultural and industrial sectors (from our earlier chapters) and the GDP growth rates (obtained from the 8th Plan document), we may obtain the growth rates for this sector, for the target plans, as explained below:

Assume that the base year ratios of agricultural value added to total GDP and that of industrial value added to total GDP remains constant over the entire forecasting horizon.

Define,

Ratio of agricultural value added to total GDP $= a$
Ratio of industrial value added to total GDP $= m$
Base year GDP $= y_0$

Base year commercial value added $= y_0[1-a-m]$

Suppose,

Growth rate for GDP = g
Growth rate for agricultural value added = g_a
Growth rate for industrial value added = g_m
Growth rate for commercial value added = g_c

Terminal year commercial value added

$$= y_0 \ (1+g)^t - ay_0(1+g_a)^t - m \ y_0(1+g_m)^t \qquad (3)$$

Again, terminal year commercial value added

$$= y_0 \ (1-a-m) \ (1+g_c)^t \qquad (4)$$

Now, equating equations (3) and (4), we obtain

$$g_c = \left[\left\{ \frac{(1+g)^t - a \ (1+g_a)^t - m(1+g_m)^t}{(1-a-m)} \right\}^{1/t} - 1 \right] \qquad (5)$$

Therefore, using the values for y_0, a, m, and target g, g_a, g_m we can easily obtain the target g_c for the forecasting horizon. These calculated figures are given in Table 7.3.

Now that we have obtained the target growth rates for the commercial sector value added, we can easily obtain the target growth rates in consumption of electricity using the estimated elasticity factor 1.445, as given in Table 7.2. These growth rates are given in Table 7.4.

Table 7.3

Target Growth Rates (% per annum)

Period	GDP(g) (g)	Agricultural value added (g_a)	Industrial value added (g_m)	Commercial value added (g_c)
1990-91 to 1991-92	1	0.68	1.2	1.09
1991-92 to 1992-93	4	2.72	4.8	4.3
1992-93 to 1993-94	5	3.4	6.0	5.4
1993-94 to 1996-97	5.6	3.8	6.72	6.0
1996-97 to 2001-02	6.0	4.1	7.2	6.3
2001-02 to 2006-07	6.5	4.42	7.8	6.6

Table 7.4

Target Growth Rates for Electricity Demand

Period	Growth rates (% per annum)
1990-91 to 1991-92	1.57
1991-92 to 1992-93	6.19
1992-93 to 1993-94	7.78
1993-94 to 1996-97	8.64
1996-97 to 2001-02	9.07
2001-02 to 2006-07	9.5

Using these growth rates the forecasts for the electricity demand for the target terminal years are made.

Table 7.5

Forecast of Electricity Demand (MKWh)

Year	1990-91	1996-97	2001-02	2006-07
Forecast	11180.99	16666.20	25725.47	40498.03

Thus, it is evident from the Table 7.5 that the electricity demand in the commercial sector will increase substantially over the next decades. The growth rate expected between 1990-91 and 2001-02 is 7.8% per annum; and between 1990-91 and 2006-07 it is expected to be 8.3% per annum. Therefore, as the economy develops the commercial and services sector will become increasingly power intensive.

7.1.3 Concluding Comments

The projections should be taken as normative rather than precise forecasts. Besides, the usual problem of assuming a constant elasticity factor throughout the forecasting horizon, this projection also makes other rather restrictive and simplistic assumptions. For example, the assumption of constant agricultural value added to GDP and industrial value added to GDP ratios, throughout the forecasting horizon is rather restrictive. These relative shares will be changing over the successive plans. Moreover, the assumption of commercial sectors value added being calculated as a residual, is also a very simplistic assumption.

Besides, it would have been better if data on other parameters such as the number of electrical appliances used in the commercial sector and their specific consumption were available. The forecast definitely would have been richer if it was projected as a derived demand. Thus, the need to improve the database to facilitate the estimation on a more accurate basis is strongly felt.

7.2 Transport Sector

The transportation system, spatially spread over a vast area, is quite complex. It is used for carrying both passenger and freight traffic by rail, road, inland waterways, pipelines and airways. In rural India drought animals continue to be a major mode of transport even though tractors and trucks are gradually making inroads.

Both the passenger and freight traffic in India is growing, although the road traffic is growing at a faster rate. The population of vehicles have also been growing at a considerable rate, of which the growth rate of private transport registered the highest growth of 18.6% between 1980 and 1986.

The transport sector is an important user of energy, which has been growing over the years. It increased at the rate of 2.09% per annum between 1953 and 1970 to 3.2% between 1970 and 1987. The intensity of energy consumption with respect to value added was 479.3 ktoe/ Rs billion but fell to 304.4 ktoe/Rs billion in 1987. This falling intensity inspite of increase in energy consumption and increase in population of vehicles is on account of more efficient rail transport based on diesel and electricity and the introduction of fuel efficient vehicles. The trends in the elasticity of energy consumption in the transport sector with respect to both value added and GDP have been increasing. For example, the elasticity of commercial energy consumption with respect to GDP increased from 0.53 between 1953 and 1970 to 0.83 between 1970 and 1987, and with respect to gross value added it increased from 0.34 between 1953 and 1970 to 0.47 between 1970 and 1987.

The transport sector has been a large consumer of coal. But over the years there has been a shift from coal to oil. The transport sectors relative dependence on oil has increased considerably. The growth in consumption of electricity has not, however, been high but steady. The relative share of oil in various fuels in transport sector increased from 38.3% in 1970 to 82.1% in 1987, while that for electricity went up from 1% in 1970 to 1.4% in 1987. But the share of electricity consumption by transport sector in the total consumption of electricity of the economy, has been declining continuously over the last few decades; in 1987 this share was as low as 2.4%. Thus, electricity demand in the transport sector is quite low and the excessive dependence is on oil. It is the diesel engine which is essentially replacing the steam locos and not the electricity operated engines which is doing the replacement. Also the increasing dependence on road transport both for passenger and freight traffic has caused the share of oil to go up and that of electricity to fall. Considering the present road vehicle population and the high infrastructural cost of electrifying tracks there is little or no reason to expect that consumption of electricity will increase to any significant extent over the next two plans. It isn't difficult to visualize the declining trend of share of transport sector in total electricity consumption in the near future. According to the General Review published by CEA, the consumption of electricity by transport sector in 1970-71 was 1364.57 MKWh, increased only to 2265.91 MKWh in 1980-81. and finally to 3772.26 MKWh in 1988-89.

Even though the growth rate increased in the decade of the 80's over the decade of the 70's, still its relative share in overall electricity consumption declined.

Because of its relatively small share and bleak prospects of any substantial increase over the next two plans, we did not carry out an independent analysis and projections of electricity demand for the terminal years of the target plans. We have, however, accepted the projections made in "Sectoral Energy Demand in India", a study conducted by Energy Policy Division of Planning Commission (Government of India) 1991, as the future normative forecast of electricity demand for the transport sector.

The demand for energy is derived demand depending upon the demand for transport activity. But the demand for transport activity is itself derived from the activity levels of industry agriculture and household sectors. The approach taken by the Energy Policy Division (EPD) is on the basis of these factors. The EPD estimated the demand for all fuels by transport sector individually and electricity is one of them. Thus, the past trends in the transport sector upto the base year 1986 of their study have been considered in detail and energy demand has been projected upto the year 2009. The study covers both passenger and freight traffic, where in the case of passenger traffic all the three subsectors i.e., public, private and sub-urban traffic were considered. All the existing modes of transport which consume commercial energy where considered. The sub-urban traffic of only four cities (Calcutta, Bombay, Delhi and Madras) were considered.

The base case assumption for projection that they made was that the economy will grow at the rate of 6% per annum for the period 1990-2010. It was assumed that the agricultural share in total GDP will decline from 26.6% in 1994 to 21% in 2004 and then to 19% in 2009. The share of industry was assumed to increase from

30.9% in 1994 to 37.7% in 2004 and further to 39.0% in 2009. The rest was assigned to all other sectors grouped together. It was assumed that the share of railways in freight traffic which is declining will be arrested in view of the greater energy efficiency in the railways. The share of electric traction in the movement of goods and services is expected to increase. Steam locos is expected to be phased out by 1994. The share of diesel traction is expected to decline over the forecasting horizon. But still in 2009 it is expected to account for about 55% of the total traction and rest will be electric traction. Elasticities of private and public mode of transport with respect to per capita GDP and GDP were obtained. They also made assumptions on the technoeconomic parameters for different vehicles.

On the basis of these assumptions they made their projections for the year 1994, 1999, 2004 and 2009. The projections that they made can be broadly categorized into two groups - traffic projections and projections regarding fuel requirements. We, however, present here only the projections regarding electricity requirement in the target terminal years by the transport sector.

The passenger and freight traffic by train is expected to increase over the target terminal years but the share of train in passenger transport is expected to decline from 12.3% in 1994 to 7.8% in 2009. As regards freight traffic the share of railways is expected to increase from 42.8% in 1994 to 48.2% in 2009.

As regards the projection of fuel requirements the projections of electricity requirement for freight and passenger traffic are expected to increase (refer Table 7.6).

Table 7.6

Electricity Requirement in Transport Sector (KTOE)

	1994	1999	2004	2009
For passenger movement	160	172	212	254
For freight movement	305	402	637	976
Total	465	574	849	1230

Note: KTOE = Kilo-tons of oil equivalent.

However, it is expected that the share of railways, where electricity is used, in total demand for energy by the transport sector, will decline from 7.8% in 1994 to 6.7% in 1999, and again 6.5% in 2004 to 6.3% in 2009.

According to their projections the share of electricity in total energy requirement by the transport sector will be quite low. They expect that the share of electricity should be 1.4% in 1994, 1.1% in 1999, 1.2% in 2004 and 1.4% in 2009. Thus, the share of electric traction has not increased appreciably despite the conscious efforts made in this direction and a major share of increased traffic is expected to be moved by diesel traction. This explains for the lower demand for electricity in 1999.

It is evident from their projections and analysis that unless there is a shift of passenger and freight traffic towards railways and the dependence on road transport falls the electricity requirement by the transport sector in overall electricity requirement won't be significant. Moreover, given the present trend there is little possibility for electricity demand by transport sector to increase over the next two plans.

CHAPTER VIII

COMPARISON AND COMMENTS

Against the target growth rates for the 8th, 9th and 10th Plans, in this study we have obtained the electricity demand projections at the aggregative and sectoral level.

The aggregative demand projections are obtained at the macro level for the economy as a whole. The macro demand function, which was used to make the projections was made a function of the GDP. This demand function thus gives us the electricity requirement in order to achieve the target growth of the economy in the terminal years of the target plans.

On the other hand, we can arrive at the total electricity requirement of the economy in the terminal years of the target plans by adding up the sectoral requirements. These sectoral requirements are arrived at by analysing the demand at the disaggregative or sectoral level under various sectoral assumptions for the target plans. Moreover, the sectoral level analysis uses different techniques and methodologies to obtain the demand for electricity in the terminal years. The data sources for the demand analysis of electricity are also different. Besides, the aggregative projection takes into consideration demand for both utilities and non-utilities, whereas the sectoral projections only takes demand for utilities into consideration. These together may cause the aggregative projections to somewhat diverge from that of the all sectors together. For the sake of convenience we shall name the aggregative projections as overall electricity demand and the sum total of all sector demand together as the all sector demand for electricity.

The overall demand for electricity includes both the demand for utilities and non-utilities. It is expected to grow at the rate of 8.6% p.a. between 1990-91 and 2006-07. The demand for electricity is expected to grow at the rate of 8.6% p.a. over the 9th Plan and decline marginally to 8.4% p.a. over the 10th Plan. Thus, a substantial growth in demand for electricity is expected between 1996-97 and 2006-07. The most important thing to observe is that this growth in demand is higher than the growth rate of GDP. This implies that over the next two plans the economy will become more power intensive and is expected to be 0.142 in 2001-02, and then further increase to 0.155 in 2006-07. The per capita demand for electricity is also expected to grow significantly with an annual growth rate of 6.77% between 1996-97 and 2001-02, and at the rate of 6.76% between 2001-02 and 2006-07. In order to have a more detailed analysis we need to consider the sectoral demand pattern over the entire target plan horizon. Even though there exists discrepancy between overall and all sector demand projections, still in the normative sense our analyses should be comparable. The difference in all sector and overall electricity demand may be partly explained by the different methodologies adopted for projection. Moreover, the sectoral level projections are based on more detailed assumptions and at a much disaggregated level unlike the macro projections.

To illustrate, take the case of the Residential sector. In this sector we explicitly assume the expected poverty ratios for the terminal years of target plans. By doing this we take into consideration the impact of the poverty elimination policies. But at the aggregate level such an assumption on the spending ability of the people is not made. Moreover, for the residential sector the analysis is further carried out for rural and urban sectors separately. As the consumption pattern is different in the two sectors, it will have an impact on future projections through differing elasticities. The data source for the aggregative analysis and residential sector analysis is also different. Another assumption made for residential sector but not for macro analysis is that of urbanisation factor being falling. Such an assumption means that we assume that standard of living in the rural sector to improve over the next two plans.

Let us now take the case of agricultural sector, where electricity is assumed to be required only for operating irrigation pumpsets. At the macro level we do not make any such assumption. But in the agricultural sector assumptions on technoeconomic factors along with those on macro aggregates are made. Besides this, the substitution possibility between electrified pumpsets and diesel pumpsets is modelled explicitly. These are not considered explicitly for the macro level analysis. Moreover, while considering agricultural sector projections we have differentiated between feasible demand and potential demand.

Similarly, we have considered the substitution possibilities explicitly while making projections for the industrial sector, which were not assumed for the macro projections. The data source for this sector is also different.

These diverse assumptions along with difference in methodologies may well cause the macro projections to diverge from all sector projections. Moreover, we have not considered the transport sector within the all sector projections. Even though the share of this sector in the total requirement of electricity in the terminal years of the target plans is expected to be very small, still it may cause the two projections to differ. But, since we consider the projections as normative rather than precise forecasts, so neglecting the difference in growth rates of the two projections we may infer about the causes of such rapid growth in overall demand by studying the sectoral projections (refer Table 8.1)

At the sectoral level the residential sectors demand for electricity is expected to grow at the rate 7.9% p.a. between 1990-91 and 2006-07. It is expected to grow at the rate 8.3% p.a. over the 9th Plan and thereafter decline to 6% p.a. during the 10th Plan. This is based on the assumption that by the end of the 9th Plan poverty ratio will fall to 5% and by the end of the 10th Plan it will further fall to 1%. Along with this the assumption of decreasing urbanisation factor, pushes up the growth rate of demand for electricity in this sector. The share of electricity demand in this sector will continue to increase.

The agricultural sectors demand for electricity will also increase considerably over the 9th and the 10th Plans. With the assumption that more and more electric pumpsets will be replacing diesel pumpsets, the demand is expected to grow at the rate 7.6% p.a. between 1990-91 and 2006-07. Over the 9th Plan demand for electricity is expected to have a growth rate of 8.2% p.a. and then go up to 8.6% p.a. However, this is the growth of feasible demand. The growth rate of potential demand is expected to be even higher. With the increasing pressure on the agricultural sector to increase production over the next two plans, to meet the requirements for the growing population and sustain the target GDP growth rates for the economy, it is natural to expect the growth rate for electricity demand to be high. Thus, to increase productivity, irrigational requirements would increase, and with the assumption that the electric pumps would be

Table 8.1

Electricity Consumption Projections Sectorwise and All India (in Gwh)

Year	Domestic	Industry	Agriculture	Commercial	All sector	All India
1990-91	35061.48	133744.25	39546.55	11180.99	219533.27	211568.4
1996-97	59042.76	246946	57643.56	16666.2	380298.5	351578.9
2001-02	87975.02	318185.8	85518.68	25725.47	517405.0	530643.7
2006-07	117685.2	367077.4	129256.2	40498.03	654516.9	794309.9

replacing diesel pumps, the consumption requirement of electricity would go up considerably. Therefore, it is expected that over the next two plans the agricultural sector would become highly power intensive, as the growth rate in electricity requirement is much higher than the growth rate in value added in this sector. Thus, the share of agricultural sector in total demand for electricity is expected to increase substantially over the next two plans. We may mention here that besides electricity requirements for irrigational purposes, there are other uses to which electricity is put to in the agricultural sector. This demand is also expected to go up with the prosperity of the farmers and with greater accessibility to electricity. It is not an absurd proposition, that demand for electricity for these purposes would also go up over the next two plans, which will only add to the power intensiveness of this sector.

The commercial sector is expected to grow over the next two plans and assume an important position in the development process. The commercial sector being an important consumer of electricity, is expected to increase its demand over the next two plans. The demand for electricity in this sector is expected to grow at the rate of 8.4% p.a. between 1990-91 and 2006-07. over the 9th Plan and the 10th Plan it is expected to grow at the rate of 9% p.a. and 9.5% p.a. respectively. This sector is expected to become highly power intensive over the next two plans. The commercial sectors share in total consumption of electricity is also expected to go up over the next two plans.

Therefore, the high growth rates in these three sectors would considerably raise the demand for electricity in the economy. Going by the projections of the Planning Commission the growth in the demand for electricity for the transport sector over the next two plans won't be substantial and its share in total demand for electricity should be slightly more than 1%.

As far as the demand for electricity by the industrial sector is concerned, it is believed that it will continue to have the lion's share in the total demand for electricity. However, the growth rate for electricity requirement is expected to be only 6.5% between 1990-91 and 2006-07. Moreover, the demand for electricity is expected to grow at a declining rate with 5.3% p.a. over the 9th Plan and 2.9% p.a. over the 10th Plan. With the increasing technical efficiency and conservation measures, the demand for electricity would be brought down further, in the industry. The industry is expected to remain quite power intensive over the next two plans, though the share of electricity demand in total demand is expected to decline over the next two plans.

However, our observations about the demand pattern for the various sectors is obviously within the bounds of the assumptions we made during the analysis. There are additional factors which we have not considered but cause the demand to increase further, some of which we have already mentioned as passing comments.

With proactive efforts being taken by the government, as clearly mentioned in the 8th Plan document, to increase the pace of electrification and develop the rural non agricultural sector, it is expected that during the 9th Plan and by the end of 10th Plan a considerable increase in demand for electricity in rural sector shall take place. More households shall be electrified and all rural households shall have access to electricity by the 10th Plan. With the increase in rural income, electricity shall be increasingly affordable. Besides these, the effective population control programmes, which are being undertaken, imply a change in the fertility behaviour of the society. Such change can only come about with the extension of health care and methods of ensuring child survival, an increase in income, the spread of education and literacy, and growth of employment opportunities. All these would materialize through a larger use of electricity.

With increasing income in the rural sector and increasing pace of rural electrification, more farmers should be able to afford to operate electric pumpsets. With increasing credit facilities, the number of electric pumpsets would increase. These would increase the consumption of electricity over the 9th and 10th Plans. Increase in development would require the agricultural productivity to go up. This will raise the utilisation rate of the pumpsets and increase the potential demand for electricity. Actual demand, however, will be considered by the availability of ground water.

With increasing pace of technological innovation and conservation measures the demand for electricity in the industrial sector is expected to come down over the next two plans.But it will still continue to be the major consumer of electricity.

All these together will create a lot of pressure on the demand for electricity, in addition to what we have already observed from our projections. It is clear from the above sectoral analysis of our projections that the economy will continue to undergo a structural change over the 9th and 10th Plans. Such a structural change in the economy, in the path of development, will push up the demand for electricity to a considerable extent. The increasing pace of electrification of rural sector undertaken during the 8th Plan will have its impact felt in the 9th and 10th Plan through a significant rise in demand for electricity in the residential and agricultural sectors. The commercial and services sector will gain in importance and will contribute to increase the demand for electricity substantially by the end of the 10th Plan.

To test for the credibility of our projections, let us compare our projections, for the terminal years of the 10th Plan, with those of Energy Policy Division (EPD) study (1991) and Advisory Board on Energy Study (1985). On comparing our projections with those of the study by EPD (1991) and ABE (1985), we observe that the projections are not exactly same. But considering the fact that different methodologies and assumptions are adopted by these studies from ours, the projections are not noncomparable. To be slightly more illuminating let us compare the projections sector by sector.

For the residential sector if we choose the projection of ABE corresponding to population 1046 million and for EPD study 1060 million for the year 2004-05 and compare our projections corresponding to population 1086 million in 2006-07, we observe that with projection 117.7 TWh our projections are different from both ABE's with 100 TWh and EPD study 134.4 TWh. The EPD study take explicit assumption that by 2004-05 all houses will be completely electrified and electricity will replace kerosene for lighting. Besides this, their assumptions on poverty ratio, mean monthly per capita expenditure, urbanisation factors and share of electricity in total expenditure on fuel and light are different from ours. The EPD study have assumed a constant GDP growth rate of 6% p.a.. As regards our discrepancy with ABE study may be attributed to different methodology, assumptions and data source. We have used the NSSO data for 38th Round and used price of electricity implicit in the data.

As regards the projections for the agricultural sector our projection of 129.3 TWh in 2006-07 is much more comparable to those of EPD study with 109.2 TWh than the ABE's with 42-45.2 TWh. Whatever difference exists in our projections with the EPD study may be attributed to the difference in methodology and some of the assumptions. For example the assumptions on utilisation rate are different from ours. The model used to carry out projections are also different. On the other hand ABE study estimated electricity requirements using regression techniques, by projecting number of pumpsets, which were correlated to value of output and using norms they obtained the electricity requirements. As regards norms on utilization rate of a pump, they used their best judgement to make the assumption. They, thus, assumed the utilization rate 3588 Kwh/pump which is lower than our assumption. This can explain somewhat the difference in their projection from ours.

For the industrial sector, our projections of 367 TWh in 2006-07 are much more comparable to those of ABE's enduse estimates of 367 TWh in 2004-05, than their regression estimates of 267 TWh in 2004-05. The EPD study used a disaggregated analysis by obtaining trends of consumption of energy in different industries. Besides considering the energy requirement of the major energy consuming industries, they considered the scope of energy conservation and changes in technology mix while carrying out projections. But such energy conservation and changes in technology mix were not considered by ABE study. In that sense the EPD study was an improvement over ABE study. However, the results of the EPD study are comparable to those of ABE's regression analysis. Because of different methodology and assumption made for projection by EPD study, our projections are not exactly comparable to theirs. In our projections we have neither incorporated energy conservation measures nor change in technology mix. However, we have incorporated the fuel and non-fuel factor substitution possibilities in the model.

As regards the projections for commercial sector, our projections of 40.5 TWh in 2006-07 are slightly lower than the EPD study's projection of 49.4 TWh in 2004-05. But this is probably because of the different methodology and assumption used for projection. They used a linear equation for projection whereas we have used the elasticity factor to carry out projection. Also they have assumed a constant GDP growth rate of 6% p.a. which is different from our assumption on GDP growth rates. Still both projections are comparable.

Thus, by and large, our projections for the terminal years of the 10th Plan are comparable to the earlier studies. It is therefore, quite evident from our projections, that the demand for electricity by the terminal year of the Tenth Plan will be substantially high. If we consider our projections to be indicative, then it has serious implications for the future development of the economy and its sustainability. Since the power sector involves long gestation period, power planning has to be conducted 15 to 20 years in advance. Unless serious consideration is given now to meet the requirement of electricity, then it is bound to have serious repercussions on the economy's performance.

The present scenario of the power situation is not too encouraging. There is a persistent shortfall of achievement over target in capacity addition. In 1990-91 the gap was 36.49%, in 1991-92 this 20.49% and in 1992-93 about 20.66%; which shows that this will cost the economy dearly in future. The overall problems in the power sector, at present, fall into several categories. These include, resource crunch for further addition of capacity, generation inefficiencies, high transmission and distribution losses, theft and pilferages of power in agriculture, industry and household sectors, and increasing losses of State Electricity Boards. On top of this an optimal generation mix is lacking, leading to unnecessary wastage of non-renewable resources and creating environmental hazards.

The current poor performance of the power sector with supply shortage and poor voltage conditions in most parts of the country are having serious adverse effects on industry and agriculture. An obvious consequence of this is that industrial units engaged in export oriented manufacturing and other large industrial units have started installing diesel generating sets. Farmers who can afford to keep standby diesel pumpsets and a section of domestic consumers are acquiring portable generators. This raises the demand for petroleum products, which in turn has serious repercussions on the financial health and competitiveness of the economy.

However, the main problem with the power sector in India has been the financial performance of the power sector, going from bad to worse everyday. In 1992-93 the losses incurred by the State Electricity Boards (SEB's) amounted to Rs 47 billion (Economic Survey, 1993-94). These losses are not only unsustainable but have increased because of inflation, low levels of operational efficiency and high transmission and distribution losses. These have been further aggravated by the populist and highly subsidised tariffs rates for agricultural, domestic and industrial sectors. Cheap electricity in the form of low tariff that is being charged has put generation and supply under tremendous pressure. The costs of generation and distribution have risen but the recovery, in the form of tariff rates, is very low. Given the present power situation to prevail in future, our projections of demand have very little chances of being met. This will then have very serious repercussions on the economy.

Unless the performance of the power sector improves the target growth rates of GDP and objectives of economic liberalization will never be achieved. The power sector being highly capital intensive requires large capital investments to set up additional generating capacity, and distribution and transmission facilities. So given the indicative projections for the terminal year of the 10th Plan, the need of the hour is enough resources to be mobilised, and improvement in the technical and financial health of the power sector, if the demand has to be met and make the development process sustainable.

These ask for some measures to be taken for the better performance of the power sector.

Among the measures is, structural reform of the SEB's. The SEB's should be split into entities in charge of generation and distribution with separate accounts and accountability. Professionalism in various management disciplines, and financial and personnel management needs to be improved in SEB's. There is a high degree of over staffing at all levels in most of the SEB's.

Financial viability of the SEB's have to be prevented from eroding. This can be brought about through revising the tariff structure periodically, so as to keep pace with the inflationary increases in the cost of power supply. The gap between the unit cost of power supply and the revenue rate realised from some consumer categories, particularly farmers, have increased substantially over the years. These agricultural consumers contribute to only 5% of the revenues realised by the SEB's, when about a one third of the electricity is sold to them. On the other hand, agricultural subsidy has increased from 17% in early 1980s to 27% in 1991-92. Even the domestic sector is highly subsidised. Part of these losses due to subsidies were regained through the surpluses generated from sale to industrial, commercial and other sectors. Inspite of this, the uncovered subsidy was Rs 4700 crores in 1992-93, and is likely to increase to Rs 4935 crores in 1993-94. However, if the SEB's were to earn only the stipulated 3% of returns, they would generate an additional revenue of more than Rs 6000 crores in 1993-94. If the tariff in agriculture was raised to 50 paise/KWh, the overall rate of return would earn SEB's an additional revenue of Rs 1924 crore in 1993-94. Thus, periodic revision of tariff structures would improve the financial health of the SEB's substantially.

The operational performance of the generating stations need to be improved by setting up dedicated forces. These task forces should set up programmes and plans for eliminating and solving all adverse factors related to the functioning or operation of the generating stations. The continued high transmission and distribution (T&D) losses have plagued the SEB's. The T&D losses have remained above 22%. These are mainly due to a sparsely distributed load over large area, mainly in the rural sectors, lack of investment in the transmission systems and high degree of pilferage of power. These losses can be brought down through system improvement schemes and investments in T&D systems. Such investments may prove to be highly productive; e.g. adding 1MW of power to the grid through reduction in T&D losses is far more economical than adding the same by setting up new generating capacities.

In order to smooth the process of capacity addition and release investible resources the Government has openned the gates for domestic and foreign private companies, by amending the Indian Electricity Act, 1910, and Electricity Supply Act, 1948. Attractive incentives are being given to the domestic and foreign private sectors but the response is not as encouraging as it was thought. The objective of the private sector is to earn optimum returns on investment. It is the financial performance of the SEB's and low current rate of return which is keeping them back. Besides these there are other problems to private sector participation. Without going into all that detail, we may say that the approach for involving private parties should be recast without any delay and the SEB's should increase their strength to invite bidders and negotiate with them, if necessary with external assistance. Private sector should be invited in large scale to the area of power distribution.

Most of the projects implemented by power utilities are capital intensive, and hence cost and time overruns are very costly, not to forget the adverse impact on GDP growth rate caused by supply shortages. Thus, good project management which includes structuring new institutions, development of detailed management system, etc., may improve the situation to a great extent.

Demand side management is often not fully appreciated, but has the power to ameliorate the failing situation to a great extent. Thus, through management of electrical energy on the consumption side, a higher rate of return may be achieved. Demand side management includes restructuring of tariffs rates and T&D losses, which we have already discussed. Through energy conservation the power sector can gain a lot of lost ground. According to the expert groups, enough savings of all forms of energy is possible in the industrial sector. The potential energy savings in the agricultural sector was estimated at 30% of the total consumption of electricity. A lot of this wasteful consumption arises from the exceptionally low tariff structure in agricultural sector. According to the expert group set upto in 1982, the potential for saving electricity in just these two sectors could be 2000 MW. This is almost the capacity that may be added during the 8th Plan at a capital cost of 5000 crore. the estimate that the experts provided show that by spending only one third of this amount the necessary amount may be saved through conservation measures. The areas of conservation include cogeneration, installation of instrumentation and computerised process control system, and the adoption of newer energy efficient technologies.

If we consider our projections to be indicative, rather than precise numbers, of the size and pattern of electricity demand in the terminal years of the target plans, then it is clear that by the end of the Tenth Plan India will become highly power intensive. Along with development India will experience a structural change, which will be the major contributor in making the economy power intensive. Within the existing framework there is very little scope for electricity conservation. When we talk about demand increasing substantially by the terminal year of the Tenth Plan, we implicitly assume that the development process will continue, with the economy moving along its target growth path unhindered. But we cannot ignore the causality which runs from electricity requirement to GDP.

To sum up, therefore, this entire study was devoted to obtain projections for the electricity requirements for the terminal years of the target plans. But these projections were based on the assumptions of target GDP growth rates. The forecasts imply that if the economy moves towards these GDP growth rates, then the industry would demand more power and Indian farmers would clamour for more of the same. The urban and rural household will join the cacophony. This will lead to an explosive situation in the country if the existing power performance continues in future. The measures suggested will be able to ameliorate the situation somewhat and also release enough funds to carry out proper supply side planning efficiently. We did not concern us with the supply side story here, but which needs to be considered to get a complete view of the power situation in future. This we propose to keep for future research.

It is true that a more detailed analysis of the demand side, taking into consideration electricity using appliance stocks, statewise or regionwise disaggregation, industrywise disaggregation, separate analysis for energy intensive industries, disaggregation into agro-climatic zones, etc., would have been more fruitful. Even though the models used for the forecasting suffer from certain inadequacies, still they provide us with valuable insights, such as insensitivity of consumption of electricity to its price, robustness of GDP as a forecasting tool, significance of the effect of spending ability on consumption, etc. There is scope for improvement and further research in this area, but for that an improved database is required. However, given the limitations of data and time this study is indicative enough of the critical power demand situation of the economy by the terminal year of the Tenth Plan. It is also apprehended that, given the indicative projections, unless the performance of the power sector improves the objective of government liberalization policies and growth in GDP are not likely to be achieved.

APPENDICES

APPENDIX TO CHAPTER 3

3.A.1. We have already seen in the previous two models as to how expectation might play an important role in the evolution of demand for electricity. But both the models do not incorporate price of electricity as an explanatory variable. So we look at the expectation model in a different framework by incorporating price of electricity as an explanatory variable. In doing so we adopt a model similar to that used by Saram, Anandlingam and Mubayi (1987) to estimate demand for petroleum products in Sri Lanka.

Often adjustment to price changes in consumption cannot be made immediately in the short run because of factors such as existing technology, existing appliance stock, infrastructural requirements, geographical location, habits, etc. As a consequence, benefits to the full extent cannot be reaped immediately, which takes a longer time at the expense of some costs. So, optimal level of consumption may take some time to be achieved. The model, thus, takes the form of partial adjustment model.

Therefore, the demand function takes the form:

$$C_t^* = \alpha (y_t)^{\beta} (P_t)^{r}, \qquad (A)$$

where,

C_t^* = desired optimal per capita consumption in the ith period.

C_t = per capita consumption in t^{th} period

y_t = per capita income in t^{th} period

P_t = relative price of electricity.

The partial adjustment mechanism is specified as

$$\frac{C_t}{C_{t-1}} = \left(\frac{C_t^{*}}{C_{t-1}} \right)^{1-\cap} . e^{u_t} \quad , 0 \le \cap \le 1 \qquad (B)$$

where,

u_t = disturbance term

The error term is introduced in the specification of C_t in equation (B) and not in (A).

Now, carrying out necessary logarithmic transformation to (A) and (B) and combining them we obtain,

$$\ln C_t = \ln\alpha + \cap \ln C_{t-1} + \beta(1-\cap)\ln y_t + r(1-\cap)\ln P_t + u_t \qquad (C)$$

The presence of lagged dependent variable as an explanatory variables has similar undesirable consequences as the previous two models. As a result, Durbin's h-test to test for the existence of autocorrelation and instrumental variable estimation procedure needs to be adopted. Estimated value of C_{t-1} is used instead of C_{t-1} in the equation (C) to obtain estimates of the coefficients.

The data used to estimate the model is a time series for the period 1960-61 to 1990-91. Data for per capita consumption and per capita income variables are same as those used for the previous two expectation models. Data for the price variable is taken as that used in the translog functional form model in section 3.3.

The results are tabulated below,

$h = -0.06432$

therefore,

$|h| < 1.96$

So we do not reject the null hypothesis of the non existence of autocorrelation.

Variable	Coefficients	t-statistics	2 tail significance
Constant	-1.855	-2.643	0.014
$\ln y_t$	0.271	1.908	0.068
$\ln P_t$	0.082	1.342	0.192
$\ln C_{t-1}$	0.897	20.001	0.000

dependent variable = $\ln C_t$

The parameter estimates are:

$\cap = 0.896$, $\alpha = -17.84$, $\beta = 2.60$, $r = 0.78$

$R^2 = 0.9975$ shows that variance in dependent variable is very well explained by the explanatory variables.

$DW = 2.0364$, $h = -0.0999$, shows the absence of autocorrelation in the estimated equation.

However, both the $\ln y_t$ and $\ln P_t$ are insignificant at 5% level of significance. Price variable is highly insignificant. This is not an unnatural phenomenon as price of electricity is administered in India and does not really affect the consumption decision. Which could also explain for opposite sign of the coefficient for price variable.

Using the above estimates we obtained estimates of elasticities: under non-optimal conditions they are,

$$\mu_{11} = \frac{\partial \ln C_t}{\partial \ln y_t} = \beta(1-\eta) = 0.27$$

$$\mu_{12} = \frac{\partial \ln C_t}{\partial \ln P_t} = \gamma(1-\eta) = 0.08$$

Thus we have a positive, but very small, price elasticity for consumption of electricity, which could be because of the fact that prices being administered do not affect consumption decision.

Elasticity under optimal conditions are:

$$\mu_1 = \frac{\mu_{11}}{1-\eta} = 2.6$$

$$\mu_2 = \frac{\mu_{12}}{1-\eta} = 0.78$$

The income elasticity though small under non optimal conditions or in short run, in the long run it is highly elastic. Moreover, both the long run elasticities are greater than short run elasticities. This conforms to the theory that adjustment take longer time which requires dynamics to be build in the model explicitly.

However, since both $\ln y_t$ and $\ln P_t$ coefficients are statistically insignificant so we could not use this model for the purpose of projection. The model, moreover, suffers from the drawback that fixed adjustment rates are assumed; but a more serious criticism is that same rate of adjustment is adopted for both price and income. This is slightly unrealistic because even though the form of adjustment may be similar, there is no a priori reason to believe why the speed of adjustment should be same.

3.A.2 Stepwise regression procedure is often used in deciding the best set of explanatory variables for a regression model. The procedure is to introduce explanatory variables one at a time and calculating the F-statistic and deciding on whether to keep the variable or drop it. Once decided to keep the first explanatory variable a second one is introduced and F-statistic is calculated a fresh for both variables. Then it is decided whether to keep both or reject one of them. This procedure continues till no more variables can be added to the model. Thus, the decision to add or drop a variable is usually made on the basis of the contribution of that variable to the explained sum of squares as judged by the F-test. Therefore, stepwise regression takes care of inclusion of irrelevant variables which lowers the tolerance or raises the standard error of the variables.

Tolerance is defined as $1-R_i^2$ where R_i^2 indicate that the ith independent variable is almost a linear function or combination of other independent variables. R_i^2, thus, is the multiple correlation when ith independent variable is regressed on all other independent variables.

Standard error of the ith independent variable, S_{Bi} is given by,

$$S_{Bi}^2 = \frac{S^2}{(1-R_i^2)\ (n-1)S_i^2}$$

where,

S = sample standard error

S_i = sample standard error when ith independent variable is the dependent variable.

Stepwise regression procedures are used to take account of the multicollinearity problem in the data.

$\boxed{\text{3.A.3}}$ Method of Obtaining Principal Components

Suppose we have a matrix of explanatory variables X of n observations on K variables:

$$X = \begin{bmatrix} X_{11} & \cdots\cdots\cdots & X_{K1} \\ \cdot & & \cdot \\ \cdot & & \cdot \\ X_{1n} & \cdots\cdots\cdots & X_{Kn} \end{bmatrix}$$

Here observations have been standardized by using their sample mean and standard deviation. This makes the variables free of units. The method requires transformation of the X's to a new set of variables which will be pairwise uncorrelated and of which the first will have the maximum possible variance, the second the maximum variance among those uncorrelated with the first, and so on and forth.

$$\text{Let } P_{1t} = a_{11} X_{1t} + a_{21} X_{2t} + \ldots\ldots + a_{K1} X_{Kt},\ t = 1,\ldots,n$$

denote the first new variable

therefore in matrix form, $P_1 = Xa_1$

where P_1 is an n - element vector and a_1 is k - element vector. The sum of squares of P_1 is

$$P_1'P_1 = a_1'X'Xa_1$$

In order to maximize $P_1'P_1$, the constraint $a_1'a_1=1$ is imposed (otherwise $P_1'P_1$ would be unbounded).

So, $\quad L = P_1'P_1 - \cap_1 (a_1'a_1-1)$

or $\quad L = a_1'X'Xa_1 - \cap_1 (a_1'a_1-1)$

Now,

$$\frac{\partial L}{\partial a_1} = 2\ (X'X)a_1 - 2\cap_1 a_1 = 0$$

therefore,

$$(X'X)a_1 = \cap_1 a_1$$

Thus, a_1 is an eigen vector of $(X'X)$ corresponding to the characteristic root $\cap_1$.

$$\text{Then, } P_1'P_1 = a_1'X'Xa_1 = \cap_1 a_1'a_1 = \cap_1, \quad (\text{because } a_1'a_1 = 1)$$

So, largest $\cap_1$ is chosen, to maximize $P_1'P_1$, among all the eigen values of $(X'X)$.

For $(X'X)$ positive definite, it will have positive eigen values. Then the first principal component of X is P_1.

Now say, $P_2 = Xa_2$ and choose a_2 such that $P_2'P_2$ is maximum subject to $a_2'a_2 = 1$ and $a_1'a_2 = 0$. The second constraint ensures that P_2 is uncorrelated to P_1, because eigen vectors corresponding to distinct eigen values are orthogonal.

$$a_1'X'Xa_2 = \cap a_1'a_2 = 0 \text{ if } a_1'a_2 = 0$$

Thus covariation between P_1 and P_2 is zero.

Now, $L = a_2'X'Xa_2 - \cap_2 (a_2'a_2-1) - \mu(a_1'a_2)$

therefore,

$$\frac{\partial L}{\partial a_2} = 2X'Xa_2 - 2\cap_2 a_2 - \mu a_1 = 0$$

Now, $2a_1'X'Xa_2 - 2\cap_2 a_1'a_2 - \mu a_1'a_1 = 0$

or $\quad 2a_1'X'Xa_2 - \mu = 0$

But $\quad a_1'X'Xa_2 = 0$

therefore, $\mu = 0$

So, $\quad 2X'Xa_2 = 2\cap_2 a_2$

or $\quad (X'X)a_2 = \cap_2 a_2$

Therefore $\cap_2$ is so chosen that it is the second largest latent root of $(X'X)$ as $(X'X)a_2 = \cap_2 \cdot a_2$

Proceeding in the way for each of K roots of (X'X) and assembling the resulting vectors in the orthogonal matrix, A,

$$A = [a_1\ a_2\ \ldots\ldots\ldots\ a_K],$$

the K principal components is obtained.

therefore, $P = XA$,

where,

P = matrix of K principal components; matrix is nxK.

$P'P = A'X'XA = \Gamma$ = diagonal matrix of eigen values.

[therefore, orthogonal matrix of eigen vectors diagonalises X'X]

Thus principal components are pairwise uncorrelated and that their variances are given by,

$$P_i'P_i = \cap_i \ , \ i=1,\ldots\ldots K.$$

Total variation in X's is given by,

$$\Sigma_t X_{1t}^2 + \ldots\ldots + \Sigma_t X_{Kt}^2 = \mathrm{tr}\ (X'X)$$

but $\mathrm{tr}(A'X'XA) = \mathrm{tr}(X'XAA') = \mathrm{tr}(X'X);\ A'A=I$

therefore,

$$\sum_{i=1}^{K} \sum_{t=1}^{n} X_{it}^2 = \mathrm{tr}\ (X'X) = \mathrm{tr}\ (A'X'XA) = \mathrm{tr}(\Gamma) = \sum_{i=1}^{K} \cap_i$$

therefore,

$\frac{\eta_i}{\Sigma \eta_i}$ = proportion of contribution of each principal component to the total variation of the X'S.

Only a small number of principal components account for a large variation in the X's.

According to Kaiser's decision rule only those principal components with latent roots greater than 1 are to be retained. So all principal components are not used; some are left out of the analysis.

This method can be used to remedy multicollinearity in the model, which invalidates the OLS estimation procedure to the original model. So the original model can be transformed to another model using the principal components, as the new set of explanatory variables. Since there is no correlationship between the principal components, one can apply OLS technique to the transformed model and obtain estimates of the coefficients, the coefficients of the original model can be obtained, this is a popular technique inspite of severe criticisms.

So even though in the original model of form:

$Y = X\beta+\epsilon$, X = matrix of explanatory variables.

OLS technique was inapplicable because of the presence of multicollinearity in the model; OLS technique is applicable to the transformed model of form:

$Y = P\tau + u$, P = matrix of principal components generated from the X matrix.

(Johnston, J., "Econometric Methods", (3rd edn.), McGraw Hill, 1984, pg. 536-540).

3.A.4 P_3 and P_4 are principal component of case (b).

$$\ln IE = b + b_3 P_3 + b_4 P_4 + u, \text{ where } u = \text{error term}$$

applying OLS to this equation we obtain the result:

Variable	Coefficient	2 tail significance
Constant	-2.810	0.000
P_3	0.361	0.000
P_4	0.038	0.002

$\bar{R}^2 = 0.9725$
D-W. = 1.166, no autocorrelation at 1% level of significance.

Using these coefficient estimates we obtain the estimates of the model represented by equation (45) as:

$$\begin{aligned}\ln IE = {} & -5.189 + 0.217\ln y - 0.276\ln P + 0.088\ln Ps + 0.059\ln t \\ & + 0.014(\ln y)^2 + 0.004(\ln y)(\ln P) + 0.011(\ln y)(\ln Ps) \\ & + 0.007(\ln y)(\ln t) - 0.031(\ln P)^2 + 0.008(\ln P)(\ln Ps) \\ & + 0.012(\ln P)(\ln t) + 0.011(\ln Ps)^2 + 0.012(\ln Ps)(\ln t) \\ & + 0.013(\ln t)^2\end{aligned}$$

3.A.5 Projections in the presence of autocorrelated disturbance terms requires consideration of estimated autocorrelation coefficients and error term of the final model. This is so because we have obtained estimate of the parameters of a function whose error terms are autocorrelated. Thus, what we do is estimate the parameters from the transformed data,

$$Y_t^* = \beta_0 + \beta_1 X_{1t}^* + \beta_2 X_{2t}^* ,$$

where

$$Y_t^* = Y_t - PY_{t-1} , X_{1t}^* = X_{1t} - PX_{1t-1} , X_{2t}^* = X_{2t} - PX_{2t-1}$$

P = autocorrelation coefficient.

We are given the values of X's in period (n+1), where n is the last observation of our sample and we want to estimate the value of Y in period (n+1).

The most efficient prediction is obtained from the expression

$$Y_{n+1} = \beta_0^* + \beta_1^* X_{1n+1} + \beta_2^* X_{2n+1} + P^* e_n ,$$

where,

e_n = residual of the nth observation in final model

P^* = estimated autocorrelation coefficient from final iteration.

β_i^* = estimates of β_i's from the transformed variables in the final iteration

$$e_n = Y_n - \beta_0^* - \beta_1^* X_{1n} - \beta_2^* X_{2n}$$

3.A.6 Projections of Aggregate Consumption of Electricity in GWh using the expectation model are given below:

Year	Projections (with intercept term of equation (7))	Projections (without intercept term of equation (7))
1996-97	351578.9	329141.2
2001-02	530643.7	497460.6
2006-07	794309.9	754029.0

APPENDIX TO CHAPTER 4

4.A.1 In order to estimate the Engel's function we have pooled the data. While pooling the data we have assumed that the data is cross sectionally heteroscedastic and time wise autoregressive. Thus the model and its stochastic specification is as follows:

$$\ln y_{it} = \alpha_0 + \ln x_{it} + e_{it}$$

and

$$e_{it} = P\, e_{it-1} + v_{it}, \qquad \text{for all } i, \text{ for all } t$$

$$E(v_{it})=0;\ E(v_{it}, v_{jt}) = \sigma_{ij},\ E(v_{it}, v_{js}) = 0, \text{ for all } t \neq s$$

where,

y_{it} = per capita monthly expenditure on fuel and light for ith share in t^{th} period.

x_{it} = per capita monthly total private final consumption expenditure for ith share in t^{th} period.

e_{it} = disturbance term for ith state in t^{th} period.

v_{it} = error term for ith state in t^{th} period

P = first order autocorrelation coefficient.

If, $e_i = (e_{i1}, \ldots\ldots e_{iT})$, then it is assumed,

$$E(e_i) = 0 \qquad \text{for all } i = 1, \ldots\ldots, N$$

and

$$E(e_i e_j') = \frac{\sigma_{ij}}{1-P^2} \begin{bmatrix} 1 & P & \cdots & P^{T-1} \\ P & 1 & \cdots & P^{T-2} \\ \vdots & & & \vdots \\ \rho^{T-1} & \cdots & \cdots & 1 \end{bmatrix}$$

The covariance matrix results from the assumptions on v_{it}.

Now, in the presence of such a stochastic framework, following Kmenta (1971), a feasible generalized least square technique is applied.

4.A.2 BUSE'S R^2

One possibility for a measure of goodness of fit is the R^2 obtained by applying least squares to the whole system. If we measure the proportion of explained variation in y for a given equation around the mean for that equation, this definition is given by,

$$R^2 = 1 - \frac{\hat{e}'\hat{e}}{y'(I_M \otimes D_T)y}$$

where

$\hat{e} = y - X\hat{\beta}$ are the least square residuals

and

$$D_T = I_T - \frac{jj'}{T} \text{ with } j = (1...1...1)'$$

The matrix D_T transforms a given y_i from its original observations into deviations around its mean; D_T is idempotent and

$$[(I_M \otimes D_T)y]' [(I_M \otimes D_T)y] = y' (I_M \otimes D_T)y.$$

If R_i^2 is the coefficient for determination for the ith equation, then

$$R^2 = \sum_{i=1}^{M} R_i^2 \frac{y_i' D_T y_i}{y' (I_M \otimes D_T)y}$$

Thus, this definition is a weighted average of the coefficients for each equation with the weight of the ith equation given by the equations proportion of the total dependent variable variation. However, it is based on least squares residuals not those of the GLS estimator. Thus, Buse proposed that the problem can be overcome by using Feasible GLS residuals, $\tilde{e} = y - X\tilde{\beta}_{GLS}$ in place of $\hat{e}$, but there is a possibility that R^2 may be negative in this case (Judge, et.al., 1985).

4.A.3 The assumptions for sensitivity analysis are given below:

Case 2: Assumptions (in '83-'84 Prices) - Rural

	1990-91	1996-97	2001-02	2006-07
GDP (Rs crore)	271310	346400	454881	608733
PFCE (Rs crore)	201093	251881	324544	424569
Population (millions)	837	925	1006	1086
Rural population (millions)	619	668	699	723
Urbanization factor	1.57	1.57	1.5	1.45
Share of expenditure on electricity in total expenditure on fuel and light	0.10	0.15	0.20	0.22
Implicit price of electricity in Rs/ KWh	0.43	0.43	0.43	0.43

4·A·3 (Contd.) **Case 2: Assumptions (in '83-'84 Prices) - Urban**

	1990-91	1996-97	2001-02	2006-07
GDP (Rs crore)	271310	346400	454881	608733
PFCE (Rs crore)	201093	251881	324544	424569
Population (millions)	837	925	1006	1086
Rural population (millions)	218	257	307	363
Urbanization factor	1.57	1.57	1.5	1.45
Share of expenditure on electricity in total expenditure on fuel and light	0.22	0.25	0.27	0.29
Implicit price of electricity in Rs/ KWh	0.49	0.49	0.49	0.49

4.A.3 (Contd.) **Case 3: Assumptions (in '83-'84 Prices) - Rural**

	1990-91	1996-97	2001-02	2006-07
GDP (Rs crore)	271310	354389	485539	680994
PFCE (Rs crore)	201093	258691	345861	472526
Population (millions)	837	925	1006	1086
Rural population (millions)	619	668	699	723
Urbanization factor	1.57	1.57	1.5	1.45
Share of expenditure on electricity in total expenditure on fuel and light	0.10	0.15	0.20	0.22
Implicit price of electricity in Rs/ KWh	0.43	0.43	0.43	0.43

4·A·3 (Contd.) **Case 3: Assumptions (in '83-'84 Prices) - Urban**

	1990-91	1996-97	2001-02	2006-07
GDP (Rs crore)	271310	354389	485539	680994
PFCE (Rs crore)	201093	258691	345861	472526
Population (millions)	837	925	1006	1086
Rural population (millions)	218	257	307	363
Urbanization factor	1.57	1.57	1.5	1.45
Share of expenditure on electricity in total expenditure on fuel and light	0.22	0.25	0.27	0.29
Implicit price of electricity in Rs/ KWh	0.49	0.49	0.49	0.49

4.A.4 Projections of Distribution of Monthly Consumption Expenditure Per Person For Different Terminal Years

RURAL BASE CASE UNIT: MILLION

Consumption expenditure classes Rs/month/person		Assumed mean of class expenditure Rs/month/person	Population			
Lower limit	Upper limit		1990-91	1996-97	2001-02	2006-07
0	50	35.34	16.22	0.844285	0.326083	0.012580
50	60	55.23	16.34	2.361313	0.978110	0.065359
60	70	65.15	23.21	5.174795	2.354092	0.247482
70	85	77.35	42.46	16.69499	7.935187	1.255055
85	100	92.28	49.64	26.89755	15.22268	3.583766
100	125	111.52	86.29	72.76463	44.51141	15.12790
125	150	136.45	80.28	90.86483	62.98542	31.86868
150	200	171.16	120.02	173.9526	151.6100	109.5217
200	250	221.46	75.46	120.9556	137.9644	136.8699
250	300	272.12	44.82	73.94132	101.5842	128.7073
> 300		445.47	64.26	83.54802	173.5282	295.7401
Poverty Ratio			27%	10%	5%	1%
Mean consumption expenditure (Rs/month/person)			174.36	199.65	241.10	300.29
Average expenditure on fuel and light (Rs/month/person)			10.13	11.27	12.65	14.23
Average monthly expenditure on electricity (Rs/month/person)			1.01	1.69	2.53	3.13

4.A.5 Projections of Distribution of Monthly Consumption Expenditure Per Person For Different Terminal Years

RURAL | CASE 2 | UNIT: MILLION

Consumption expenditure classes Rs/month/person		Assumed mean of class expenditure Rs/month/person	Population			
Lower limit	Upper limit		1990-91	1996-97	2001-02	2006-07
0	50	35.64	16.22	0.054508	0.001537	0.000072
50	60	55.23	16.34	0.344688	0.016356	0.000361
60	70	65.15	23.21	1.30761	0.102193	0.003831
70	85	77.35	42.46	6.459159	0.854946	0.054731
85	100	92.28	49.64	16.36767	3.365545	0.329760
100	125	111.52	86.29	59.01439	19.69069	3.287625
125	150	136.45	80.28	93.03596	47.29629	79.51901
150	200	171.16	120.02	210.3614	169.5326	14.89119
200	250	221.46	75.46	145.2705	185.7123	151.0435
250	300	272.12	44.82	76.66061	130.3421	161.1687
> 300		445.47	64.26	59.12334	142.0853	312.7011
Poverty Ratio			27%	5%	1%	0.1%
Mean consumption expenditure (Rs/month/person)			174.36	199.65	241.10	300.29
Average expenditure on fuel and light (Rs/month/person)			10.13	11.26	12.77	14.56
Average monthly expenditure on electricity (Rs/month/person)			1.01	1.69	2.55	3.20

4.A.6 Projections of Distribution of Monthly Consumption Expenditure Per Person For Different Terminal Years

RURAL CASE 3 UNIT: MILLION

Consumption expenditure classes Rs/month/person		Assumed mean of class expenditure Rs/month/person	Population			
Lower limit	Upper limit		1990-91	1996-97	2001-02	2006-07
0	50	35.34	16.22	10.53943	2.730993	0.884084
50	60	55.23	16.34	11.92206	4.191273	1.622556
60	70	65.15	23.21	17.20427	7.529697	3.260223
70	85	77.35	42.46	34.63747	18.03664	8.824865
85	100	92.28	49.64	41.66743	26.08290	14.37107
100	125	111.52	86.29	78.52400	57.47870	36.19591
125	150	136.45	80.28	78.74798	68.72854	51.30726
150	200	171.16	120.02	134.4118	136.8816	116.8881
200	250	221.46	75.46	92.39101	115.5751	113.7301
250	300	272.12	44.82	60.34832	83.78025	94.1346
> 300		445.47	64.26	107.6061	177.9842	281.7811
Poverty Ratio			27%	20%	10%	5%
Mean consumption expenditure (Rs/month/person)			174.36	199.65	241.10	300.29
Average expenditure on fuel and light (Rs/month/person)			10.13	10.99	12.33	13.66
Average monthly expenditure on electricity (Rs/month/person)			1.01	1.65	2.47	3.00

4.A.7 Projections of Distribution of Monthly Consumption Expenditure Per Person For Different Terminal Years

URBAN BASE CASE UNIT: MILLION

Consumption expenditure classes Rs/month/person		Assumed mean of class expenditure Rs/month/person	Population			
Lower limit	Upper limit		1990-91	1996-97	2001-02	2006-07
0	50	34.53	7.50	0.510916	0.138180	0.004065
50	60	55.55	4.95	0.833965	0.290053	0.016516
60	70	65.32	5.82	1.484868	0.604575	0.052054
70	85	77.50	7.94	3.594710	1.772403	0.233989
85	100	92.56	13.34	5.520565	3.242472	0.620875
100	125	112.08	18.07	13.37597	9.140065	2.667324
125	150	137.22	18.31	16.70957	13.49142	5.693655
150	200	171.94	31.33	39.08214	36.36043	22.83992
200	250	222.72	24.94	37.15153	41.87876	35.65563
250	300	273.04	19.31	31.60945	39.23751	42.94028
> 300		466.06	66.49	107.1262	160.8441	252.2756
Poverty Ratio			27%	10%	5%	1%
Mean consumption expenditure (Rs/month/person)			273.7	313.45	361.65	435.42
Average expenditure on fuel and light (Rs/month/person)			16.42	17.5	19.03	21.14
Average monthly expenditure on electricity (Rs/month/person)			3.61	4.38	5.14	6.13

4.A.8 Projections of Distribution of Monthly Consumption Expenditure Per Person For Different Terminal Years

URBAN CASE 2 UNIT: MILLION

Consumption expenditure classes Rs/month/person		Assumed mean of class expenditure Rs/month/person	Population			
Lower limit	Upper limit		1990-91	1996-97	2001-02	2006-07
0	50	34.53	7.50	0.045874	0.00105	0.000006
50	60	55.55	4.95	0.136955	0.006416	0.000078
60	70	65.32	5.82	0.344637	0.026893	0.000579
70	85	77.50	7.94	1.208748	0.155618	0.006197
85	100	92.56	13.34	2.526335	0.502466	0.033831
100	125	112.08	18.07	7.934592	2.513838	0.310546
125	150	137.22	18.31	13.12385	6.231424	1.244690
150	200	171.94	31.33	37.66895	26.48835	9.563380
200	250	222.72	24.94	43.13449	42.24433	25.23964
250	300	273.04	19.31	37.69729	48.60077	40.50455
> 300		466.06	66.49	113.1782	180.2287	286.0964
Poverty Ratio			27%	5%	1%	0.1%
Mean consumption expenditure (Rs/month/person)			273.7	313.45	361.65	435.42
Average expenditure on fuel and light (Rs/month/person)			16.42	18.19	20.12	22.05
Average monthly expenditure on electricity (Rs/month/person)			3.61	4.55	5.43	6.39

4.A.9 Projections of Distribution of Monthly Consumption Expenditure Per Person For Different Terminal Years

URBAN CASE 3 UNIT: MILLION

Consumption expenditure classes Rs/month/person		Assumed mean of class expenditure Rs/month/person	Population			
Lower limit	Upper limit		1990-91	1996-97	2001-02	2006-07
0	50	34.53	7.50	4.941133	1.032809	0.328260
50	60	55.55	4.95	3.700491	1.284856	0.516585
60	70	65.32	5.82	4.880712	1.950678	0.948373
70	85	77.50	7.94	8.814817	4.547652	2.310059
85	100	92.56	13.34	9.806323	6.371754	3.770807
100	125	112.08	18.07	18.65578	14.00730	9.715876
125	150	137.22	18.31	18.82997	18.04125	13.38972
150	200	171.94	31.33	36.49520	39.01758	33.91977
200	250	222.72	24.94	28.52355	38.13179	39.55004
250	300	273.04	19.31	25.13390	32.78802	38.42006
> 300		466.06	66.49	97.21808	149.8262	220.1304
Poverty Ratio			27%	20%	10%	5%
Mean consumption expenditure (Rs/month/person)			273.7	313.45	361.65	435.42
Average expenditure on fuel and light (Rs/month/person)			16.42	16.30	18.24	19.86
Average monthly expenditure on electricity (Rs/month/person)			3.61	4.08	4.92	5.76

APPENDIX TO CHAPTER 5

$\boxed{5.A.1.}$ **Proposition:** A cost function is separable in input prices and output if and only if the production function is homothetic.

Proof : Suppose, $y = h\,(f(x))$ is a homothetic production function, where y = output, x = vector of inputs $h' > 0$ and $f(x)$ is homogeneous of degree τ.

Now, h^{-1} exists because h is monotonic

therefore $h^{-1}(y) = f(x)$

or $m(y) = f(x)$ where $m(.) = h^{-1}(.)$

Say, $f(x^*)) = 1$, [x^* produces 1 unit of output]

therefore, $m(y) \,.\, f(x^*) = m(y)$

therefore, $f\,[x^*.n(y)] = m(y)$, where $n(y) = (m(y))^{1/\tau}$.

Now suppose, $C(p,1) = px^*$ [$C(p,y)$ is the cost function which minimises cost to produce y units of output]

therefore,

$$C(p,y) = px^*.n(y)$$

Now, $x^*n(y)$ minimises cost (proof by contradiction).

Therefore

$$C(p,y) = n(y) \cdot C(p,1)$$

Again, suppose $C(p,y) = k(y) \cdot C(p,1)$

Define, $V(y) = \{x: f(x) \geq y\}$

and

$$\bar{V}(y) = \{x: px \geq C(p,y), \text{ for all } p \geq 0\}$$

therefore,

$$V(y) \subseteq \bar{V}(y)$$

Suppose $V(1) = \bar{V}(1)$

then $x \in V(1) = \bar{V}(1)$

claim, $k(y) \cdot x \in V(y)$

say $k(y)x \notin V(y)$

Then, $k(y) \cdot x \notin V(y)$ [because $V(y) \subseteq V(y)$]

therefore, $\exists\ p \mid p \cdot k(y) \cdot x < C(p,y)$

But $C(p,y) = k(y) \cdot C(p,1)$, given

So, $\exists\ p \mid p \cdot k(y) \cdot x < k(y) \cdot C(p,1)$

or $\exists\ p \mid px < C(p,1)$

or $x \notin \bar{V}(1)$

or $x \notin V(1)$, contradiction

therefore $k(y).x \in V(y)$

Now, if $k(y) = (m(y))^{1/\tau}$ and $(m^{-1})' > 0$

then $v(y)$ is homothetic.

$\boxed{5.A.2}$ The disturbance term of the cost function is v and the disturbance term of a share equation is u_i.

Suppose there are q such share equations

Now, since $\Sigma_i u_i = 0$, so the covariance matrix is singular. Thus, in order to estimate we drop one share equation and estimate the cost equation and $(q-1)$ share equations jointly. Thus, now we have q independent equations to be estimated jointly. Let us define the disturbance terms of this new system of equations as:

$$\epsilon_i, \; i = 1, \ldots, q.$$

where,

$$\epsilon_1 = v \quad , \epsilon_2 = u_2 \quad , \ldots\ldots, \epsilon_q = u_q$$

if we drop the first share equation. For the sake of convenience, let us assume that we have dropped the first share equation.

We also assume that,

$$E(\epsilon_i \epsilon_i') = \sigma_{ii} I \; , \; i=1,\ldots,q$$

and

$$E(\epsilon_i \epsilon_j') = \sigma_{ij} I \; , \; i \neq j; \; i,j = 1,\ldots, q$$

Thus, the disturbance variance is different in various equations, but within the equation it is homoscedastic and has zero covariance. It is also assumed that the disturbances in different equations have non zero covariances and that for any pair the covariance is same at each sample point, (Johnston, 1984). Thus collecting these variances and covariances in a symmetric positive definite matrix we have.

$$\Sigma = \begin{bmatrix} \sigma_{11} \cdots\cdots & \sigma_{1q} \\ \vdots & \vdots \\ \sigma_{q1} \cdots\cdots & \sigma_{qq} \end{bmatrix}$$

Therefore, the covariance matrix for the random disturbance for all observations, t=1,....,T, we have:

$$V(\epsilon) = \Sigma \otimes I$$

where,

$$\epsilon = (\epsilon_{11} \cdots\cdots \epsilon_{qT})'$$

define, $V = \Sigma \otimes I$

The appropriate, estimation procedure to the system of equation, in our case, given by the cost equation and share equations with the first share equation deleted, would be GLS:

$$\beta_{GLS} = (X'V^{-1}X)^{-1}X'V^{-1}Y$$

where X is matrix of explanatory variables of the system to be estimated and Y is the vector of dependent variables of the system and, V the covariance matrix defined above.

However, V is unknown because Σ is unknown. So, Zellner suggested the procedure where OLS is separately applied to each equation obtaining vector of estimated residuals $(\epsilon_1, \ldots\ldots \epsilon_q)$, then these estimated residuals are used to estimate Σ.

Thus,

$$S_{ii} = \frac{\hat{\epsilon}_i' \hat{\epsilon}_i}{n} \text{ and } S_{ij} = \frac{\hat{\epsilon}_i' \hat{\epsilon}_j}{n}$$

These S_{ii} and S_{ij} are used in place of σ_{ii} and σ_{ij} to obtain estimated Σ as $\hat{\Sigma}$, which is then used to obtain the GLS estimates.

In the iterative procedure, S_{ij} and S_{ii} are calculated as described above and hence Σ is obtained. This Σ is used to calculate β_{GLS}. Again, this β'_{GLS} is used to obtain fresh estimates of vector of residuals say, $(\hat{\hat{\epsilon}}_1, \ldots\ldots \hat{\hat{\epsilon}}_q)$. These are then used to obtain new values of S_{ii} and S_{ij} and hence a new $\hat{\Sigma}$ say, $\hat{\hat{\Sigma}}$, to obtain in turn a new β_{GLS}. This procedure is repeated again and again until convergence is achieved. The β_{GLS} obtained in the final stage of iteration is also maximum likelihood estimate and hence is asymptotically consistent.

$\boxed{\textbf{5.A.3.}}$ If we substitute the MLE's obtained on estimation of the unrestricted model in the log likelihood function we get the maximized log likelihood,

$$\ln L_u = - T/2 \ (1 + \ln 2\pi) - T/2 \ \ln \left| \hat{\Omega}_u \right|$$

Similarly, for the restricted model we obtain the maximized log likelihood as,

$$\ln L_R = - T/2 \ (1+\ln 2\pi) - T/2 \ \ln \ | \ \hat{\Omega}_R |$$

Now, likelihood ratio is given by,

$$\cap = (\ |\hat{\Omega}_R| \ / \ | \ \hat{\Omega}_u \ |)^{-T/2}$$

therefore under the null hypothesis of valid restrictions, the maximized likelihood L_R and L_u should be very similar. That is the likelihood ratio, L_R/L_u, should be close to unity and its logarithm, $(\ln L_R - \ln L_u)$, close to zero. If at least one of the restrictions are invalid, then we expect $(L_R/L_u) < 1$ and hence $(\ln L_R - \ln L_u) < 0$. Thus, the idea behind likelihood ratio test is that we reject the null hypothesis of valid restrictions if $(\ln L_R - \ln L_u)$ is sufficiently negative.

Therefore,

$$\ln \cap = \ln L_R - \ln L_u = -T/2 \ [\ \ln |\hat{\Omega}_R| - \ln |\hat{\Omega}_u| \ ]$$

Now, $LR = -2 \ [\ln \ (L_R) - \ln(L_u) \ ] = T \ [\ln |\hat{\Omega}_R - \ln |\hat{\Omega}_u| \ ]$.

For large samples, the likelihood ratio statistic,

$LR = -2\ln\cap$, has a chi square distribution with degrees of freedom equal to total number of parametric restrictions.

Restrictions are rejected if the test statistic LR is sufficiently positive, i.e., if it exceeds the relevant critical value taken from χ^2-distribution. [(Greene (1991), pgs. 387-393].

Table 5.A.4

PROJECTION FOR SHARE OF FUEL IN TOTAL COST AND TOTAL EXPENDITURE ON FUELS IN 1988-89 PRICE

YEAR	SHARE OF FUEL IN TOTAL COST	TOTAL EXPENDITURE ON FUEL (Rs. LAKH)
1990-91	0.3945	2762055
1996-97	0.4437	3489545
2001-02	0.4985	4184815
2006-07	0.5577	4652229

Table 5.A.5

ESTIMATED PROJECTION GROWTH RATES FOR SHARE OF EXPENDITURE ON ELECTRICITY IN TOTAL EXPENDITURE ON ALL FUELS

PERIOD	GROWTH RATE (%)
1988-89 to 1989-90	5.64
1989-90 to 1990-91	5.45
1990-91 to 1991-92	5.26
1991-92 to 1992-93	5.06
1992-93 to 1993-94	4.86
1993-94 to 1994-95	4.66
1994-95 to 1995-96	4.46
1995-96 to 1996-97	4.25
1996-97 to 1997-98	4.05
1997-98 to 1998-99	3.85
1998-99 to 1999-2000	3.65
1999-2000 to 2000-01	3.46
2000-2001 to 2001-02	3.27
2001-2002 to 2002-03	3.08
2002-2003 to 2003-04	2.9
2003-2004 to 2004-05	2.72
2004-2005 to 2005-06	2.55
2005-2006 to 2006-07	2.38

ANNEXURE TABLES
(STATISTICAL TABLES)

TABLE S1

YEAR	Tot Cons(GWh) (uti+nonuti)	Tot.Cons(GWh) (nonutility)	PCCon(KWh) (uti+nonuti)	NU/N	VE/TV
1960-61	16448.6	2607.96	37.9	0.181881	0.039125
1961-62	19358.4	2910.11	43.6	0.183634	0.045276
1962-63	22019	3339.98	48.5	0.185499	0.052397
1963-64	25241.6	3447.62	54.4	0.187473	0.060634
1964-65	27255	3035.73	57.5	0.189557	0.070169
1965-66	29779	3044.06	61.4	0.191353	0.081201
1966-67	32769	3641.36	66.2	0.193656	0.098048
1967-68	36229.6	3542.73	71.6	0.195680	0.112482
1968-69	40352.2	2999.85	77.9	0.197436	0.132624
1969-70	44171.5	3109.8	83.5	0.199692	0.159767
1970-71	48581.8	4857.64	89.8	0.201689	0.188744
1971-72	51965.2	4902	93.8	0.204606	0.219604
1972-73	54602.1	5514.04	96.3	0.207680	0.251007
1973-74	56538.4	6292.02	97.48	0.210911	0.281886
1974-75	58701.07	6069.43	98.99	0.214300	0.312109
1975-76	66739.65	6493.84	109.95	0.217489	0.334187
1976-77	74015.6	7407.03	119.38	0.221200	0.363938
1977-78	76542.82	7287.79	120.73	0.224717	0.390041
1978-79	84849.12	7556.3	130.94	0.228402	0.418651
1979-80	86645.36	8561.74	130.49	0.231556	0.449278
1980-81	89858.86	7491.68	132.34	0.235239	0.489724
1981-82	97758.84	7513.51	141.27	0.238069	0.533282
1982-83	104111.4	8522.83	147.05	0.239997	0.582519
1983-84	111623.9	9279.48	154.39	0.242399	0.625115
1984-85	124367.7	10299.82	168.52	0.244930	0.666064
1985-86	134196.9	11197.58	177.98	0.247262	0.701965
1986-87	147839.2	11887.17	191.75	0.249405	0.746124
1987-88	159776.7	14163.92	203.02	0.252008	0.783548
1988-89	177414.8	17218.39	220.94	0.254744	0.819228
1989-90	195119	19700.05	237.95	0.257297	0.846830
1990-91	211568.4	21211.1	252.77	0.259989	0.865330

Source : [1] General Review , CEA ; various years.
[2] Census of India,1991,Series 1,Paper 2 of 1992,Final Population Total
[3] National Accounts Statistics,CSO,GOI;various years.

Note : [1] PCCon=per capita consumption of electricity.
[2] uti+nonuti=utilities & nonutilities together.
[3] TotCons=total consumption of electricity,utilities & nonutilities to
[4] Total number of villages = 5.56 lakhs.
[5] NU/N=share of urban population in total population.
[6] VE/TV= proportion of villages electrified.

TABLE S2

	GDP def	WPI('81-'82base)		WPI('80-'81base)		(1980-81base)	
YEAR	base80-81	ELEC	MINOIL	ELEC	MINOIL	Relec	Roil
1960-61	0.242	23.104	12.468	26.950	15.087	111.137	62.215
1961-62	0.248	23.820	12.707	27.785	15.377	111.947	61.956
1962-63	0.260	25.250	12.887	29.453	15.595	113.331	60.005
1963-64	0.283	27.396	15.664	31.957	18.956	113.038	67.050
1964-65	0.307	28.469	15.644	33.208	18.931	108.172	61.667
1965-66	0.334	29.757	15.884	34.710	19.221	104.034	57.611
1966-67	0.376	32.654	16.823	38.089	20.358	101.319	54.153
1967-68	0.409	32.511	17.522	37.922	21.204	92.824	51.902
1968-69	0.420	34.120	17.902	39.800	21.663	94.790	51.595
1969-70	0.433	34.263	19.061	39.967	23.066	92.196	53.209
1970-71	0.439	35.765	19.980	41.719	24.178	95.005	55.060
1971-72	0.463	36.660	21.618	42.762	26.161	92.450	56.558
1972-73	0.510	37.804	22.298	44.097	26.983	86.393	52.863
1973-74	0.598	39.807	28.332	46.433	34.284	77.607	57.302
1974-75	0.696	49.070	47.992	57.238	58.075	82.219	83.421
1975-76	0.678	56.545	51.389	65.957	62.186	97.238	91.677
1976-77	0.720	61.373	53.447	71.589	64.676	99.411	89.811
1977-78	0.765	65.272	53.546	76.137	64.797	99.556	84.728
1978-79	0.779	74.785	53.926	87.234	65.256	111.973	83.763
1979-80	0.897	80.687	61.698	94.118	74.662	104.953	83.257
1980-81	1.000	85.730	82.637	100.000	100.000	100.000	100.000
1981-82	1.103	100.000	100.000	116.646	121.011	105.791	109.750
1982-83	1.190	111.500	102.800	130.060	124.399	109.269	104.513
1983-84	1.289	120.500	106.300	140.558	128.634	109.049	99.798
1984-85	1.386	124.800	107.100	145.574	129.602	105.015	93.493
1985-86	1.493	139.700	120.300	162.954	145.576	109.124	97.486
1986-87	1.593	153.500	125.600	179.051	151.989	112.425	95.433
1987-88	1.732	166.700	126.300	194.449	152.836	112.280	88.252
1988-89	1.866	176.600	129.200	205.997	156.346	110.371	83.769
1989-90	2.015	187.700	129.700	218.944	156.951	108.679	77.907
1990-91	2.245	200.900	154.700	234.341	187.203	104.366	83.373

Source : [1] India Database :The Economy ,H.L.Chandhok & The Policy Group;1990.
[2] National Accounts Statistics,CSO,GOI;various years.
[3] RBI Bulletin, Various years.

Note : [1] Relative Prices are relative to the GDP deflator.
[2] Relec=relative price of electricity (80-81 base)
[3] Roil=relative price of mineral oil (80-81 base).
[4] GDPdef=Gross Domestic Product deflator (80-81 base).
[5] WPI ELEC=wholesale price index of electricity.
[6] WPI MINOIL=wholesale price index of mineral oil.

TABLE S3

YEAR	TC	CE	TE	EF	Y	PK	PL	PF
1968-69	249152	80662	123233	45257	563113	0.040	3104.82	0.260
1969-70	282601	88837	141718	52046	638700	0.043	3306.06	0.271
1970-71	338311	109411	167400	61500	786293	0.050	3209.36	0.282
1971-72	379758	122058	188500	69200	808833	0.057	3467.62	0.299
1972-73	430742	134387	216775	79580	893580	0.052	3692.38	0.311
1973-74	494426	152250	249874	92302	902479	0.073	4293.29	0.369
1974-75	622076	178876	305200	138000	927670	0.095	5042.13	0.560
1975-76	751375	221675	346296	183404	941169	0.111	5427.20	0.619
1976-77	825826	252470	363670	209686	1044630	0.111	5469.34	0.651
1977-78	939866	296509	419361	223996	1116611	0.111	5912.00	0.661
1978-79	1099014	353711	461172	284131	1256100	0.121	6362.65	0.691
1979-80	1284410	409190	537190	338030	1223274	0.139	6996.24	0.799
1980-81	1493540	460796	609651	423093	1192877	0.154	7762.03	1
1981-82	1766398	563915	677753	524730	1339882	0.181	8585.40	1.207
1982-83	2111312	656814	804609	649889	1454079	0.193	9852.96	1.297
1983-84	2730771	824386	921825	984560	1634551	0.218	11530.88	1.397
1984-85	2938361	953869	1066021	918471	1592436	0.240	13356.37	1.463
1985-86	3248052	1040905	1108113	1099034	1633414	0.266	14611.18	1.637
1986-87	3572618	1136996	1229918	1205704	1734255	0.277	16292.99	1.748
1987-88	4250560	1409966	1408105	1432489	1822616	0.312	17815.49	1.812
1988-89	4594510	1603556	1572832	1418122	2032485	0.341	20014.96	1.912

Total Emoluments (Rs Lakh)	Fuels Consumed (Rs Lakh)	Real Value Added (Rs Lakh)	Total Cost (Rs Lakh)
TE	EF	Y	TC
Avg.Price of Labour (Rs/person)	Price of Capital Services	Value of Cap.Services (Rs Lakh)	WPI of fuel&light 80-81 base
PL	PK	CE	PF

Source: [1] Annual Survey of Industries,CSO,GOI;(various years).
[2] India Database:The Economy,H.L.Chandhok & The Policy Group,vol-I,1990.
[3] National Accounts Statistics,CSO,GOI,(various years).

TABLE S4

YEAR	PEL	REL	UEL	EF	RATIO1
1981-82	0.347	395263	135374.9	524730	0.342
1982-83	0.396	381798.0	147875.5	649889	0.387
1983-84	0.480	454299.9	116644.8	984560	0.257
1984-85	0.468	550220.6	79972.62	918471	0.145
1985-86	0.658	496666.0	173134.5	1099034	0.349
1986-87	0.749	520657.1	182311.5	1205704	0.350
1987-88	0.895	548449.3	143351.6	1432489	0.261
1988-89	0.935	565520.5	188595.8	1418122	0.333

REL= ElecCons RegManuf (Lakh KWh)

UEL= Cons Unregis manuf (Lakh KWh)

EF= Fuels Consumed (Rs Lakh)

PEL= AvgPrice of Elec in Rs/KWh

RATIO1= Ratio of UEL to REL

Source: [1] Report on The Working of State Electricity Boards,Planning Commission; various issues.
[2] Annual Survey of Industries,CSO,GOI;various issues.
[3] General Review,CEA,1990-91.

TABLE S5

YEAR	YEAR	DP	EP	Y
1971-72	1971-72	1277	1466	0.374369
1972-73	1972-73	1545	1618	0.353115
1973-74	1973-74	1750	2430	0.419880
1974-75	1974-75	1884	2432	0.402220
1975-76	1975-76	2027	2434	0.384957
1976-77	1976-77	2182	2436	0.367856
1977-78	1977-78	2349	2438	0.351067
1978-79	1978-79	2500	3599	0.428695
1979-80	1979-80	2654	3966	0.437860
1980-81	1980-81	2825	4331	0.444171
1981-82	1981-82	3013	4650	0.445811
1982-83	1982-83	3187	4973	0.448533
1983-84	1983-84	3385	5309	0.449797
1984-85	1984-85	3554	5709	0.455723
1985-86	1985-86	3745	6152	0.461281
1986-87	1986-87	4050	6657	0.461429
1987-88	1987-88	4240	7226	0.470430
1988-89	1988-89	4308	7819	0.486139
1989-90	1989-90	4355	8358	0.500088

SOURCE: SOURCE: [1] STATISTICAL ABSTRACT , CSO ; various issues.
[2] CMIE , various issues.

NOTE: NOTE: [1] DP = Diesel Pumpsets in '000 numbers.
[2] EP = Electrified Pumpsets in '000 numbers.
[3] Utilisation Rate for electric pump is 4423 kwh/year/pump; Report by Planning Commission for ESCAP & UNDP,1991.
[4] Utilisation Rate for diesel pumpset is 883 lts/year/pump; Report by Planning Commission for ESCAP & UNDP,1991.
[5] Y = share of energy consumed by electric pumps in total energy cosumption by pumps for irrigation.

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