ELECTRICITY DEMAND AND PRICING IN INDIA: 1947-1986

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Submitted for the Degree of Doctor of Philosophy
at The London School of Economics and Political Science,
University of London, 1991.

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ABSTRACT

Over the years 1947-86, electricity has become an important source of energy. The social, political, economic and institutional conditions under which the electricity industry has evolved in India are studied in this thesis.

Though electricity demand has increased in India, due to electricity supply shortages after 1972 it was difficult to study electricity demand since no data are available on unconstrained demand. Hence, the factors affecting electricity sales are studied at all-India level for three consumer groups: i) industrial ii) agricultural and iii) "other" consumers. Since states in India differ in their characteristics, electricity sales to industrial and agricultural consumers were studied for the States of Bihar, Kerala, Maharashtra and Punjab.

In this analysis, economic and econometric principles are applied to historical data. On the basis of demand theory, income elasticities were expected to be positive and the price elasticities were expected to be negative. From the analysis, it was found that income and price elasticities varied across States and across different consumer groups. Income elasticities were found to be positive and high in each case. Price elasticities were negative and very low in each case with the exception of industrial consumers in Punjab.

The time-of-day ("unrestricted") demand for power in Gujarat was studied for the years 1985-86 to 1988-89. The expectation of an hourly and seasonal pattern in the ("unrestricted") demand for power was confirmed. A series of 24 seemingly unrelated equations testing the effects of employment and price on "unrestricted" demand for power at each hour of the day were analysed. It was found that the observed hourly pattern of power demand could not be affected in the desired manner with the existing pricing policy and structure in Gujarat.

Pricing remains an important practical tool for managing electricity demand. Pricing also directly affects the performance of the State Electricity Board. The financial performance of Gujarat State Electricity Board was examined and found to be poor due to its pricing policy. On the basis of the literature on the theory of pricing in public enterprises, a method of calculating prices in Gujarat was derived. Due to data constraints, the estimation of prices in the period 1961-86 was limited to prices charged to all consumers of the Gujarat Electricity Board taken as a group. For similar reasons, it also ignored the response of consumers at different time of the day. The prices charged by Gujarat Electricity Board were then compared with the estimated prices. It was found that the estimated prices were higher than the prices charged by

Gujarat Electricity Board in the period 1961-86. One of the consequences of low electricity prices was Gujarat Electricity Board's poor financial performance.

The study concludes that it is important for the State Electricity Boards in India to study their costs and demand in order to derive a pricing policy that allows the consumer to be aware of the costs and helps the State Electricity Boards to eliminate financial losses.

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ACKNOWLEDGEMENTS

I would like to thank Professor Leslie Hannah and Dr Mary Morgan for their guidance and support. Without their patience to go through the drafts of this thesis, I would not have completed this work.

I am grateful to Professor S.R.Hashim who introduced me to the area: economics of public utilities.I wish to thank Professor A.C.Harvey and Mr. Jim Thomas who enlightened me on certain issues of the econometric aspects of my work.

I would like to thank Commonwealth Commission for making it possible for me to stay in London and study at London School of Economics.

Above all, I thank Vimal, for his constant encouragement though from a distance.

INTRODUCTION

Despite its rather modest contribution to the gross product, energy plays a decisive role in economic development, since, to the extent that it is available, it stimulates or hinders economic growth.

Electricity constitutes an advanced form of energy and its development has not only made it possible to take advantage much more intensively of some renewable resources like water, but it has also created a number of new uses for all kinds of energy in production and social processes. Industrial development, mechanisation and urban progress are profoundly affected by electricity supplies.

The unique position of power in economic development justifies a study in depth of this sector. India has made major progress since Independence (in 1947) in developing indigenous energy supplies for a rapidly increasing and diversified set of economic activities. But progress has not been without problems. The history of government regulations of this industry in India and its management partly explains the movement from electricity as a luxury good to a necessary input in a production process. It also indicates the causes of the problems that the industry is facing. One of the causes of poor financial performance could be the pricing of electricity. It is important to work out the possibility of poor pricing policy as a plausible cause of poor performance of the electricity boards in India.

Section I is concerned with the growth of the electricity industry since it started until 1986. Chapter I narrates the social, economic and political environment in India in the period when the electricity industry evolved. The regulation of the industry over the period prior to Independence and after Independence is also discussed in the first Chapter. Chapter II discusses important aspects of the electricity industry over the period. The growing demand within capacity constraint was one of the features.

Section II deals with the study of electricity demand. Chapter III discusses important contributions to the study of electricity demand elsewhere and in India. Chapter IV covers electricity sales at the all-India level. Economic and econometric principles are applied to historical data to study the effect of important variables like price and income on the electricity sales to different consumer groups. Chapter V discusses the disparity over different regions in India and again the effect of important variables on electricity sales is observed in four different states. From the findings of Chapters IV and V, it was gathered that some states may have failed to use pricing as a tool to manage electricity demand. To get some idea of the extent to which any State Electricity Board may have mispriced electricity, we need to know about the cost of generating and distributing electricity. In Chapter VI, the effects of Gujarat Electricity Board's (GEB) pricing policy on the demand for power at each hour of the day is further analysed.

Section III deals with pricing. In Chapter VII, the financial performance of Gujarat State Electricity Board is evaluated. The tariff policy of Gujarat Electricity Board is also analysed. Having realised the need to change the tariff policy from the analysis of the electricity tariff, Chapter VIII scans through the vast literature on pricing in public enterprises, and on the basis of that literature derives a method for estimating electricity prices for Gujarat Electricity Board. Having derived the method, Chapter IX estimates electricity prices while incorporating the costs of generating and distributing electricity in Gujarat. Despite considerable data limitations, this analysis allowed much to be said about the pricing that was practised and whether it was efficient or not.

SECTION I: EVOLUTION OF ELECTRICITY INDUSTRY IN INDIA.

Introduction.

Section I includes a general discussion of the Indian economy in the nineteenth century. The discussion provides a background within which the electricity industry started. It also includes the explanation of the rules regulating the electricity industry from the time the first plant started till 1986.

The progress of the electricity industry is also examined with the help of conventional measures of intensity of plant use.

CHAPTER I

THE HISTORICAL BACKGROUND OF THE INDIAN ECONOMY AND THE STATUS OF THE ELECTRICITY INDUSTRY IN INDIA.

I.1 The social and political environment of the Indian subcontinent.

Indian society is considered to be one of the most complex in existence. According to Morris[1] the neglect of India's economic history particularly the period 1800-1947 has kept the world unaware about its structure, functioning, development and dynamics.

India's economic and cultural development depends in the main upon its geography and the quality and the quantity of its people. India lies about half in the torrid and half in the north temperate zone.[2] Variety but not abundance characterises its material resources. The tropical heat tends to induce plant growth at all times of the year but much of the soil is infertile. Mineral resources were fairly abundant but their concentration in restricted areas involved great difficulties of transport over the wide stretches of the country.

In the nineteenth century the "traditional India" was a subsistence economy which was self contained and static. People were organised in a rigid economic and social system, a unit of which was the agricultural village. The effect of the rigid social structure was observed by many

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[1] M.D. Morris, "Towards Reinterpretation of Nineteenth Century Indian Economic History", Journal of Economic History (December 1963), Reprinted in Indian economy in the nineteenth Century: A Symposium, edited by M.D.Morris, Published by the Indian Economic and Social History Association, Delhi School of Economics, (Delhi, 1969).

[2] L.Dudley Stamp, Asia, (1929), pp. 166-356.

scholars.[3] There was a somewhat elaborate division of occupations based mainly upon caste. Each kind of work was hereditary. The number and variety of artisans in a village depended upon the part of the country in which it was located and its particular conditions. The few cities of political, religious or commercial importance constituted the only exception to this rural life.

It is observed that there was a lack of political unity and stability. Despite a Hindu tradition of imperial expansion, at no time in Indian history over any large region did a stable political unit survive for more than a century. British rule was firmly established by 1820 and two thirds of the territory (three-fourths of the people) were directly under the British Government; while the remaining area and people within the states were ruled by Indian princes whose positions were guaranteed by the British.

I.1.1 The effect of British rule on Indian economy.

It is fatuous to generalise about conditions before the accession of the Crown. There were good and bad years, prosperous and impoverished areas. A common speculation before and during the British rule, was that the "standard of living", "economic conditions" and "prosperity" deteriorated, or at best, failed to improve from 1858 until

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[3] For example in 1966 D.H.Buchanan in his book Development of Capitalistic Enterprise in India, (1st edition, new impression, 1934, 1966), finds a lack of ambition for economic and financial success in the religious thinking of the Indian community. But Dr. Harold Mann, Director of the Agriculture Department in Bombay Presidency expresses, in Annals of the American Academy of Political and Social Science, part II, (1934), p.80, the view that the idea of innate conservatism among the rural classes was not correct and possibly they were less averse to change than a very large proportion of the farmers of the western countries.

Independence. With some exceptions,[4] the bulk of Indian and some other writers until the 1950s took this view. Nehru maintained that "no statistics, facts or numbers are wanted to convince you of this, that India has suffered terrible economic decline.[5]

Indian writers typically stress the exploitative features of British rule as the cause of nineteenth century decay. Western scholars, to the extent that they do not accept the "exploitation thesis", attribute the failure of the Indian economy to respond to the warming influences of the industrial revolution to the society's "other worldliness", to its lack of enterprise and to the class exclusiveness of groups within the society.

Without any doubt, India had a "special relationship" with Britain. In L.H.Jenks' words; "It is India which made the empire".[6] According to Amiya Bagchi,[7] Britain's economic policy in India discouraged large scale industrial development. A large scale development of industry could have been supported by an increase in agricultural production and then Indian cultivators would not have been so vulnerable to business cycles in advanced capitalist countries. The small cultivators or landless labourers could have been absorbed into industry and with continued

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[4] M.G. Ranade in Essays on Indian Economics (Madras, 1906) and R.Sharma, "The Legacy of the British Rule in India", Journal of Indian History, Vol.XXXIV, Part III, (December 1956).

[5] Jawaharlal Nehru, "Address to the League against Imperialism", quoted in Seminar, Vol.LIX, (1962-4).

[6] L.H. Jenks, The Migration of British Capital to India (First published in 1927, reprinted in London, 1963), p.206.

[7] Amiya Bagchi, "Foreign Capital and Economic Development in India:A Schematic View", in K.Gough and H.P.Sharma(ed). Imperialism and revolution in South Asia (1973).

economic growth, could have escaped the tyranny of rural slums. But such a development would have been contrary to the basic interests of the ruling classes of Britain, and the maintenance of "free trade" (rather "one way free trade") provided the best guarantee against such a development. Barrington-Moore, in a widely discussed book,[8] points out that India became a "landlords' paradise" under British rule. According to M. D. Morris, the Indian Government had no self-conscious programme of active economic development. He further stated that:

> "One does not need to argue in terms of the evilness of imperial policy. Certainly, the general object of the "raj" was the welfare of the society. The difficulty is that British economic policy in India could not rise above the ideological and policy level at work at home. And a general economic policy appropriate for Britain at the peak of her economic power was not adequate to provide for long run growth in India."[9]

India had been vitally important to Britain in the pre-war years in three respects- as a vast market for British manufactures, as a guaranteed outlet for profitable investment and as a crucial link in the settlement of Britain's balance of payments. India's political and economic subordination had resulted in an artificially heavy trade deficit with Britain. In Dr.R.K.Ray's view:[10]

> "The strategic, political and financial aspects of the relationship between the two countries gained ground at the expense of the diminishing exchange of goods and services......... Britain's great 'vested interest' in India, the sterling debt, was wiped out by her enormous borrowing from India in order to meet the financial requirements of the Second World War: the Second World War wiped out at one stroke the

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[8] Barrington-Moore Jr., Social Origins of Dictatorship and Democracy, (1967).

[9] M.D. Morris, op.cit, footnote 34, p.12.

[10] R.K.Ray, Industrialisation in India 1914-1947, (New Delhi, 1979), p.14.

> financial stake of Britain in India, removing thereby a potential impediment to her withdrawal at the end of the war."

The state of India was summed up by William Digby[11] as follows:

> " There are two Indias: the India of the Presidency and the chief provincial cities, of the railway systems, of the hill stations...There are two countries:Anglostan, the land especially ruled by the English, in which investments have been made and Hindustan, practically all India fifty miles from each side of the railway lines".

Thus, the views of different scholars on the effect of the British economic policy in India on the economic pattern of the Indian society prevailing at that time is a controversial issue.

I.2 The growth of national income in India during the nineteenth century.

The available information on India's overall performance is not enough to make any definite conclusions on the progress of the Indian economy. Many details as well as some of the significant features of growth are not reflected in national income and allied aggregates. The institutional set up, the growth of the educational and health services, the progress in specific and technological research, the improvement in social relations and changes in the socio-political environment are all imperfectly represented by the national income figures and their breakdowns. Apart from this, even within the sphere to which national income relates, difficulties of comparison arise as a result of changes in the structure of production and consumption. Net output generally becomes a smaller percentage of the total value of output in most of the sectors and hence the meaning of aggregate net output as an

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[11] William Digby, "Prosperous" British India, (1901), pp.291-292.

indicator of output changes over time. The pattern of consumption also changes and it becomes progressively more difficult to decide upon a basket of goods representative of the national economy at both past and current point of time. This makes it difficult to estimate changes in real consumer expenditures in a rigorous way. Similarly, changes in the real content of investment are difficult to ascertain. A process of growth in a relatively less developed economy leads to an expansion of the market economy as a result of which it becomes progressively necessary to buy goods and services which were obtained free in the past. The consequence of this is an overestimation of the rate of growth.

However, the general evidence as shown in Table I.1 is clearly indicative of a sustained, but very slow growth of per capita income, and is not consistent with a hypothesis of a constant or declining per capita income at constant prices over the century in question. During the first 40 years i.e.1860-1900, per capita income at 1948-49 prices rose from about Rs. 170 to Rs. 200 or by about 18%. As population increased by about 22% during the period, the national income in real terms grew by a little more than 40% in forty years. The main finding in the first half of the twentieth century is that per capita income at constant 1948-49 prices grew from about Rs.200 in 1900 to about Rs. 260 in about 1930, i.e., by 30% in 30 years. Then the level of income remained stable, or perhaps declined after World War II to a level of about Rs. 250. After 1950, the per capita income again started to grow, the figure being Rs. 295 for 1962-63. The large rise between 1900 and 1930, followed by a stability until 1950 in terms of per capita income, does not, however, depict the rates of growth of national product because of the dissimilar rates of population growth during the two periods.

Table I.1
Average per capita national income of India at 1948-49 prices for overlapping nine year periods. (1860-1955).

Period	Centering	Per Capita Income in Rupees. In 1948-49 prices	Index of Per Capita Income at 1948-49 prices with reference year 1860 = 100.
1	2	3	4
1857-1863	1860	169	100
1861-1869	1865	169	100
1866-1874	1870	172	102
1871-1879	1875	177	105
1876-1884	1880	197	117
1881-1889	1885	216	128
1886-1894	1890	204	121
1891-1899	1895	201	119
1896-1904	1900	199	118
1901-1909	1905	203	120
1906-1914	1910	220	130
1911-1919	1915	241	143
1916-1924	1920	253	150
1921-1929	1925	261	154
1926-1934	1930	260	154
1931-1939	1935	260	154
1936-1944	1940	265	157
1941-1949	1945	255	151
1946-1954	1950	253	150
1952-1958	1955	275	163

Source: From M.Mukherjee National Income of India and structure, 1969, (p. 61, Table 2.5).
N.B. Column 4 is derived from column 3 taking 1860=100.

While the population grew by only 18% during the first 30 years, it increased by 29% during the next twenty years. Thus, roughly speaking, the national product grew by a little less than 50% during the next 20 years.While the tempo of growth slackened, the performance of the nation between 1930 and 1950 is not as bad as is conveyed by the figures of per capita income. The lack of information regarding indicators like the capital stock in different years, or the rate at which saving and investment took place, do not allow us to study the effects of certain hypothetical assumptions in respect to these magnitudes.

Also, there does not exist any study of how the process of growth of a modern type got initiated in a poor country like India.

I.3 Urbanisation in the economy.

The state of urbanisation in India depended on factors like race, rainfall, plague and pilgrims. The growth of trade and industries did play a role as was commented upon in the 1911 Census report on Bengal, Bihar and Orissa:

"After the somewhat dreary sketch of urban decay, stagnation or decimation by disease.. it is refreshing to turn to the number of towns, some old, some young and nascent, which are fast developing owing to the expansion of trade and industrial enterprise, often introduced and directed by Europeans."[12]

Table I.2 gives the percentage variation for each of the five decades, in total, rural and urban population separately.

Table I.2
Percentage (Decade) variation in total, rural and urban population of India (1901-1951).

Decade	Total	Rural	Urban
1901-11	5.8	6.4	0.4
1911-21	-0.3	-1.3	8.3
1921-31	11.0	10.0	19.1
1931-41	14.2	11.8	32.0
1941-51	13.3	8.8	41.4

Source: Derived from the data, available in Census of India, 1901, 1911, 1921, 1931, 1941, 1951.

In the 1901-11 decade, the rate of growth of the rural population was much higher than that of the urban population, while in the following decade (1911-21) there was an absolute decrease in the rural population and a

[12] Census of India, Report on Bengal, Bihar, Orissa and Sikkim, Volume V, (New Delhi, 1911), pp.27-28.

modest increase in the urban population. In the decade 1921-31, the rural population increased by 10.0% while the urban population increased by 19.1%. The decade 1931-41 witnessed a fairly rapid growth of urban population, namely 32.0%, while there was only nominal increase in the rate of growth of rural population. The decade 1941-51 witnessed the highest rate of urban growth, namely 41.4% while the rate of growth of the rural population decreased in this decade compared to the previous decade.

I.4 Agricultural development in India.

Agriculture in India has been largely dependent upon nature. The amount of rainfall at a particular time of the year was the main factor determining agricultural output. Assured water supply at a particular time of the year, depending upon the crop pattern, was one of the necessities in the agricultural sector to reduce the fluctuations in agricultural output. Irrigation was one solution for assured water supply. The decision regarding the choice of the means of irrigation was dependent upon the geographical condition of the area to be irrigated. In many areas construction of canals without adequate drainage facilities led to extensive waterlogging and salinity, ultimately converting millions of areas of land into desert. The cultivator had no protection against such external diseconomies of canals. The development of irrigation works was met with almost unqualified approval from Indian nationalists and British officials alike. But agricultural production was not, under British rule, raised to such an extent that India could be self sufficient even in the production of food grains; and as a result India continued to be dependent on foreign aid after Independence. The sluggishness of Indian agricultural growth has been due not simply to the lack of new inputs or information, or to the lack of proper incentive to the farmers, although these played an important part in the late 1950s. One basic difficulty has been that Indian farmers have not been acting under a purely competitive environment. The richer farmers, many of whom belong to old "zamindar" families or to prosperous professional or business families, have been able to act as monopolists within the village and have been cushioned against the consequences of economic changes by this monopolistic slack.

I.5 Industrial development in India.

India's annual rate of industrial growth from 1880 to 1913 was about 4 to 5%. Between 1850 and 1914 India had created the world's largest jute manufacturing industry, fourth largest cotton industry and third largest railway network. This was possible mainly due to the increasing inflow of British capital to India. Industrial growth in India under the British Empire was also affected by the First and Second World Wars.

The First World War interrupted the inflow of British capital to India. On the one hand the diminishing inflow of British investment after the First World War enabled Indian merchants and manufacturers to seize the initiative for developing newer industries; on the other hand the repatriation of British capital acted as an adverse factor on general conditions of trade and industry which had been particularly prosperous during 1900-1914 on an ample inflow of British capital. In the interwar period India did better than most other tropical countries. With the onset of the depression, new issues of British capital thinned out and the British financial crisis of 1931 put a stop to the export of capital to India from Britain. From 1930 to 1932 India experienced a brief recession. From 1932 to 1938, India was called on to pay, in addition to the interest and dividends, part of the principal lent to her earlier. There was a sudden, massive and persistent withdrawal of capital from India. Yet large scale manufacturing in India grew at a rapid rate of 7.3% between 1913-1914 and 1946-1947. However, since small scale industries (which until 1940-41 outweighed large scale industry) grew only at the rate of 0.6%, the overall income from the secondary sector increased at a slower rate of 2.5% per annum.[13] Both in the period preceding the First World War and in the period following it, India's considerable industrial development occurred through import substitution due to more effective use of supply factors such as raw materials, skilled labour, technical expertise, financial resources and business experience. At the end of the interwar period, India was not only consuming less British manufactures but had also started competing with British products in many external markets.

Just as in agriculture one can put one's finger on the decisive cause of slow growth- inadequate expenditure on irrigation -so also in manufacturing industries one major failure stands out- inadequate development of iron and steel production. The very process of import substitution on a large scale was bound in the long run to create a new demand for basic capital goods.[14]

The outbreak of the Second World War implied a structural transformation of India's industrial economy, leading to production of heavy chemicals, sophisticated machinery, aircraft, automobiles, locomotives, ships and a variety of other heavy capital goods. The enormous needs of global war shortened the gestation period for this new phase of production.

Industrial growth between 1914 and 1947 was affected by both demand constraints and supply constraints.

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[13] R.K. Ray, op.cit.

[14] A.K. Bagchi, Private Investment in India, (Cambridge, 1972).

The size of the population and its growth did not necessarily create a demand that encouraged machine production. The average per capita income was very low. Much of this income was produced in non-monetised activities. Unequal distribution of income created market demand for different goods. The demand from the concentrated higher income groups -traditional luxury-loving social groups in urban areas- was mainly for the special items which could not be mass-produced. The bulk of domestic demand was heavily dependent upon agricultural performance and this unstable demand had adverse effects on entrepreneurial behaviour.

On the supply side most factors of production were costly. All machinery had to be imported. Skilled labour was scarce and initially had to be imported from abroad. Fuel was costly and so was domestic transport. Only labour was cheap and this worked against mechanisation. Businessmen were encouraged to expand existing organisations rather than shift to techniques where capital requirements were relatively greater. Capital was also immobile. There was always a substantial element of uncertainty along with risk. Thus the incalculability of demand and uncertainties of the cost of production intimidated the potential entrepreneur.

Generally the factors that a native or foreign businessmen had to consider were the nature of the demand for products, supply of productive resources, the prices at which output could be sold, the cost of producing it and relative rates of profit. But there is an important body of literature which emphasises "demotivating" factors of a cultural and sociological character that influence the private businessmen's attitude and decisions in business. The difficulties of the social class system and the effects of colonial rule have already been discussed. In addition to that, the fact that India failed to industrialise at the end of the nineteenth century had certain extremely important effects on the structure of the economy and society. With the growth of population, stagnation in industrial production and the closure of the higher offices and more profitable occupations to upper class Indians, both the rich and the poor were made increasingly dependent on a single source of income: land. With the partial introduction of a market in land in late 1930s and the removal of many protective devices built into the traditional systems against the total separation of a cultivator from a permanent claim on the income of the land, a large number of people in rural areas found themselves unemployed for a large portion of the year.

I.6 Importance of energy in overall development.

Social scientists are apt to point out the extent to which a given geographical setting can be transformed in spite of severe natural limitations by the human element working on it. Economic miracles like that achieved by Japan, a country poorly equipped in minerals, have encouraged this tendency. But for a poor and underdeveloped country like India where the gap between the potential resources and economic utilisation of them is immense, there is low probability of such miracles. One of the main gaps was failure of energy supplies to increase as demand grew.

The slow growth in output of the energy sector has been one of the major supply constraints for Indian agriculture and industries. For example, Sir William Stampe[15] expressed his view regarding the causal relationship between the availability of cheap "grid" power and the industrial development in India during 1920s and

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[15] William Stampe, "Some Aspects of cheap power development under the new constitution in India", The Asiatic Review, Volume 34, (1938), pp.650-710.

1930s. He gave examples of the brass turning and polishing industry in Moradabad and other towns, the flour-milling industry in major large towns, cotton-spinning and weaving mills in Punjab and Madras. Consumption of non-commercial sources of energy is one of the characteristics of a less developed economy. In the process of development, the consumption of commercial sources of energy is gradually substituted for non-commercial sources of energy. In India, the particular climatic and geographical features of the landscape made it difficult and usually impossible to employ water wheels and windmills as power sources. Agricultural development thus necessitates an adequate supply of power to run irrigation pumpsets, to electrify villages, and to operate agro-based industries.

There was clearly a link between the smallness of most coal mining operations, the absence of more efficient modes of transport and the very limited production and use of metals. Electric Power could be generated from coal, oil or water. But in the pre-independence period ~~the~~ coal was distributed unevenly in India and was not available to Southern and Western India at all. Large deposits of good coking coal were available only in Ranigunj and Jharia but their high ash content and the consequent low calorific value reduced their radius of economic use. Large-scale export of coal, which would have alleviated the supply problems arising from the low and uncertain consumption of coal at home, could not be developed on account of these defects. India was not well endowed in oil resources. As for water power, it was difficult to develop this as a source of power for industries on account of the seasonal character of rainfall which made storage a necessity. The outlay necessary for construction of storage facilities, unless the water could be used for irrigation afterwards, tended to raise the cost of water power in relation to other sources of power.

The cotton-textile industry in Bombay was dependent, up to the First World War, on regular supplies of coal from Bengal and Bihar, which entailed a long and expensive railway haul across the peninsula. The vast distance separating the coalfields in the east from the cotton tracts in the west led to the formulation of a great hydro-electric scheme by the Tatas (one of the Indian industrial groups in the cotton textile industry) which became operational during the First World War. Although initiated under Indian enterprise, the scheme also attracted the support of British cotton manufacturing in Bombay. The undertaking of the Sassoons (a cotton textile industrial group managed by the British) to take a substantial amount of electric power from the scheme when it was completed was characteristic of the optimistic and dynamic attitude of British managing agencies in Bombay and it helped in finding the enormous capital needed for the scheme. Without the assured supply of electric power which the great Tata hydro-electric scheme made possible, the great and rapid expansion of the cotton-textile industry in Bombay after the First World War would have been difficult. Although hydro-electricity gave the cotton mills a clean and reliable supply of power in Bombay, it did not cheapen the cost of power. Electric power was more expensive than coal and this was a disadvantage to Bombay in view of much cheaper rates at which electric power was supplied to Japanese mills.[16] Although inland centres could provide the cotton textile industries with much cheaper labour, this competitive advantage could not be properly exploited without solving the problem of supply of power in the inland tracts where cotton was grown. The extension of hydro-electric schemes in south India, where cotton was grown in considerable quantity but coal was not available,

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[16] R.K. Ray, op.cit, p.65.

contributed to the expansion of the cotton industry in south India in the thirties. The share of Madras Presidency in the total production of yarn in India rose from 6.3% in 1921-22 to 13% in 1938-39 as a result of the completion of several large hydro-electric schemes.[17] The unusually rapid expansion of the spinning industry in Coimbtore, Madurai and Tirunelveli was a consequence of the completion of the Pykara Hydro-electric scheme and the readiness of local industries to take advantage of new sources of power.

The experience in the paper mills was similar. The paper mills of Bombay and UP were at a disadvantage in relation to mills in Bengal. The cost of production was affected mainly by the relative distance of coal sources, the major source of energy. The development of paper manufacture in south India was made possible by the simultaneous growth of bamboo pulp technology and hydro-electric works, from which Mysore and Punalur Paper Mills, both located in the heart of the bamboo growing tracts of Bangalore and Travancore and near the sources of cheap hydro-electric power supply, benefited.

I.7 Public sector in the economy.

In Gerschenkron's view, the state has a major role to play in order to push the economy towards industrialisation. He writes,

> "Supply of capital for the needs of industrialisation required the compulsory machinery of the government, which through its taxation policies, succeeded in directing incomes from consumption to investment.."[18]

According to him, the great industrial upswing in Russia

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[17] T.R.Sharma and S.D.Singh Chauhan, Indian Industries: Development, Management, Finance and Organisation, (Agra, India, 1965), p.458.

[18] A Gerschenkron, Economic backwardness in historical perspective: A book of Essays, The Belknap Press of Harvard University Press, Cambridge, (Massachusetts, 1962), p.20.

came when the railroad building of the state assumed unprecedented proportions and became the main support of a rapid industrialisation policy. He also argues that when the economic backwardness gets reduced by state sponsored industrialisation processes, policies suitable to the new "stage of backwardness" become applicable wherein the role of the state gets reduced. He suggested that the institutional requirement for industrial development differed according to the backwardness of industries and the stage from which the industrial development started. He concludes that in the last period of industrialisation, the significance of the state gets greatly reduced.

I.7.1 Public sector in India.

Before Independence, in 1944, the leading men of Indian business and industry came to-gather to publish what is popularly known as the Bombay Plan for the development of India. This was the first major industrial policy statement by Indians, impressively titled "A Plan of Economic Development in India".[19] It worked out the actual financial outlays to be incurred over a fifteen year period aimed at doubling per capita income and registering a five fold increase in industrial production in India. The Bombay Plan also set out the strategy for resource mobilisation and for the development of related infrastructure in health

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[19] Sir Purshotamdas Thakurdas and other members, A brief Memorandum Outlining a Plan of Economic Development For India, Part 1 and 2, (Bombay, 1944) pp.1-105.
The eight signatories to the Bombay Plan were representative of a wide cross-section of India's business world. In Proper order of succession the signatories were Sir Purshotamdas Thakurdas, "king cotton" of Bombay, J.R.D.Tata, of the house of Jamsetji Tata; G.D.Birla, representing the second biggest business house in India, Sir Ardeshir Dalal, a Parsi stockbroker of the modern type; Sir Shri Ram of DCM (Delhi Cloth Mills) complex of north India; Kasturbhai Lalbhai, the leading mill owner of Ahmedabad, A.DS.Shroff, a stockbroker of Bombay and John Mathai, an economist and a Tata director.

care, education, food supply, transportation and communications and so on. Undoubtedly, it was a blue-print for industrial development and the government was given the central role in this strategy. The Bombay Plan envisaged not only state support for private capital, but also control by the state (accompanied in appropriate cases by state ownership or management) of public utilities and basic industries.

It can be argued that the role of the public sector must be seen as one of facilitating a process of "primary accumulation" of capital in an under-developed post-colonial economy wanting to speed up the process of industrialisation. The Bombay Plan's explicit preference for deficit financing (budget deficits were to contribute as much as 35% of the total outlay of Rupees 10000 crore (10 billions)), as a way of mobilising financial resources for industrialisation, illustrates the point. Apart from "creating money" (the term is used in the Bombay Plan) the state was also asked to administer land reforms, control food prices (to reduce the middlemen's profit and to facilitate agricultural surpluses), and invest in the creation of technical and managerial skills necessary for industrial development. In part II of the Bombay Plan, the authors, taking a long term view, perceived the diminishing role of the state as the economy progressed.

The national freedom movement had raised the expectations of the people regarding their economic emancipation. This led to the emergence of industrialisation with social justice as an ideology of the ruling class. To accelerate the pace of industrialisation, the country needed a comprehensive network of infrastructure; basic and heavy industries and an assured supply of energy. These industries require large capital investment, having high risk, uncertainty and a long gestation period. Profit maximising industrialists do not necessarily opt for such types of investments. However, these industries are a pre-requisite for a self reliant and independent industrial base. Therefore, the government took the task of developing these industries upon itself.

Announced

The government of India came forward with its industrial policy in April 1948, with a view to promoting a rapid rise in the standard of living of the people by exploiting the latent resources of the country, increasing production and offering opportunities to all for employment in the service of the community. The fundamental principle of the policy, which may be called the First Industrial Policy of the country, was that the State must play a progressively active role in the development of industries. The Industrial Policy Resolution, 1948, carved out an exclusive monopoly sector and a "reserve sector" for industries wherein the Government would have the sole right to establish undertakings in future, and existing private enterprise would be allowed to continue under the close watch of the Government. It was further added that the Government, if it was considered necessary, would seek the collaboration of the private sector with regard to the group of industries included in the reserved sector. The remaining industries were left to be developed by private enterprise.[20]

After the Industrial Policy Resolution, 1948, the country gave itself a Constitution which set out certain directive principles. The State shall in particular, direct its policy towards securing that: i) The ownership and

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[20] The Industrial Policy Resolution, 1948, classified industries into three categories. Under the first schedule, the following industries were included: arms and ammunition, atomic energy and railway transport. Under the second schedule, referred to as the "reserved sector" industries above, the following industries were included: coal, iron and steel, aircraft manufacture, ship-building, manufacture of telephone, telegraph, and wireless apparatus excluding radio receiving sets and mineral oils.

control of the material resources of the community are so distributed as best to serve the common good, ii) The operation of the economic system does not result in the concentration of wealth and means of production to the common detriment. In 1956, when the First Five Year Plan drew to a close and the Second Five Year Plan was about to commence it was realised that the Industrial Policy 1948, would not be able to bring about what had been envisaged in the Constitution and implied in the national objective of establishing a socialistic society. It was therefore found necessary to recast the 1948 policy. Consequently, the Industrial Policy Resolution, 1956 was presented to and accepted by Parliament. The 1956 Industrial Policy Resolution retains the old threefold classification of the industries but made significant additions to the list of industries that would fall in the public sector.[21]

Thus the evolution of the public sector in India was shaped by the Industrial Policy Resolution, 1948, the Constitution and the Industrial Policy Resolution, 1956. The growing importance of the public sector was reflected

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[21] According to Industrial Policy Resolution, 1956, 17 industries were classified in the "exclusive monopoly" schedule A, as compared to 3 in 1948 resolution. The industries that have been included in the exclusive monopoly sector are as follows: 1) arms and ammunition, 2) atomic energy, 3) iron and steel, 4) heavy casting and forging of iron and steel, 5) heavy plant and machinery, 6) heavy electrical plant, 7) coal and lignite, 8) mineral oil, 9) mining of iron ore, 10) mining and processing of copper, lead, zinc tin etc., 11) minerals connected with production and use of atomic energy, 12) aircraft, 13) air transport, 14) Railway transport, 15) ship building, 16) telephone cables, 17) generation and distribution of electricity. Schedule B - the reserved sector for the state - the industries were to be progressively state owned. There are now a dozen industries in the list. There were only six industries in this category in the 1948 Industrial Policy Resolution. The remaining industries were left to the private and co-operative sector but the state reserves the right to nationalise an industry in this sector if it should feel so inclined.

in the government regulated plan outlays as shown in the Table I.3.

Table I.3

The share of the public sector in total investment during the five year plans. (Rupees in crores i.e. 1 crore = 10 millions).

Period/ Plan	Total Outlay	Total Investment	Investment in Public Sector	Investment in Private Sector	% of Public Sector I. to Total Investment	Ratio*
1951-52 1955-56 I^{st} Plan	3,760	3,360	1,560	1,800	46.4	1:1.15
1956-57 1960-61 II^{nd} Plan	7,772	6,831	3,731	3,100	54.6	1:0.83
1961-62 1965-66 III^{rd} Plan	12,677	11,280	7,180	$4,100^t$	63.7	1:0.57
1969-70 1973-74 IV^{th} Plan	$24,759^e$	$22,635^t$	$13,655^t$	$8,980^t$	60.3	1:0.65
1974-75 1978-79 V^{th} Plan	$66,474^e$	$63,751^t$	$36,703^t$	$27,048^t$	57.6	1:0.73
1980-81 1984-85 VI^{th} Plan	$185,531^e$	$158,710^t$	$84,000^t$	$74,710^t$	52.9	1:0.89
1985-86 1989-90 VII^{th} Plan	$348,148^t$	$322,366^t$	$154,218^t$	$168,148^t$	47.8	1:1.09

* Ratio of Public Sector Investment to Private Sector Investment. t Target. e Estimate.
Source: Statistical yearbook, Tata Economic Consultancy Services, Bombay, Published in 1988.

The share of public enterprises in the Net Domestic Product increased from 3% to 12.33% in the same period. As can be seen from Table I.4 the share of public sector in the capital formation as a proportion of Gross Domestic Product has been less compared to the private sector in the period 1951-1986.

Table I.4
Share of public sector and private sector in the domestic capital formation as a percentage of GDP. (at current prices).

Years	Public	Private
	% Share of capital formation in the gross domestic product.	
1950-51	2.7	9.1
1055-56	4.9	8.9
1960-61	7.6	9.6
1965-66	9.2	9.2
1970-71	6.8	11.4
1975-76	10.3	11.9
1980-81	11.0	13.7
1985-86	11.7	14.4

Source: Economic Survey, 1987-88, Ministry of Finance, Government of India.

Analysis of the performance of the public sector provides some clues about the unsatisfactory growth of the industrial sector. Public sector investment in industry has been largely in capital intensive industries. The public sector in India includes basic and heavy industries, electrical equipment, various sources of commercial energy and infrastructural facilities which were crucial to increasing the productive capacity of the country and are therefore of great significance.

Table I.5
Share of the employment generated by public sector and private sector in the total employment generated by public and private sectors. (in percentages).

Years	% of Total employment in Public Sector	% of Total employment in Private Sector
1951-52	N.A.	(5400000 persons.)
1955-56	46.48	53.51
1961-62	58.97	41.02
1965-66	57.9	42.06
1971-72	62.54	34.45
1975-76	66.06	33.94
1981-82	67.87	32.12
1985-86	70.6	29.03

Source: Economic Survey, Ministry of Finance, Government of India.

The public sector's share in total employment has been very high as can be observed from Table I.5.

The inability of the public sector to generate satisfactory levels of investible surpluses has been one of the main factors contributing to slowdown in the growth rate of the industrial sector.

Thus we find that though the public sector was believed to be crucial to the development of the Indian Economy, it's growth has coincided with poor performance in recent years.

I.8 Regulation of the electricity industry in India: The changing environment.

There have been three central government acts governing this industry from 1887.

1) The Electricity Act; 1887
2) The Indian Electricity Act; 1910
3) The Electricity (Supply) Act: 1948

Before independence, this industry was regulated by the Indian Electricity Act 1910. Private electric companies were issued licenses for the supply of electric power in specified areas. After independence this industry was placed in the public sector. The Electricity (Supply) Act was passed in 1948 with the objective of rationalising the generation and distribution of electricity and its development on a regional basis.

I.8.1 Procedure in India before 1910.

In 1887 the Government of India decided to introduce the first legislative measure dealing with the matter, which had allegedly put a stop to all electrical progress for six years. The Government of India did not commit itself hastily to exhaustive or detailed legislation on so complicated a subject. The Act of 1887 professed to be no more than a temporary measure, designed to give the

Government a sufficient controlling power for the adequate protection of the public until the time should be ripe for full consideration of the subject. At that time little experience was available in India on which a measure of such industrial importance could be based.

The Calcutta licenses were revoked by consent, new licenses being granted under the passing of the Imperial Act i.e. Indian Electricity Act; 1903. Up to the year 1903, the Indian statute Book contained only three enactments relating to electricity, one general and the other two of purely local application, namely, the Electricity Act (XIII of 1887), the Calcutta Electric Lighting Act (Bengal Act IX of 1895) and the Howrah Bridge Electric Lighting Act (Bengal Act I of 1902). The only undertaking working under statutory powers in that year was one for general supply in Calcutta, where it was found that the legislation in force was by no means satisfactory either to Government, the company or to the public. In point of simplicity the Indian Act of 1903 was found a great improvement on its English models.[22] Some of the best points in the Indian Act of 1903 had been embodied in a Bill which had been several times before Parliament, designed to carry out the recommendations of the two Joint Select Committees which reported on the subject so long ago as 1893[23] and 1898.[24]

Although the secretary to the government of India, Mr. T. Higham, had revised the Electric Lighting Rules in 1901 under the Section 4 of Act XIII of 1887, it was only in 1903, under the Indian Electricity Act, that a considerable

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[22] J.W. Mears, The law relating to electrical energy in India, being the electricity supply Act, 1910, (Calcutta, 1910).

[23] Report on Electric Power (Protective Clauses), Government of India, (India, 1893).

[24] Report on Electrical Energy (Generating Stations and Supply), (India, 1898).

number of licenses were granted in connection with the ordinary supply of electricity for lighting and power in towns, from steam generating stations on the spot. But none of the various schemes for the supply of energy over large areas, for industrial and general purposes, utilising either water power or coal near the pits' mouth in conjunction with electrical transmission of power, had started by 1910. The state of the money market and matters connected with the purchase clauses of the Act were largely responsible for this state of affairs. Meantime the striking success of the Mysore installation, transmitting power from the Cauvery Falls to the Kolar Gold Fields and Bangalore led the Kashmir Durbar to embark on a large hydro-electric development on the Jhelum river. Neither of these states, however were included in British India.

Owing to the large number of amendments and verbal alterations being found necessary either by the committee or subsequently, it was ultimately decided to repeal and re-enact the Act rather than to pass an amending Bill. Thus, the Indian Electricity Act, 1910 (Act IX of 1910), received the assent of the Governor General on the 18th March, 1910. It consisted of four parts aggregating 58 sections, and of a schedule of 17 clauses.

I.8.2 Procedure after 1910.

The Indian Electricity Act (1910) gave the Provincial Governments a certain measure of control, but the amount of financial control which a Provincial Government could exercise was inadequate and was lacking both in precision and uniformity.[25] In any license granted by a Provincial Government, although a schedule of maximum prices was incorporated, the other operations could not be regulated

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[25] Rules regulating the generation, transmission, supply and use of electrical energy, by Public Works Department, Issued on 23 December, 1910, (Calcutta, 1911).

to any appreciable extent. Under these conditions the interests of the consumer took second place to those of the shareholder. Several licensees paid unduly high rates of interest on their capital. So long as this continued to be the case the cost of electricity to the consumer remained unnecessarily high.

After the application of the Indian Electricity Act; 1910, there were no major changes in the regulation of the electricity industry as such till 1947. But while electricity generation was in the private sector of the economy before Independence, there were various committees set up by the government of India to evaluate either the functioning of electricity companies in a particular area or the performance of a particular company.

The first committee in this period was set up in 1936.[26] The government of India appointed a committee to examine the supply of electricity in Delhi Province. The Committee found that the supply of electrical energy in Delhi was adversely affected by the uncertainty regarding the supply position between New Delhi Municipal Corporation and the Company. The supply of electricity in Delhi was found to be inadequate and the Committee recommended the installation of additional generating equipment. But they felt that the concentration of generation was most essential in Delhi.

Also in 1936, the Government of Bengal's Department of Commerce published a report of the Committee[27] appointed to enquire into the charges for electrical energy levied by the Calcutta Electricity Supply Corporation Limited. The Committee was quite surprised by the high standard of plant

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[26] Report by Delhi Electric Supply Enquiry Committee, Government of India. (India, 1936).

[27] Report by Calcutta Electric Supply Corporation charges Enquiry Committee, Government of India, (India, 1935-36).

and equipment used and also by the excellent way in which the plant and equipment were maintained. At the same time the Committee criticised the company's expenditure on repairs and maintenance which amounted to 0.69 annas per unit generated (in 1934) as being excessive and suggested that savings could be made which would reduce this figure to 0.26 annas per unit generated.

Such government committees did little to change overall policies, although electric power in this period established its place as a productive input in industries. There was a marked difference between the availability of power supply and the efficiency of the electric companies in different regions. The evidence of diversity between states is given in the following Chapter.

In 1944 it was observed that the electricity supply industry in India was characterised by multiple small undertakings, the issued capital of which in the great majority of cases was under 5 lakhs of rupees. The development of large, commercially owned electricity undertakings had been impeded by difficulties experienced in raising capital and the high rate of interest demanded for its provision. According to the government advisory Committee,[28] the monopolistic character of the Electricity Supply Industry could lead to abuses in the absence of adequate control. Due to a number of reasons it was expected that the existing licenses would remain in existence for some considerable time and therefore an effective and uniform method of control by Provincial Governments was found to be necessary.

The advisory Committee of the Government of India outlined some Principles for the control of public utility electric supply companies on a standard basis. The

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[28] Report of the Advisory Board on the Principles for the control of public utility electricity finance, Department of Works, mines and Power, (Delhi, 1947).

principles were referred to the Provinces, the Federation of Electricity Supply Undertakings and some individual electricity supply undertakings. The main aims of the principles were:[29]

a) To safeguard the interest of the consumer by limiting interest and dividends payable to the minimum necessary to ensure an adequate flow of capital and a reduction in the selling price of electricity.

b) To safeguard the interests of investors by insistence on a properly devised system of compulsory depreciation and at the same time permit the earning of a "reasonable" or "fair" return on investment, though there were no clear cut declarations of what the fair return on capital was.

The Policy Committee (no. 3-c Public Works and Electric Power) of Reconstruction Committee of Council, Government of India, at its second meeting held on 2nd February, 1945 resolved that,

a) The development of electricity supply in areas outside existing licensed areas should be actively pursued as far as possible, as a state or quasi-state enterprise; but if for any reason the state was not prepared to undertake such development in any area within a reasonable time, private enterprise should not be excluded.

b) Provided efficient and economic operation could be assured to the public, options existing under any license to acquire an undertaking should, as a general rule, be exercised when they arise,

c) That steps be taken to eradicate any factors that retard the healthy and economical growth of electrical development on regional lines whether in Provincial state or Local authority owned or in commercially owned electrical undertakings.

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[29] Ibid, pp.16-18.

Under the Electricity (Supply) Bill 1946 most provinces were expected to set up Public Electricity Supply Boards. It was proposed that the Principles set up by the Committee should be incorporated in the Bill to govern the relationship between Licensees and Electricity Supply Boards. The Committee looking into the matter was reorganised four times at different points and there were difference of opinion between the Committee Members and Mr.I.A.Macpherson, advisor to the government of India on various issues. Finally the report was ready in 1947.

I.8.3 Procedure after Independence.

After Independence, this industry was placed in the public sector. The Electricity (Supply) Act was passed in 1948 with the objective of rationalising the generation and distribution of electricity and its development on a regional basis.

We observed in the previous Section that in each of the committee reports beginning from the year 1910 the committee members seem to have realised the need to protect the consumers' interest. They also realised the need for investments by the states due to the heavy capital requirements of the industry as well as its monopolistic nature. But it was only after Independence that these aspects could be enacted.

According to the federal constitution of the union of India, the supply of electricity is a "concurrent" subject i.e. it comes within the purview of both the central and the state governments.

However, the major burden of its development is the responsibility of the states. According to the Electricity Supply Act of 1948, generation and distribution was decentralised to some extent by creating State Electricity Boards. Under section 5 of the Electricity (Supply) Act; 1948, State Electricity Boards were constituted so as to promote the coordinated development of the generation of electricity within the state in the most efficient and economic manner with particular reference to such development in areas which are not at all served or only inadequately served by any licensee. Thus, after Independence, though the electricity industry was not nationalised as such, encouragement was given to the state to invest more in this public utility, and private investment was discouraged. Under the Electricity (Supply) Act; 1948, five Regional Electricity Boards were set up to achieve regional operation of power systems. The functions assigned to them were:

1) Reviewing the progress of power development schemes in the region.

2) Planning and ensuring the integrated operation of the systems in such a manner that at any time the total amount of electricity generated and transmitted shall give the maximum possible benefits to the region as a whole.

3) Preparation of a coordinated overhaul and maintenance programme for the generating plants in the region.

4) Determining the quantity of power available for exchanges from time to time between the States, over and above the requirements of each State.

5) Determining the generation schedules to be followed by the constituent systems.

6) Determination of a suitable tariff structure to govern exchanges of power within the region.

The five Boards-for the Northern, Western, Southern, Eastern and North Eastern regions-were also engaged in developing Load Despatch Centres so that systems in each region could work in an integrated manner for utilising the existing capacity so as to give maximum benefits to the region as a whole.

The act also provided for the creation of the Central

Electricity Authority. It coordinates the activities of the Planning agencies, acts as arbitrator in matters arising between the State Governments or State Electricity Boards and licensees, collects data concerning generation, distribution and utilisation of power, and publishes relevant statistics concerning electricity supply and assessment and reports on power surveys.

In the 1956 industrial policy resolution, the future development of the generation and distribution of electricity became the exclusive responsibility of the states. Since then, investment in the electricity supply industry has been largely public sector investment and the Central Electricity Board was constituted with powers to make rules for regulating generation, transmission, supply and use of electrical energy.

The Rural Electrification Corporation (REC) was set up in July 1969. The REC has given a special consideration to rural electrification schemes in backward areas. The loans and viability norms have been devised specially to take into account the fact that it takes a longer time for the demand for electricity to materialise in these areas and, consequently, it takes more time for a scheme to become viable.

The Central Electricity Consultative Council was reconstituted in 1972. This Council is an advisory body. Its objective is to establish closer relations between the suppliers and users of electricity. During the late 1970s the Electricity Supply Act was amended to allow the setting up of central organisations called the National Thermal Power Corporation and National Hydro-electric Power Corporation to build large thermal power stations in the case of the former and large hydro-electric power stations by the latter organisation. The purpose of setting up these organisations was fully to exploit economies of scale which would have been beyond the resources of individual states and could best be taken advantage of by funding directly from the central government and by sharing the benefits between groups of states.

Thus, we can observe a movement from small electricity companies in the private sector to electricity generation and distribution in the public sector. The central government was cautious not to repeat the results of private electric companies, deriving instead the economies of scale in generation, and also taking consideration of the consumers' interest.

As we have observed, all possible policy instruments were adopted to utilise the economies of scale benefits. And in this respect the transition from small companies in the Pre-Independence period to State Electricity Boards along with the central organisations in the Post-Independence period have been successful.

As far as the consumers' interest was concerned, in the Pre-Independence period the electric companies did charge high prices and also made profits. The supply was quite unreliable[30] But the efficiency levels of some electric companies were very high as observed by the Committee which was appointed in 1936 to enquire into the changes for electrical energy levied by the Calcutta Electric Supply Corporation.

In the Post-Independence period, the State Electricity Boards charged "reasonable prices" for electricity in order to protect the "consumers' interest". Though we find a lot of variation in the electricity prices between the states,

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[30] The reliability of the electric supply was observed by the Delhi Electric Supply Enquiry committee. One of the responses to their questionnaire was "At the present time the interruptions of power supply cause us the greatest trouble in this respect. The number of shut downs we obtain is greater than should be expected from a present day power supply system....." According to the report of the Committee this reply was representative of many replies that they received.

for example in 1978-79 the average revenue in Orissa was 0.154 rupees per KWH against 0.383 rupees per KWH in Assam. These differences led to differences in the forward linkages between the states. Two questions emerge in this context. i) What was the real or social cost of power supply? ii) Why were the State Electricity Boards making financial losses?

As far as the reliability is concerned the occasional blackouts and frequent brownouts were no surprise to the electricity consumers. And the consumers got used to the scheduled power cuts imposed by the State Electricity Boards. The result of these shortages in the late 1970s was obvious in the development of "captive power generation" i.e. industrial units developed their own generating capacity either to support their demand or as standby arrangements in case of power cuts. The fact that none of the State Electricity Boards had any department to deal with the consumers' complaints or/and to observe the consumers' response to their supply reflects the level of electric utilities' concern for the consumers!

CHAPTER II

THE GROWTH OF THE ELECTRICITY INDUSTRY IN INDIA.

II.1 Developments in the electricity industry prior to 1900.

Although the principle of the electric dynamo was developed as early as 1831, practical use of it was made only from the late 1870s. The electric generating plant at that time was mainly designed to provide lighting for homes, streets and public buildings.

The first installation of generating plant in India was in 1897 at Darjeeling, when the local Municipality launched their hydro-electric project utilising the local river waters. The installed capacity of 9 small hydro-electric plants was of the order of 130 KW. Soon after, in 1899, the first 1,000 KW coal-based plant was installed at Calcutta by the Calcutta Electric Supply Corporation. Otherwise the only prime movers in service prior to 1900 in India were water wheels, supplying motive power to small mills and factories. Such water wheels of crude design had been in use for several centuries in some places in India.

II.2 Development during 1901-1920.

Earlier in the century, one commentator remarked:

> "The electrical era in India has scarcely commenced; for so far as I know there are, excluding private plants, only three public electric supply stations and one tramway system actually working and about half-a-dozen more schemes in contemplation or under construction. Calcutta was the first place with its extensive installations both for general electrical supply and for tramway, the latter nearly completed by 1903. Light railways, which in many countries were almost all electrical, were worked by steam where they existed in India at all......"[31]

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[31] J.W. Mears,(Electrical Advisor to GOI), Lectures on Electrical Engineering, (Six lectures delivered at the Civil Engineering College, Sibpur in March 1902), Lecture 1 on "Electric Traction", (Calcutta, 1913), p.1.

During this period electric supply for purely lighting purposes was started in some of the large towns and cities. Only well-to-do people were able to enjoy the luxury of electric lights. Industries were generally dependent on manual or animal labour; but some installations were mechanically driven by steam engines. Motive power through the medium of electric drives had not yet become very popular. A few of the important installations constructed during this period are as follows.[32]

a) Coal-based Electric Plants:

The Madras Electricity Supply corporation Ltd. commissioned a 3,000 KW power station in 1906, the capacity of which was raised to 9,000 KW by 1914. The Kanpur Electric Supply Co. Ltd., brought into operation in 1906 generating plant of 2,170 KW capacity. The Calcutta Electric Supply Corporation Ltd. commissioned, in 1912, a new power station of 15,000 KW capacity at Cassipore. Other coal-based power plants each of less than 1,000 KW capacity were installed at various places like Bikaner, Bilaspur, Gwalior, Barrackpore, Bareilly and Joara.

b) Hydro-Electric Plants:[33]

The Mysore Government launched a 4,500 KW project on the Cauvery river at Sivasamudram in 1902 mainly to supply power to Kolar Gold Mines. The capacity of this station was progressively raised to 15,700 KW by 1920. This happened to be the first major power development in India, designed to promote industrial development. In 1909, the Kashmir Government inaugurated the Jhelum Power Station at Mohora with plant having capacity of 4,227 KW. The Simla

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[32] All the information for this period was taken from Electrical undertakings in India, Various issues which were corrected up to 1912, 1913 and 1918, Government of India, Printed in Calcutta in the respective years.

[33] J.W. Mears and R.D.Bull, Hydro-electric Survey of India, 3 Volumes, (Calcutta 1919-1922).

Municipality installed 1,250 KW of plant in 1913. The Tata Hydro Electric Power co. commissioned the first large power station of 50,000 KW capacity at Khapoli in 1914. The Bombay Government commissioned 1,024 KW of plant at Bhatnagar Dam in 1915. During this period, the plant capacity of Darjeeling was raised to 600 KW. At Mussorie a 450 KW plant was installed in 1909. A 240 KW generating station was commissioned at Patiala. A 400 KW plant was installed at Munnar to supply power to the Tea Estates in Travancore.

c) Diesel Electric Plants:

During this period diesel engine driven generators aggregating to a capacity of 6,325 KW were installed at 25 different towns including Delhi, Allahabad, Ahmedabad, Bareilly etc.

The aggregate installed capacity of the coal-based, hydro-electric and diesel plants in operation in the public electricity supply systems in India by the end of 1920 amounted to only 130,009 KW.

Technical and Financial Aspects of the Industry:

In accordance with a resolution of the second conference of Electrical Engineers and Inspectors, held in Calcutta in December 1916, reports were prepared which reveal technical and financial data on the electrical undertakings licensed under the Indian Electricity Act 1910. From Table II.1 it can be observed that out of the total 159,677 KW of capacity in 1916-17, coal-based plants were responsible for 41%, water power for 56% and oil (with steam auxiliaries) for the balance. The total connected load came to about 138,000 KW. The total units generated amounted to some 235 million, of which the Tata Hydro Electric Power Supply Company accounted for just about half. On this basis, of units generated, the average load factor was 40%.

<u>Table II.1</u>
Installed capacity and generation in the year 1912 and 1916.

	1912	1916
Installed Capacity in KW.		
Total	133,940	159,677
Native States	18,290	26,210
Coal		
Total	n.a	65,467.57
Native States	n.a	4,750.0
Oil		
Total	n.a.	4,790.31
Native States	n.a.	460.0
Water		
Total	n.a.	89,419.12
Native States	n.a.	21,000.0
Connected load in KW.		
Total	111,840	138,000
Native States	n.a.	21,000
Generation in MKWH.		
Total	210.0	235.0
Native States	83.8	102.56

Source: <u>Electrical undertakings in India</u>, Various issues which were corrected up to 1912, 1913 and 1918, Government of India, Printed in Calcutta in the respective years.

In 1916-17, the native states of India (Mysore, Kashmir, Baroda, Bikaner, Patiala and Hyderabad) had 26,210 KW of total installed capacity out of which coal was responsible for 18.12%, water power for 80.15% and oil for 1.7%. Water power (i.e. power generated from hydro-electric plants) was remarkably predominant in the native states of India compared to the remaining part of India directly under British rule. The availability of the capital required to build up the hydro-electric plant could be one of the reasons (and the capital for investment in capacity to generate electricity was made available in native states).

The electric companies in different areas had different dominant consumer groups. For example, Simla had large public and private lighting demand (KWH) as well as Public Water Works, whereas Bombay had a large traction load. The Tata Electric Supply Company, serving an industrial load in bulk, had 44 large consumers. Excluding this company 3,000 units were sold per consumer in 1916-17. But as a very large (unspecified) proportion of the sales in the combined undertakings were for traction, this figure is likely to be considerably above the median and modal use per consumer.

All the financial data were complicated by the fact that some companies had sterling capital and others rupee capital. As the greater part of the capital expenditure was incurred in pre-war days the conversion was carried out at 1s.4d. to a rupee. The capital expended on the undertakings in the list (with Rangoon added) was some 1,287 lakhs; but this includes the tramway attached to the Bombay, Delhi, Cawnpore and Rangoon undertakings. The total expenditure on licensed undertakings, omitting four of which no particulars have been given, was over 10 crores (100 million rupees). The actual capital represented by the Electric Supply and Traction Federation of India was stated to be about 14 crores (140 million rupees).

The total revenue in 1916-17, from electric supply exclusive of other sources after adding in Rangoon was about 175 lakhs (17.5 millions), or some 13.75% on the capital sum.

The revenue earned by the electric companies was affected by their pre-dominant consumer group. On the other hand the prime-mover of the plants governed the cost of the units generated. The methods of accounting as well as the efficiency in collecting the revenues from the customers were affected by the way in which the companies were managed and controlled.

Of the hydro-electric licensed undertakings, the Tata

Hydro Electric Power Supply Company was the largest. The other licensed water power installations were in the three hill stations of Simla, Mussourie and Darjeeling. These were all Municipal undertakings. In each case it was found difficult to get at their true financial position; owing to the adoption of unusual methods of finance or account keeping.[34] Simla received a large part of its capital as subsidy from the government free of charge. Though the electricity generated in Simla was largely used for pumping water, the major part of the revenue was not from the Public Water Works. This was mainly due to the mutual understanding between the Public Water Works and the Electricity Company. The revenue was largely derived from domestic consumers who used the electricity for lighting and heating purposes. Also in Mussourie no charges were taken for the large proportion of the units used in pumping water and in street lighting by the municipal corporation. The local authority was exempted from rendering statutory accounts. In Darjeeling, the Government made an annual grant towards upkeep.

The analysis of the "works cost" per unit generated shows a very wide range of results. (It must be borne in mind that these "works costs" exclude all capital charges). Naturally, the hydro-electric installations had the lowest works cost, the Tata Company heading the list with 0.111 annas (i.e. 0.444 paise) a unit. Both Simla and Mussourie had far lower costs than the best of the coal-based power stations. The works cost in Bombay was 0.831 annas (i.e. 3.324 paise) per unit generated, whereas in Calcutta the works cost was 0.694 annas (i.e.2.776 paise) per unit generated. (The works costs in Darjeeling was not found in the reports.) The stations with diesel engines had very uniform costs averaging about 1.8 annas (7.2 paise) a unit,

[34] J.W. Mears, op.cit, p.34.

which is lower than all but four of coal-based power stations. Among the newer companies, and those which had made little headway, the works costs were over 3 annas (12 paise) per unit generated. Till 1921, the highest dividend paid by any company was that paid by Calcutta Electric Supply Corporation in 1919, viz. 20% including the bonus shares issued. The Bombay Electric Supply and Tramway Company was not far behind with 18% in the same year. The small undertaking at Dacca paid 12.5% for several years and showed efficient management. Ahmedabad Electric Company also had efficient management and paid a 9% dividend in 1920. The same remark cannot be made of Lahore which paid 12.5% dividend in 1918 but had been in a state of continual trouble with its consumers and the government. The India Electric Supply and Traction Company (Cawnpore) paid 9% in 1919 and was favourably situated in an industrial area. After many vicissitudes the Madras Electric Supply Corporation reached the position in 1920 where a reasonable dividend of 8% could be declared.

II.3 Developments During 1921-1940.

The industrial boom following World War I, the realisation of the advantages of adopting electric-drive for industries, and the participation of the Provincial Governments in the business of electricity generation, contributed largely to the substantial growth of power in the period 1920-1940. During this period the aggregate installed capacity increased by about ten times i.e. from 130,009 KW to 1,208,422 KW. In areas where public utility companies were not operating, industrial undertakings like Tata Iron and Steel Co. established their own private power stations. Some of the more important installations are described below-[35]

a) Coal-based Electric Plants:

Apart from the progressive growth of the installations at Calcutta, Madras, Kanpur, Bikaner and Nagpur, etc., new coal-based plants were erected at 55 new stations raising the installed capacity from 49,245 KW, to 624,162 KW.

b) Hydro-Electric Plants:

The most notable extensions during this period were carried out by the Tata Hydro Electric Company. In 1922, a new power station of 72,000 KW was installed at Bhivpuri. A 10,000 KW generating set was added at the Khapoli power station and a third power station of 110,000 KW was commissioned at Bhiar in 1927. Additional plant aggregating to 29,250 KW was installed at Sivasamudram Power Station. A station at Shimshapura was added to the system in 1940 with a plant capacity of 17,200 KW. The installed capacity of Munnar Power Station in Travancore was raised to 1,900 KW. There were many other new plants at various places in the country.

c) Diesel Electric Plants:

The aggregate capacity of diesel plants was raised from 6,325 KW to 115,291 KW during this period due to extensions in plants in operation and installation of new plants for the electrification of about 360 towns.

Performance of the Electricity Industry:

The data availability regarding the technical and financial performance of electricity industry in the period between 1921 and 1940 is quite poor. As noted in the earlier section, the regulations governing this industry were changing. The industry was also in an infant stage. There was neither any Central Authority that could

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[35] The information was gathered from <u>Electrical Undertakings in India</u>, Corrected up to 1930, 1932, 1934; Government of India, Printed in Lahore. Very little information was published in the form of any document for the period 1932-1940.

coordinate the small units scattered in the major cities in India, nor there were any common methods of regulation to be followed. Hence, we find the relevant data in different forms, in various reports of the different electricity companies. The reports were prepared and maintained from the point of view of the individual company. The boundaries of the states were different than those of the present. Thus the data are not in comparable form to those available after Independence.

An attempt is made in this section to observe the technical and financial performance on the basis of the available data. Table II.2a and Table II.2b show that the installed capacity in different parts of the country varied enormously. The data in the Tables (i.e. II.2a, II.2b), reflect the sum of the installed capacity of the companies in each of the specified regions. Bengal, Madras Presidency, United Provinces, Central Provinces and Bombay Presidency were the dominant regions where electricity was generated. These regions were either the main centres of British trade and raw material activities or they were princely states. In either case the initial capital needed for setting up was available and private companies found some local demand (KWH), justifying investment in plants to generate electricity. In these areas electricity was a luxury good in the household sector so its sale was limited to the elite households. Realising that electricity was a very convenient fuel input, saving time and costs, the Tata cotton textile group initiated a project for a hydro-electric plant at Bombay. This example was followed by many other groups of industrialists. Thus, electricity changed from being primarily a luxury consumer good to become an important productive input. As a result, the development of electricity generation was concentrated in the areas which were comparatively industrially developed. In contrast, as we can see from the Tables (i.e. II.2a, II.2b), Bihar, Orissa, Indian States and to some extent Assam, which were almost entirely agricultural, had relatively slow and delayed growth in electricity generation.

<u>Table II.2a</u>

Total installed capacity in KW by region.

Year	Assam	Bihar	Bengal & Orissa	Punjab	Madras	United Provinces	Railways
1919	-	-	23,410	2,655	4,500	2,670[*3]	-
1920	-	-	23,260	2,655	4,500	3,170	-
1921	-	-	28,626	2,770	4,500	9,170	-
1923	-	-	54,451	3,920	9,500	11,940	-
1924	200	-	69,451	3,690	9,500	21,250	625
1925	200	-	69,801	3,690	9,500	18,000[*4]	2,190
1926	300	-	81,746	5,040	9,500	21,160	2,190
1927	300	-	74,196	8,700[*1]	9,699	21,460	2,290
1928	300	-	114,370	3,400[*2]	9,783	21,460	2,250
1929	681	2.36	114,404	15,018	16,053	27,115	2,310
1930	712	3.11	157,815	14,193	22,463	29,415	2,286
1931	888	3.7	166,681	17,470	243,215	30,140	19,966

<u>Table II.2b</u>

Year	Bombay Presi-dency	Milit-ary Eng. Works.	North West Frontier	Delhi Province	Central Provinces
1919	51,132	-	-	787	250
1920	51,446	-	-	787	250
1921	51,736	-	-	-	250
1922	52,188	-	-	-	250
1923	113,478	-	-	-	250
1924	114,298	-	-	-	250
1925	114,766	-	-	2,127	440
1926	127,277	-	-	2,127	940
1927	130,900	-	295	2,127	940
1928	241,418	-	315	2,127	3,423
1929	241,358[*2]	-	N.A.	5,227	3,223
1930	242,374	-	N.A.	3,100[*2]	N.A.
1931	198,485	539	799	2,100[*2]	3,448

*1 Hydro-electric plants not included. *2 Data not available for coal-based plants. *3 Missing data for some units. *4 Missing data for some hydro-electric plants.
Source: <u>Electrical Undertakings in India</u>, For the years 1930, 1932, 1934, Government of India, Printed in Lahore.

The data on the electricity generated (KWH) per unit of installed capacity (KW) reflects the capacity utilisation in each region. To some extent capacity utilisation reflects the electricity availability. Usually, in the absence of excess demand, capacity utilisation would reflect the characteristics of electricity demand (KWH). As can be observed from Table II.3a and Table II.3b, the generation was increasing at different rates in different regions. These differences could be due to the differences in the level of economic activity or differences in electricity availability. The differences in the availability (electricity in KWH) is the obvious result of the vast difference in the installed capacity in the different regions in the absence of the interconnections between the regions to exchange power.

Observing the installed capacity according to prime mover, we gather that in the beginning the hydro-electric plants were predominant but over a period of time there was a shift towards coal-based plants.

As seen from the Table II.4, the development of the oil-based plants over the period is slow. Assuming the available data is the total, one can compare the share of different plants in the "total". The share of the oil-based plants was not more than 7% till 1931. In absolute terms the increase in the hydro-electric plants is slower than the coal-based plants. Among the reasons are high capital requirements, the gestation period and the seasonal characteristics of the hydro-electric plants. The state governments and the British government were not interested in investing capital in electricity generation, requiring long term planning, during the disturbed years of First World War and the depression. Meanwhile private investors were in need of either low load, small generating plants satisfying domestic requirements or shorter gestation plants to satisfy industrial demand (KWH).

Table II.3a

Average capability by region. i.e. generation (in KWH) per KW of installed capacity in different regions.

Year	Assam	Bihar	Bengal Orissa	Punjab	Madras	United Provinces	Railways.
1919	-	-	1,415.5	2,227.7	1,463.3	2,181.7	-
1920	-	-	1,716.6	2,718.9	1,633.7	1,627.6	-
1921	-	-	1,548.9	2,750.6	1,742.4	-	-
1922	-	-	1,367.6	2,773.4	2,000.3	-	-
1923	-	-	1,406.2	2,447.8	1,131.2	700.3	-
1924	734.0	-	1,407.8	1,537.2	1,122.3	607.3	172.3
1925	412.3	-	1,768.0	2,790.5	1,217.2	750.6	70.5
1926	616.8	-	1,509.8	2,235.8	1,311.7	1,204.4	91.9
1927	721.0	-	1,769.4	1,026.8	2,198.5	1,143.4	112.7
1928	804.5	-	1,472.1	622.5	1,944.5	1,446.7	81.4
1929	723.6	1,179	1,674.4	1,148.6	1,271.9	1,573.4	88.0
1930	879.1	1,144	1,208.7	1,449.5	998.7	1,740.2	84.3
1931	966.0	1,162	1,169.7	1,328.8	109.7	1,893.6	14.9

Table II.3b

Year	Bombay Presidency	Military Eng. Works	North West Frontier	Delhi Province	Central Provinces
1919	1,744.2	-	-	2,587.4	955.9
1920	1,892.0	-	-	2,975.5	1,117.8
1921	2,132.5	-	-	-	1,321.5
1922	2,351.5	-	-	-	1,321.5
1923	1,221.0	-	-	-	1,516.6
1924	1,706.3	-	-	-	2,109.5
1925	2,254.7	-	-	1,853.3	1,715.7
1926	977.5	-	-	1,941.8	858.7
1927	2,253.2	-	620.2	2,107.3	1,036.1
1928	1,207.1	-	618.5	2,630.5	770.4
1929	1,224.3	-	-	2,632.5	1,124.9
1930	1,671.7	-	-	5,066.5	-
1931	2,034.8	2,010.0	598.2	-	668.1

Source: Calculated from Table II.2a and Table II.2b.
- means data unavailable.

N.B. Due to non-availability of data either in the installed capacity or in the units sold of some plants in some regions the figures give us general picture and not a very clear idea about efficiency in the particular region over a period of time.

Table II.4
Installed capacity by prime-mover at all-India level. (in KW).

Year	Coal-based plants		Hydro-ele. plants		Oil-based plants		Total
	Total	% share	Total	% share	Total	% share	
1919	31,321	36.7	51,850	60.7	2,233	2.6	85,404
1920	32,135	37.4	51,850	60.2	2,083	2.4	86,068
1921	34,280[*1]	49.9	51,850	59	1,752[*2]	2.0	87,882
1922	54,220	50.1	52,350	48.1	2,184	2.0	108,754
1923	76,360	39.5	114,500	59.1	2,679	1.4	193,539
1924	101,465	46.3	114,400	52.2	3,199	1.5	219,064
1925	102,800	46.3	112,550[*1]	50.8	6,743	3.0	222,093
1926	118,711	47.5	124,300	49.7	7,252	2.9	250,263
1927	122,441	47.3	124,300	48	12,221	4.7	258,962
1928	162,481	39.7	232,050[*3]	56.6	15,235	3.7	409,766
1929	176,284[*4]	40.5	236,700	54.3	22,459	5.1	435,443
1930	220,398	46	238,632	49.8	20,269[*5]	4.2	479,299

* Missing data in:
1 United Provinces
2 Delhi
3 Punjab
4 Bombay
5 Delhi and Central Provinces.
Source: Calculated from the yearly statements maintained by the individual companies in India in the respective years.

The availability of natural fuel resources and the availability of capital in different regions largely determined the choice of prime-mover. Though with no inter-connection between the states, this left each area vulnerable to supply interruptions. Punjab was an exception to this, with a more balanced mix of hydro-electric and coal-based plants since 1919 and, after 1926, oil-based plants were also added to its total capacity. Its electricity generation was largely from the coal based plants and the share of the hydro-electric plants was decreasing over a period of time. However, in states like Assam, there was initially complete reliance on the hydro-electric plants. After the introduction of oil-based plants from 1928, the share of the hydro-electric plants reduced to 50%. Electricity generation in Bengal and Madras Presidency was mainly from coal-based plants and this continued for the whole period. In the Bombay Presidency, though hydro-electric plants were the major source of electric power, there were also coal-based and oil-based electric power plants with a very limited share in the total capacity. In the Central Provinces electricity was generated mainly from oil-based plants until 1925 when the lead was taken over by coal-based plants.

Table II.5
Expenditure (in Indian Rupees) per unit (KWH) of electricity sold in major states.[36]

Year	Assam	Bihar	Bengal Orissa	Punjab	Madras	United Provinces	Bombay
1919	-	-	.67	0.63	2.11	1.0	1.0
1920	-	-	.68	0.57	1.87	0.92	1.3
1921	-	-	.78	0.62	1.77	0.94	1.09
1922	-	-	0.93	0.52	1.89	0.97	-
1923	-	-	0.72	0.68	2.13	0.89	1.31
1924	2.75	-	0.59	1.18	1.68	0.98	0.96
1925	5.15	-	2.70	0.79	1.58	1.0	0.47
1926	2.44	-	0.55	0.82	1.62	1.06	0.53
1927	2.19	-	0.45	1.19	1.72	0.69	0.55
1928	2.12	-	0.41	5.84	1.56	0.87	0.38
1929	2.41	1.10	0.38	0.74	1.19	0.88	0.49
1930	1.91	0.95	3.8	0.50	0.97	0.87	0.45
1931	1.57	1.04	0.44	0.66	1.69	0.78	0.43
1932	1.90	0.04	0.0013	0.23	0.75	0.19	0.71

Source: Calculated from the yearly statements maintained by the individual companies in India in the respective years.
Note: The data on expenditure as mentioned, were recorded by the individual electricity companies and no uniform pattern was followed to maintain the records. Some electric companies maintained these records in Pound-Sterling and some in Rupee-Paise. Also, the records of all electric companies are not available today. Hence, this representation is just an approximation and the data are unconvincing.

[36] The data on expenditure as mentioned, were recorded by the individual electricity companies and no uniform pattern was followed to maintain the records. Some electric companies maintained these records in Pound-Sterling and some in Rupee-Paise. Also, the records of all electric companies are not available today, hence, this representation is just an attempt and may not appear convincing.

The presence of natural resources was not always sufficient to guarantee the development of electricity generation. For example, regions like Bihar were well endowed with coal but the development of electricity generation was slowest in Bihar. This was mainly due to lack of local demand (KWH) for electricity.

Data on total expenditure and revenue were also collected for various purposes by the companies. For many companies the data is missing, nevertheless the conclusions drawn on the basis of this data throw some light on the financial position of the industry before World War II. The expenditure per unit of electricity sold is shown in Table II.5. It is obvious that the states having larger installed capacity in hydro-electric plants had lower unit expenditure than the rest.

The data on unit expenditure (as can be seen from Table II.5) even in one state did not always follow any trend and the fluctuations could be due to the way in which the records were maintained. Hence, it is not possible to draw any definite conclusions from the financial data. The data on revenue earned per unit of electricity sold is much more unreliable. It seems that the revenue per unit is less than the expenditure per unit; on the other hand the reports give us evidence regarding the interest paid to the shareholders!

II.4 Developments during the period 1941-1950.

The growth of power facilities during the decade was largely affected by the Second World War (1939-1945) and the abnormal post-war conditions that followed. During the War, all the available power supply resources were strictly controlled and regulated from the point of view of the war effort. The available plants were used to the maximum extent possible; wear and tear became very heavy and spare parts could not be produced. Provision of additional capacity and other equipment was often impossible, while poor maintenance and frequent breakdowns aggravated the condition of the plants in service.[37] The coal-fired stations suffered particularly due to deterioration of the quality of coal supplies, resulting in reduced outputs. Shortage of fuel oil compelled a number of diesel power stations to operate for a few hours only during the day.

At the end of the war, the power supply industry found itself in a very precarious situation. Apart from the expansion of the capacity needed to meet the unsatisfied and future power demands (KW), the plants in operation needed considerable rehabilitation. The country was partitioned in August 1947. The installed capacity which fell within the jurisdiction of Pakistan immediately after partition amounted to 74,570 KW.[38] A significant feature of electric power development in India during the latter half of this decade was the increasing participation in the electric supply industry by the various State Governments. Punjab, Madras, Mysore, Travancore and Uttar Pradesh were already in the field and certain other states viz., Bengal, Bihar, Bombay, Madhya Pradesh and Orissa entered the field after the War. During the period several private electric utilities were also responsible for substantial plant extensions in their respective areas. The important additions to plant capacity during this period were-

a) Coal-based Electric Plants-

During this decade, particularly in the later half,

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[37] Record of the 1st and 2nd meetings of Policy Committee no. 3c, Reconstruction Committee of Council, Public Works and Electric Power, held in October 1943, February 1945, Published in 1945 at New Delhi. Also see, Report of the advisory Board on the Principles for the control of public utility electricity supply finance, op.cit, p.45.

[38] Though this was 5% of the total installed capacity at all India level, Punjab and Bombay state were affected severely since they lost some of their plants.

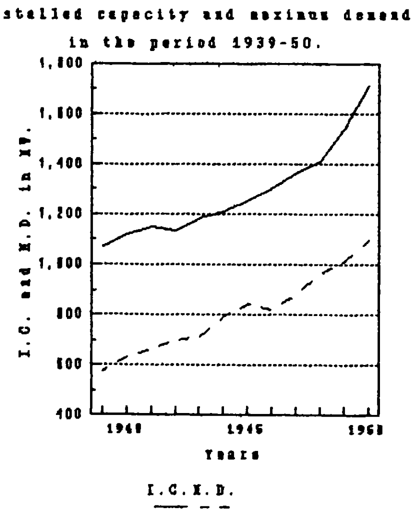
there was an addition of 380,000 KW of coal-based generating plant in public utility undertakings, so that the total installed capacity at the end of this period stood at 1,004,434 KW which represents an increase of 61% over the capacity in 1940. The major installations were at Calcutta, Ahmedabad, Kanpur, Delhi, Allahabad, Agra, Banaras, Jabalpur, Patna, Hyderabad and Vijayawada.

b) Hydro-Electric Plants-

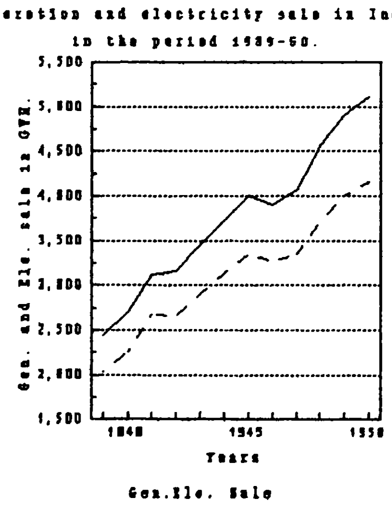
The expansion of the capacity of hydro-electric plants was much less than that of coal-based plants. Among the new installations commissioned were Papanasam in Madras State-21,000 KW (1944) and -Jog falls station in Mysore (1st stage)-48,000 KW (1947-49). Extensions to existing stations were completed at Mettur in Madras-10,000 KW (1946) and at Pallivasal in erstwhile Travancore 15,000 KW (1947-49). The aggregate capacity in hydro-electric plants in 1950 was over 559,000 KW which represents an increase of about 20% over the 1940 level.

c) Diesel Electric Plants- Some 25 new towns were electrified during this period with diesel power plants. The aggregate installed capacity at the end of 1950 was 148,796 KW.

Graph II.1



Graph II.2



As can be observed from Graph II.1 and II.2, the installed capacity and electricity generated increased almost continuously throughout the period. The energy sold to the consumers and the peak load also had increasing trends.

II.5 Developments during 1951-1986.

During the period 1951-1971, the national economy was affected by the strategy adopted in the Second Five Year Plan, based on the Mahalanobis model. The basic philosophy of the Second Plan was to give a "big push" to the economy through rapid industrialisation. The Draft Outline of the Second Five-Year Plan observed,[39]

> "The Indian economy at present depends excessively on agriculture. It has to be diversified, and special stress has to be laid on development in the future if industries are to be sustained. The increase in agriculture during the First Plan period has prepared the ground for a greater emphasis on industrialisation."

The Second Five Year Plan encouraged the basic and heavy industries which were also capital and energy intensive.[40] Political factors like the war with China and Pakistan in 1960s and the Bangladesh war in the early 1970s created the problem of refugees and particularly affected the neighbouring regions of India.

In the period after 1973, the continuity in investment was disturbed by the "state of emergency" declared by the Congress Party and the rapid changes in the party in power.

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[39] Second Five-Year Plan, Government of India, (New Delhi, 1956), p.5.

[40] Accordingly, the Second Plan aimed at (a) a sizable increase in national income so as to raise the level of living in the country; (b) rapid industrialisation with particular emphasis on the development of basic and heavy industries; (c) a large expansion of employment opportunities; (d) reduction of inequalities in income and wealth and a more even distribution of economic power.

Some assets in industry in the 1970s were already 20 or more years old and needed rehabilitation. The low quality of coal affected the plants' performance, creating high demand for investment in maintenance. The "oil crisis" affected the economy more than the power sector since generation from imported oil was low. But the substitution of non-oil for oil power continued due to the oil crisis. Electricity demand (KWH) was growing and much encouragement was given to the rural electrification programmes.

The emphasis on public sector investment in electric power changed the structure of the industry: as can be seen from Table II.6, the public sector share increased from 38% to 95.4% between 1951-1971. The share of the public sector in the total installed capacity increased over the period 1971-86, while the share of the private sector in the total installed capacity decreased till 1982. However after 1982 it increased only marginally. It was in this period that the of captive power plants (i.e. generating capacity owned by the individual consumers either to support their own electricity demand (KWH) or as standby capacity in case of power cuts) emerged due to the increasing unreliability of power supply by the utilities. Also in this period the share of the private sector in total generation was higher than its share in the total installed capacity.

Despite the rapid progress in the post Independence period, electricity was still provided by a large number of small and very old plants. They were operating at a low fuel efficiency and were inadequately interconnected. The growth of generation depends upon the capacity planned and installed in the past. Capacity in the period 1951-1971 increased by 11% per annum but the problems of increasing electricity supplies were great. By contrast, in the period 1971-86, the installed capacity increased at only 8.4% per annum.

Table II.6
Capacity and generation by ownership and their respective share in the total.

Year	Public Sector I.C MW.	Gen. GWH[1].	Private sector I.C MW.	Gen. GWH.	Total I.C MW.	Gen. GWH.
1	2	3	4	5	6	7
1951	698.3	2,457.8	1,131.1	3,400.5	1,835.4	5,858
% Share	38.0	41.9	61.9	58.04		
1954	1,209.5	3,390.0	1,284.4	4,131.8	2,493.9	7,522
% Share	48.5	45.1	51.5	54.93		
1958	2,216.2	7,982.9	1,295.4	5,011.0	3,511.6	12,994
% Share	63.1	61.4	36.8	38.6		
1962	4,305.6	16,070.4	1,474.2	6,294.7	5,779.8	22,365
% Share	74.5	71.8	25.5	28.14		
1966	8,677.6	30,675.9	1,571.5	5,701.7	10,189.1	36,375
% Share	85.1	84.3	14.8	15.7		
1970	13,221.4	49,561.8	1,487.6	6,265.8	14,708.9	55,828
% Share	89.9	88.8	10.1	11.22		
1971	13,768.9	53,990.7	1,485.5	6,934.9	15,254.4	60,926
% Share	90.3	88.6	9.7	11.4		
1974	16,067	63,460	1,289	6,102.0	17,356.0	69,562
% Share	92.6	91.2	7.4	8.77		
1978	25,291.2	95,637.4	1,388.9	6,885.3	26,680.0	102,523
% Share	94.8	93.3	5.2	6.71		
1982	33,959.1	124,377	144.2	7,004.2	35,363.0	131,382
% Share	96.1	94.7	3.9	5.33		
1986	44,603.8	160,347	2,165.2	10,003.1	46,769.0	170,350
% Share	95.4	94.1	4.6	5.88		

1: GWH = Million KWH. Source: Public Electricity Supply: All India Statistics, Ministry of Irrigation and Power, Yearly Publication for the Years 1950-51 to 1986-87.

Plant Mix:

Due to the change in ownership and control after Independence, there was change in the plant mix of the capacity. The share of the hydro-electric plants increased (though at a lower rate than the coal-based plants) until 1963 and then decreased. The share of oil-based plants decreased from 9.1% to 1.5%. In the late 1960s gas based and nuclear plants were introduced. The government successfully discouraged the expensive oil-based plants, but at the same time failed to achieve the cost advantage from the hydro-electric plants due to capital shortages.

The private sector's share of coal-based plant capacity was slowly taken over by the public sector, whereas the private sector's share in the oil-based plants increased till 1965-66 and then decreased. In the case of hydro-electric plants the installed capacity in the private sector increased from 253.44 MW to 277.51 MW during the period 1951-71. Nuclear and gas based plants were in the public sector from the beginning.

As can be seen from Table II.7, the share of hydro-electric capacity continued to decrease after 1971.

Table II.7
Plant Mix; i.e., installed capacity in MW by prime-mover.

Year	Total	Hydro-	Coal	Oil	Gas	Nuclear
1951	1,835	575	1,097.6	162.7	-	-
% Share		31.3	59.8	8.9		
1954	2,494	793	1,491.0	209.6	-	-
% Share		31.8	59.8	8.4		
1958	3,512	1,362	1,879.6	270.2	-	-
% Share		38.8	53.5	7.7		
1962	5,780	2,916	2,536.3	327.2	-	-
% Share		50.5	43.9	5.7		
1966	10,189	4,782	4,941.5	331.7	134.0	-
% Share		46.9	48.5	3.3	1.31	
1970	14,709	6,383	7,508.2	229.5	168	420
% Share		43.4	51.1	1.5	1.14	2.85
1974	17,356	7,279	9,000.0	237.0	200	640
% Share		41.9	51.8	1.4	1.2	3.7
1978	26,680	10,833	14,874.9	164.1	168	640
% Share		40.6	55.7	0.615	0.62	2.39
1982	35,363	13,056	20,712.2	176.2	559.0	860
% Share		36.9	58.6	0.4	1.6	2.43
1986	46,769	15,472	28,808.6	180.3	978.5	1,330.0
% Share		33.1	61.6	0.4	2.1	2.85

Source: Public Electricity Supply; All India Statistics, years 1950-51 to 1986-87.
Note: - represents zero.

The share of oil-based plants also decreased as a direct effect of the disturbance in the balance of payments due to the oil crisis in the early seventies. The supply options have raised certain issues in planning. First, because of their long gestation lags and high capital requirements, hydro-electric options in the past have been overridden by coal plants. However, according to the National Power Plan, hydro-electric power will come back in a big way replacing coal plants. Earlier, as we have seen, the contribution of hydro-electric plants in total electricity generation was much higher. Secondly, there has been a considerable difference of opinion amongst government officials regarding the environmental effects of hydro-electric projects. Thirdly, the pace of hydro-electric power development was affected by inter-state disputes regarding their share in energy generation using the water of the river that passes through more than one state, political interference and technological hang-up on multi-purpose river valley systems. The grid on the regional basis helped in balancing the plant mix at least within each region.

Though at the all-India level, we find a balance between coal-based and hydro-electric plants, this may be due to the aggregation of installed capacity of individual states. The individual state supply systems were not inter-connected, and it is important to observe the optimality of the plant mix at the state level. In planning the expansion of the electricity system, the choice between different plants would be partly determined by the availability of the resources and the capital. In a vast country like India, the states are not all similarly endowed with natural resources. The southern part of India has more water resources whereas the eastern part of India has coal mines. The western part of India is dependent on coal from the east. Thus, we find that southern states like Kerala depend upon hydro-electric plants. This system, in the absence of interconnection, is inadequate when it comes to responding to certain problems, as in the case of a bad monsoon.

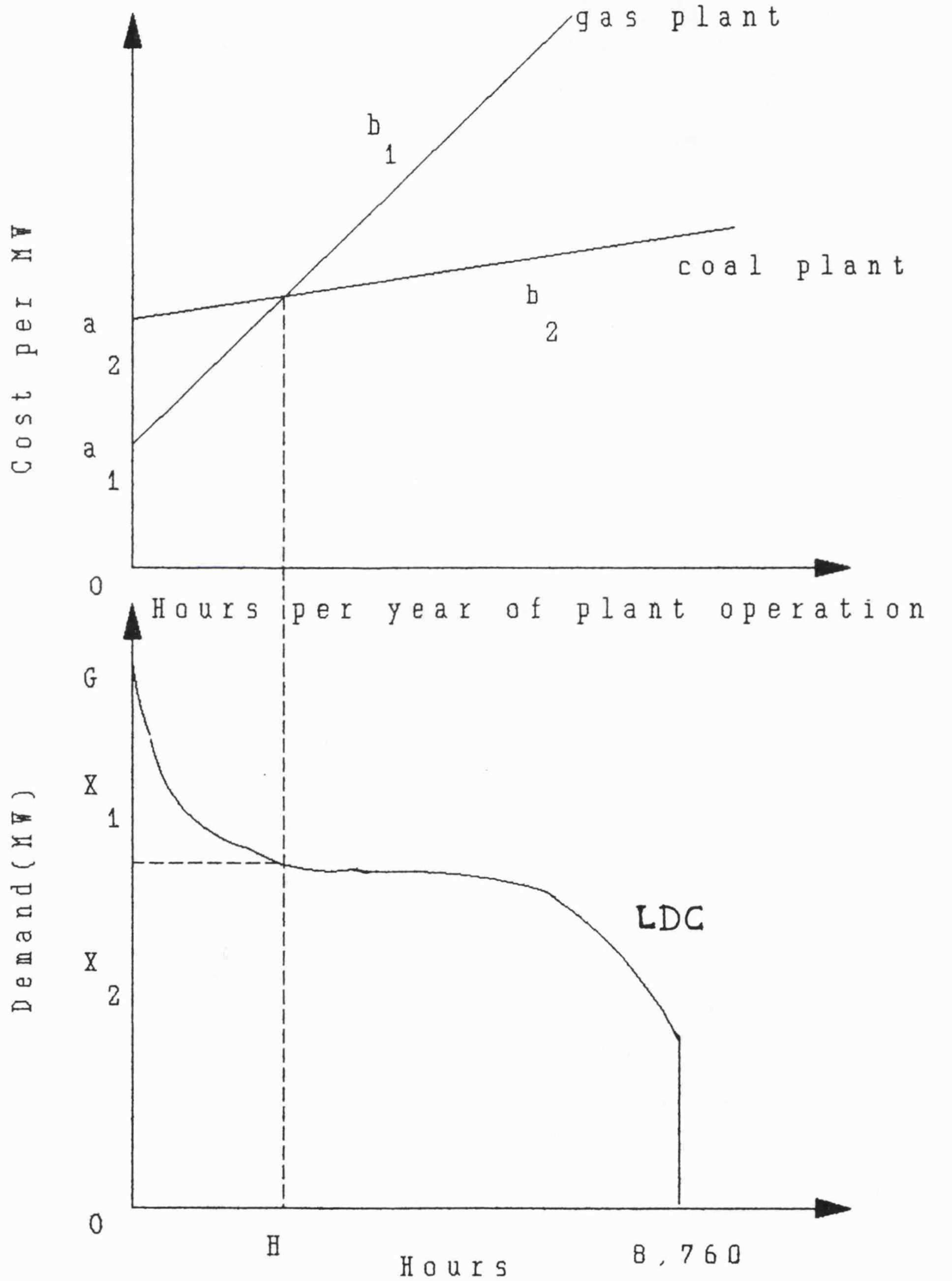
The selection of an appropriate plant mix is best discussed in the context of the annual load duration curve (LDC) for a system. For example, in the LDC shown in Figure II.1, the hourly megawatt demand of the system is plotted against the number of hours of the year during which this level of demand is equalled or exceeded. The peak demand MW occurs only over a short period of time. Since the average level of megawatt demand --that is, the total energy in megawatt-hours or area under the LDC curve divided by 8,760 hours-- is less than the peak demand, the load factor will be less than unity.

For simplicity, only two kinds of generating units are considered: gas turbines and base-load coal plants. The relevant characteristics of both these types of machines are shown by the solid lines in the upper diagram of Figure II.1, which is a linearised graph of the total average cost per megawatt of installed capacity, that is capital cost plus operating cost, plotted as a function of the numbers of hours of operation. Gas turbines have lower capital costs represented by the intercept a_1, which is the investment cost of a megawatt annuitized over the lifetime of the machine. They have higher fuel costs then coal plants, as indicated by the slope b_1 of the operating cost curve.

First, consider the problem of determining the amounts of new gas turbine and coal-based plant capacity that must be built to meet the given load. From the economic point of view, gas turbines are more expensive than base-load units if they are to be used more than H hours a year.

This essentially static picture is only illustrative, because the relevant streams of present discounted investment and the operating costs of the machines would have to be compared over many years.

Figure II.1 Types of generating plants needed to meet the annual load duration curve.



To pursue this further, the lower diagram indicates that it would be economical to serve the bottom X_2 megawatts (the base load) with coal-based plants and the upper X_1 megawatts (the peak load) with gas turbines. A reserve margin may be included if necessary. Thus, planning an expansion of electric system is done in such a manner that gas turbines are to be used only for a short time of the year, whereas the coal-based plants (or any other plants designed to meet the base-load e.g., nuclear) are to be used for a long time of the year.

II.5.1 Intensity of plant use measured by different parameters.

Generally intensity of plant use is measured by average capability, load factor, or plant factor. And we shall discuss to what extent they reveal the technical efficiency of the plant.

Also, the plant factor, load factor and average capability are related to each other and we shall observe the relationship between them.

Average capability.

Average capability is measured in terms of KWH generated per KW of installed capacity. The average capability of private sector plants measured in terms of units generated per unit of installed capacity in the period 1951-71 was generally equal to or higher than the public sector plants irrespective of the prime-mover used. Average capability continued to be higher in the private sector than in the public sector in the period 1971-1986. This could be because the responsibility for dealing with the changes in the power demand, the low agricultural load and the high transmission and distribution losses fell on the public sector and not on the private sector.

As we have discussed in the section on plant mix, there would be some plants like gas turbines that are meant to be used for a short period of time in the year, we would not expect the average capability of gas turbines to be as high as the average capability of coal-based plants. In order to know the utilisation of the plants, we need to compare the actual average capability with planned average capability of the plant. It is quite likely that the hydro-electric plants in one state of India (for example Kerala) have higher capability than the hydro-electric plants in another state (for example Bihar). But this would not mean that the hydro-electric plants in Kerala are more efficient technically than the hydro-electric plants in Bihar. Instead it is quite likely that in Kerala the hydro-electric plants are designed to meet base-load of the system, whereas the hydro-electric plants in Bihar are designed to meet the peak. Thus, without being aware of the planned average capability one can not say much about average capability as a measure of utilisation of plants.

Load Factor.

Unlike the case of gas or water, electricity cannot be stored economically in appreciable quantities. The quantity of electricity demanded determines what is generated at any one time, so the load factor on a power system will generally be the load factor of the demand. The relation between the level of the maximum demand (KW) reached at any one time and the actual sales during a given time period is the load factor of the system: the higher the load factor the shorter the period of idle capacity for the system.

In its simplest form "Load Factor" may be defined as the ratio of average load to maximum load. The value of this ratio may be expressed either as a decimal fraction or as a percentage, and of course, can never exceed 1.0 or 100%. If u represents the number of KWH supplied during a time of t hours, and if M is the maximum demand in KW during the same time then,

$$\text{Load Factor} = L = u/(t * M)$$

The conception of load factor can have various applications. It can be reckoned for a complete supply system, for a composite class of consumers or for an individual; also for a single item of equipment.

Generally, the higher the load factor the better the plants are utilised. Plants can be utilised better only when there is an optimum level of demand (KW) prevailing throughout the 24 hour period of the day. In any system, a very high maximum demand (KW) for a very short time would not lead to better utilisation of plants. As noted earlier, pricing is one of the important instruments to manage demand (KW) in an efficient manner. Efficient pricing policy can avoid a situation of high maximum demand (KW) for a short period in any system and thereby can also improve the load factor of the system.

But is "load factor" a good measure of plant utilisation? As discussed earlier, it is quite obvious that the plant mix is designed in such a manner that some plants have high load factors and some have low load factors. Hence, the comparison between the planned load factors and the load factors experienced can give us some idea about plant utilisation.

Plant Factor.

Plant factor is a measure of the degree of utilisation of a piece of plant or equipment which is,

Plant Factor = (Demand Factor * Load Factor)/100

It can be defined as,

$P = U / (t * C)$

Where,

U = number of KW supplied,

t = time period,

C = capacity of the plant,

(Time period t is taken the same for U and C).

It follows that if the plant is loaded to its full capacity then the capacity of the plant becomes equal to the maximum demand (KW) i.e.C = M, and the load factor and the plant factor become identical.

Sometimes one hears of the plant factors exceeding 100%. This is really due to a confusion of terms relating to plant ratings. A plant may have a continuous maximum ratings and also a short term overload rating. If the value chosen for C in the above formula for the plant factor is taken as the continuous maximum rating then it would not be impossible for plant factors to exceed 100% by drawing on the overload capacity of the plant; but if C is defined as the true maximum output of which the plant is ever capable, then the plant factor would never exceed 100%.

Lower values of plant factor would imply that during at least part of the time, some of the available plant capacity is idle. Hence, from an economic standpoint it is desirable that the plant factor should be as high as possible. Nevertheless, despite the economic value of having very high plant factors there are practical limits to what is desirable. For security of supply, it is essential that an enterprise retain a margin of generating capacity, either as standby, or to cover the needs of plant maintenance and unforeseen breakdown.

Table II.8

Plant load factor by prime-mover; (in percentage).

Year	Coal	Hydro-	Oil	Gas	Nuclear
1951	56.8	89.4	41.38	-	-
1954	55.85	89.64	38.69	-	-
1958	68.15	85.6	35.64	-	-
1962	77.85	87.1	36.71	-	-
1966	81.55	84.84	63.18	-	-
1970	77.68	95.49	51.86	38.75	100.0
1971	79.37	98.53	55.89	44.87	96.6
1974	89.13	93.85	39.46	48.65	83.12
1978	73.78	95.2	45.27	52.67	90.0
1980	79.51	96.22	44.77	72.26	84.88

Source: Calculated from the data available in Public Electricity Supply: All India Statistics, For the years 1950-51 to 1979-80.

Hence plant factors should therefore be as high as possible consistent with the needs for spare capacity. The plant factors by prime-mover in all-India can be observed from the Table II.8. The plant factor for the hydro-electric plants has been the highest of all, except in 1970. Comparing the plant load factor of hydro-electric plants with the plant load factor of coal-based plants, one may gather that the hydro-electric plants are highly utilised. But hydro-electric generation being the cheapest mode of generating electricity, the hydro-electric plants were planned to be utilised the most, subject to water availability. Thus, it is important to compare the planned plant load factors with the observed plant load factors.

Due to the non-availability of the data regarding peak load by prime-mover after 1980, it is not possible to calculate the plant factor and the load factor after 1980.[41] The rise in the peak demand (KW) was much faster than the rise in the electricity demand (KWH) and the supply system failed to increase the capacity to fulfil the fast rising peak demand (KW).

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[41] The annual reports of Central Electricity Authority named Public Electricity Supply: All India Statistics; stopped publishing data on peak load (i.e., maximum demand) after 1980. There could be two possible reasons. The first reason is a technical one. The movement towards the National Grid led to technical difficulty in recording the simultaneous maximum demand for individual plants in different regions. The second, administrative reason is that the peak load in the system was growing much faster after 1973 and it became increasingly difficult for the electric supply system to fulfil the maximum demand. Hence, the electricity authorities considered the peak load of the system as the one that the supply authority could fulfil ignoring the level that actually would have prevailed in the system, if supplies were available. They continued publishing such a "restricted peak load" in some years after 1973 till 1980. But after 1980 the electricity supply authority stopped publishing the peak load.

Utilisation.

After 1955, there was a major shift towards electricity consumption in industries. The investment in creating the installed capacity by the government was growing and in order to utilise the additional capacity, electricity consumption was promoted. The comparative advantage of electricity over other sources of energy encouraged innovation in its uses and the cost advantage of using electricity compared to other fuels further encouraged industrialists to put these ideas into practice.

Overall electricity consumption grew at about 12.24% per annum between the period 1951-71, with the electricity sales to industries increasing by 12.7% per annum and to agriculture at 17.24% per annum. Industries were the major electricity consumer group. The share of industrial consumption of electricity in the total demand (KWH) grew sharply in the 1950s and until 1966 mainly due to three reasons. a) new industries had electricity intensive technology, b) the growth of the existing electricity intensive industries was faster and c) there were many industries switching over to electricity as their source of power. Though its share was small, the agricultural demand (KWH) for electricity was growing at a much faster rate, mainly due to the rural electrification programmes. Thus, in this period agriculture emerged as an important consumer of electricity. The data on electricity consumption by different consumer groups in the period 1951-86 are presented in Table II.9.

From the reports I gathered that the total sales for electricity between the period 1971-1986 increased at 7.2% per annum, electricity sales to industries grew at 5.7% per annum and sales to agriculture at 10.5% per annum. The shares of the domestic and agricultural sectors have been increasing during the period after 1971, while the industrial share was decreasing. According to a study by the Advisory Board on Energy in 1985, drastic changes are anticipated by the year 2004-05, putting industrial demand (KWH) back to more than 60% and reducing agriculture's share to less than 10%. These shifts are to be evaluated against the possibilities of inter-fuel substitutions in these sectors.

Table II.9
Pattern of utilisation.
[Energy consumption by category of the consumers measured in terms of GWH (i.e. Million KWH)].

Year	Dom-	Comm-	Traction	Agri.	Indus.	Others	Total
1951	595.0	331.5	329.6	203.0	3,054.7	279.5	4,793.3
%	12.4	6.9	6.9	4.3	63.7	5.8	
1954	759.2	446.1	378.4	231.4	4,075.9	361.4	6,252.5
%	12.1	7.1	6.1	3.7	65.2	5.8	
1958	1,093.6	609.8	423.3	544.6	6,166.8	507.0	9,345.2
%	11.7	6.5	4.5	6.0	66.0	5.4	
1962	1,698.1	934.1	584.8	911.1	11,545.6	695.2	16,448.3
%	10.3	5.7	3.6	6.0	70.2	4.2	
1966	2,355.1	1,650.1	1,057.3	1,891.8	18,875.9	904.7	26,734.9
%	8.8	6.2	4.0	7.1	70.6	3.3	
1970	3,491.0	2,333.3	1,448.1	3,774.1	23,878.7	1,636.3	50,246.4
%	8.6	5.7	3.5	9.2	69.1	3.9	
1974	4,644.6	2,987.5	1,530.7	6,310.2	32,481.4	2,292.0	69,255.0
%	9.2	6.0	3.0	12.6	64.6	4.6	
1978	6,821.3	4,427.6	2,296.8	10,107.4	42,635.2	2,966.8	90,245.3
%	9.8	6.4	3.3	14.6	61.6	4.3	
1982	11,439.2	5,194.4	2,504.7	15,201.2	53,063.8	3,841.6	122,999.3
%	11.6	5.7	2.8	16.8	58.8	4.3	
1986	17,257.8	7,290.1	3,182.1	23,421.9	66,980.0	4,967.2	123,098.3
%	14.0	5.9	2.5	19.0	54.5	4.0	

Source: Public Electricity Supply: All India Statistics, Central Electricity Authority, Ministry of Irrigation and Power, (Power wing), Government of India, New Delhi, Years: 1950-51 to 1985-86.

Since the commercial fuels can not be substituted in the industrial sector, their share in the total electricity consumption may not decrease after a certain level. But if the renewable energy sources (e.g. tidal, solar, wind, geothermal energy, energy from biogas) become economically viable, they can substitute for the electricity consumption by the agricultural consumers.[42] Thus, even if the percentage share of electricity consumption by the agricultural sector were to decrease over a period of time (i.e, electricity intensity in agriculture sector), it is not necessary that the energy intensity would also decrease.

The growth-rates of the total and sectoral consumption of electricity were less in the period after 1971. The sales (on the basis of which the above mentioned growth-rates were calculated) were less than demand (KWH) but we do not know the level of the unrestricted demand (KWH). There have been restrictions of three kinds: firstly, restrictions by the cutting-off of supplies during periods of excess demand (KW); secondly, restrictions in the form of limitations on the amount of electricity that might be taken by a connected customer; thirdly, restrictions in the form of refusals of applications for connection. It is very clear that in recent years the limitations of electricity supply have not only caused interruptions from time to time to industrial production but also have involved refusals of electricity supply which, if available, would have made possible a greater increase in industrial production.

It is not easy to measure the extent of the present shortfall of electricity supply, but that it existed over this recent period, there can be no question. The shortage of power can be observed from the reports published by the Ministry of Irrigation and Power. These annual surveys

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[42] For example in State of Gujarat there are villages like Mandvi, which is "adopted" by an industry and investments have been made in that village by the parent industry to experiment on solar, wind and gobar gas plants to "electrify" the village. Thus, though Mandvi is not connected by Gujarat Electricity Board, the activities like cooking, and irrigation using a pumpset have become energy intensive. Also, the energy generated using the renewable sources like the wind and solar, is used for domestic and street lighting purpose.

report the installed capacity, peak load, capability, energy availability and energy requirement for each region and the state. Footnotes in the table reveal that particularly after 1972, the data on peak load reflects the restricted peak load. Also the data regarding the energy requirement are restricted and were the same as energy availability.

Thus one of the main features of electricity industry in India was power cuts particularly after 1972-73. Though the organisation of the industry became more structured after Independence, the power shortages became a pre-dominant feature. Hence, the available data on electricity demand (KWH) or energy requirement do not reflect the 'demand' in economic sense. Neither it reflect electricity consumption since electricity consumption in true sense includes stolen electricity as well. Therefore I would prefer to call the available data on electricity demand (KWH) 'electricity sales'.

SECTION II: ELECTRICITY DEMAND ANALYSIS.

Introduction

Section II reviews the literature on demand analysis and analyses the electricity demand at the All-India level for the period 1947-86. The disparity in most of the variables affecting electricity demand over different regions in India emphasised the need to study electricity demand at the disaggregate level. Hence, electricity demand is analysed at the state-level for the period 1961-86. An attempt is made in this section to apply economic theory and econometric principles to historical data.

CHAPTER III
ELECTRICITY DEMAND ANALYSIS: THE LITERATURE.

III.1 Explanatory models for electricity demand.

Electricity does not yield utility in itself, but rather is desired as an input into other processes that do yield utility. (These processes could be productive or service, for example industrial and domestic consumption of electricity). These processes utilise a capital stock of some durability and electricity provides the energy input. The demand for electricity is thus a derived demand. The demand for electricity may therefore be thought of as the derived result of a three stage process: 1) the decision to purchase energy-using equipment; 2) the related choice (where one exists) between electrically powered or otherwise- operated equipment; and 3) the decision as to how intensively equipment is used.

III.1.1 Measuring the price of electricity.

The typical electricity price schedule could be a declining block tariff which implies a declining marginal price as the quantity of electric power consumed increases. Or it could be an increasing block tariff which implies increasing marginal price as the quantity of electric power consumed increases. Because monthly electric power consumption varies due to a variety of factors -- including climate changes, alterations in the intensity of equipment usage, and changes in equipment stock -- any individual consumer may pay two or more different marginal prices for electric power during the course of a given year. In practice, most electricity demand studies have measured the price of electricity by either of two common methods: (1) average revenue calculated by taking the ratio of total revenues to total sales; or (2) Typical electricity bills incurred by the consumer. Both of these methods reflect the electricity price per unit to a consumer. They both include certain taxes collected by utilities. But the first one may exclude the taxes levied by the Government and to that extent it understates the marginal price to the consumer. In a time-series analysis, this may not substantially affect the results since tax rates (over and above the tax by the electric utility) tend to remain stable over time. However, in a cross-section analysis, this could cause significant bias to the extent that such taxes vary regionally. In addition, each of the two measures contain other biases.

As we shall see later, average revenue has been the most frequently used electricity price measure because of its simplicity and ease of calculation. The typical electricity bill price measure is an average price for a specified level of electricity usage -- not a marginal price.

Economic research on electricity demand analysis so far clearly indicates that electricity demand contains a number of factors that have proved singularly difficult to model. The main problem lies in the fact that the consumer of electricity does not face a single price, but rather a price schedule, from which electricity is purchased in blocks at a decreasing/increasing marginal price. It has been well known since the paper of Houthakker[43] that the presence of a price schedule has important econometric implications, but the literature has focused on the question of the type of price -marginal or average- that should be included in the demand function. That the price schedule has implications for the equilibrium of the consumer and therefore for the demand function itself - has

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[43] H.S. Houthakker, "Some Calculations of electricity consumption in Great Britain", <u>Journal of the Royal Statistical Society</u> (A), Vol.114, Part.III, (1951), pp.351-371.

not been systematically investigated.

The conventional view, since Houthakker's earlier work, is that a marginal price, not an average price, should be used in the demand function; the reason being that the consumer in achieving equilibrium equates benefits with cost at the margin. Also, there is the problem that when average price is defined ex-post as the total expenditure divided by quantity consumed, a negative dependence between quantity and price is established. Though the use of a marginal price for "the" price variable has some appeal, it only conveys part of the information required, for a single marginal price is relevant to the consumer's decision only when he is consuming in the block to which it attaches. It governs behaviour while the consumer is in that block, but it does not, in and of itself, determine why he consumes in that block.

In view of the foregoing, a simple procedure is to include both a marginal and average price as predictors in the demand function. However, both of these should be taken from the actual tariff schedule and not calculated ex-post. The marginal price should refer to the last block consumed while the average price should refer to the electricity consumed up to, but not including the final block. Alternatively, the total expenditure on electricity up to the final block can be used in place of the average price. In either case, the variable will measure the income effect arising from intra-marginal price changes, thus leaving the price effect to be measured by the marginal price. This method will cause bias in the estimate of price elasticity if average and marginal price are positively correlated which is likely to be the case.

Broadly classified, studies of the demand for electricity can be divided into those that analyse the consumers' equipment choice, and those which directly examine the consumers' consumption of electric power. The methodologies applied in these studies are of two types: cross-section analysis of one or several periods of time, and time-series models, many of which are autoregressive, incorporating lagged or previous values of consumption. The cross-section studies may help to estimate long-run effects if consumers have completely adjusted to the different local conditions with which they are faced and if the world is stable in the long-run. The autoregressive models have the advantage of separately estimating short-run or immediate demand responses as well as long-run or ultimate responses to changes in price or other independent variables. Since a time series of observations is required for the development of an autoregressive model, data limitation often dictate that the specification of the explanatory factors cannot be as extensive as in a cross-section study. This in turn, leads to an increase in the possibility of biased estimates.

Using Fisher and Kaysen's model,[44] L.D.Taylor[45] suggested the distinction between a short-run demand for electricity and long-run demand for electricity. The short-run is defined by the condition that the electricity consuming capital stock is fixed, while the long run takes capital stock as variable. In essence therefore, the short-run demand for electricity can be seen as arising from the choice of short-run utilisation rate of existing capital stock; while the long-run demand is tantamount to the demand for the capital stock itself.

Following Fisher and Kaysen;[46] Taylor assumed that the

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[44] F.M. Fisher and C. Kaysen, A Study in Econometrics: The demand for electricity in U.S., Amsterdam, North Holland Publishing Co., (Amsterdam, 1962).

[45] L.D. Taylor, Demand for Electricity:A Survey, Study by the Electric Power Research Institute, Palo Alto, (California, 1968).

[46] F.M. Fisher and C. Kaysen, op.cit.

stock of electricity consuming capital goods could be measured in terms of the number of watts of electricity that the stock could potentially draw - he denoted this by s. If the amount of electricity consumed in the short run was measured in KWH, and if we denote the electricity demand in the short run by q and measured in kwh's, then:

$$q = u(x,\pi,z)s. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.1)$$

where u(.) is the utilisation rate of s and is assumed to depend upon the level of income (x) the "price" of electricity (π) and any other factors (economic, social or demographic) that might be relevant, denoted by (z).[47]

In their framework, specifying the short-run demand function for electricity was thus specifying the form of the function u,

He assumed u to be given by,

$$u = \alpha_0 + \alpha_1 x + \alpha_2 \pi + \alpha_3 z \quad \ldots\ldots\ldots\ldots\ldots\ldots(3.2)$$

u could also be specified as,

$$u = \alpha_0 + \alpha_1 \ln x + \alpha_2 \ln \pi + \alpha_3 \ln z \quad \ldots\ldots\ldots\ldots(3.3)$$

The short run demand function for electricity therefore became,

$$q = (\alpha_0 + \alpha_1 x + \alpha_2 \pi + n_3 z)s \quad \ldots\ldots\ldots\ldots(3.4)$$

or,

$$q = (\alpha_0 + \alpha_1 \ln x + \alpha_2 \ln \pi + \alpha_3 \ln z)s \quad \ldots\ldots\ldots(3.5)$$

In the long run, it is assumed that assuming that the desired stock of electricity consuming capital goods ($\hat{S}$) is

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[47] Among others things, z should include the price of natural gas.

given by,

$$\hat{S} = \beta_0 + \beta_1 x + \beta_2 \pi + \beta_3 (r+\delta)p + \beta_4 z \quad \text{.........(3.6)}$$

(r) and (δ) denote the market rate of interest and the rate of depreciation of the capital stock, respectively and (p) denotes the price per watt of additions to the capital stock, (z) was a vector of other relevant predictors.

The model thus stated that the desired stock of electricity consuming capital goods was a function of the level of income, the price of electricity, the user cost of the capital stock as represented by the term $(r+\delta)p$ and any other factor that might be thought to be important. Certainly, the prices of energy substitutes and user costs of their associated capital stocks are important enough to be included.

Thus, the distinction between short-run and long-run demand for electricity was made clear.

III.1.2 Aggregation Problems.

The consumption data that are typically collected by electric utilities deviate from optimal demand measurements because they are generally aggregated over broad (e.g. monthly or annual) time periods. First, the aggregation of consumption over time suppresses valuable information. Most electricity demand studies have been concerned with determining the directions and magnitudes of the effects of the price of electricity, the price of the substitute fuels, and income on the annual level of consumption, rather than on the rate of consumption at a moment in time. Secondly, aggregation conceals the full extent of factor variation in that average values vary less than their individual components. To the extent that aggregation restricts the range of the underlying variable demand determinants, the reliability of projections derived from such data is reduced. The third problem stemming from excessive data aggregation is that the estimated elasticities will be misleading if individual consumer groups behave differently as demand factors change.

III.1.3 Model or functional form.

The choice of the form of the model with which to estimate demand may also cover up underlying differences in elasticities, which may be vital to an understanding of the full range of demand responses to rate structure design. With one exception, all of the studies reviewed in this Chapter have chosen a functional form of the estimating equation which imposes an important restriction on the nature of the demand on electric power. Specifically, this functional form assumes that the response of consumption to a change in one of the causal variables is the same over all ranges of value of the variable in question; this is referred to as the assumption of constant elasticities of demand. In the case of demand for electric power, the assumption implies that the percentage demand response to a ten percent increase in the price of electricity will be the same at a beginning price of ten paise per KWH as it would be at a beginning price of one paise per KWH. The assumption of constant elasticities may not be valid for many of the variables which affect the demand for electric power; this may be especially true for the price of electricity. Price elasticity is likely to be relatively high at low price levels and relatively low at high price levels. Similar variations may also characterise changes in the price elasticities of demand for electricity to operate other appliances and equipment that can be fuelled by alternative energy sources. Unless the variations (jumps in values) of the elasticities with respect to these several component uses just balance each other out (which is highly doubtful), then even aggregate studies of demand (e.g., on a statewide basis) may produce misleading estimates of the (aggregate) price responsiveness of demand.

III.1.4 Exclusion of Important Causal Variables.

To derive accurately the relationship between consumption and the price of electricity, other significant factors that cause demand for electric power to vary must be accounted for. Those factors which affect the non-residential demand include: (1) the price and availability of alternative fuels; (2) the prices of the inputs into the production process; (3) the type of industrial and commercial activity; (4) the level of output; and (5) other regional factors such as climate variables. Omission of an important causal variable will bias the estimate of price elasticity of demand if that variable is highly correlated with the price of electricity. This problem is often present in time-series analysis. For example, if one has to analyse the demand for electricity in United States, and if the effects of climate and income (or output) are ignored then the estimate of demand elasticity will probably be too high. In addition the estimated elasticity may also include some reduced consumption which was due to some unusually mild weather or the recession which followed in the wake of the Arab oil embargo. If, over a cross section of utility service areas, the price of electricity is positively correlated with income and industrial output levels, estimates of the price elasticity of demand, based on this cross-sectional data, would be biased downward. Reduced consumption of electric power in high price service areas would be partially offset by the higher income and output levels in those areas, thus camouflaging the true (and higher) demand response to changes in the price of electricity in all areas. Similarly if one has to analyse the electricity demand in India ignoring factors like the policy on rural electrification programmes and ~~the~~

rainfall, it is likely that the agricultural demand for electricity may appear income inelastic i.e. there will be a downward bias in the income coefficient.

In short, elasticity is a measurement of the partial response of consumption to a change in one variable (e.g., price) when the values of all other variables are held constant. If other significant variables are not accounted for and are positively or inversely correlated with the variable in question, then that partial elasticity estimate will be biased either upward or downward. When this happens, elasticity estimates no longer indicate the effect of rate changes given probable values of the other causal factors.

A good demand study should capture several different causal factors of systemwide KWH demand as well as the interactive effect of some of these factors on total demand. Further, the response to electricity price changes may come through changes in the rate of utilisation of electricity-using machinery and appliances, and in part may occur through the process of appliance and machinery stock adjustments to permit fuel substitution; these responses (or elasticities) also need to be measured. Finally (though this hardly exhausts the list of possible factors), the model should identify any time variation in these responses which the data permit.

III.2 Literature Review.

III.2.1 Studies prior to 1972.

In any electricity supply system electricity is demanded by different consumers, either for lighting in the house, or for lighting and air conditioning the office, or it can be used as a fuel in the production process. Thus the demand for electricity can be categorised on the basis of its uses: for example, domestic/residential demand, commercial demand, industrial demand, agricultural demand and so on. In the literature we find different studies focusing on the issues of individual categories.

Taken as a whole the existing body of studies deals with each of these dimensions of electric power demand, though with considerably different degrees of frequency, completeness and success. In this section an attempt is made to synthesise the findings with respect to each of these important dimensions.

Fisher and Kaysen's monograph[48] is a standard reference on the demand for electric power in the United States. They analysed industrial demand as well as residential demand and were the first to distinguish explicitly, for residential demand, between the short run and the long run. They were also first to utilise the extensive data on electricity consumption that were regularly collected by the Federal Power Commission and published by the Edison Electric Institute. According to them, electricity played a double role as an input in the production of almost every good. They thought that, with a given size of industrial plant, electricity input had a fixed and a variable component. The intensity of electricity used for lighting of the plant, sometimes for heating and for other minor uses did not vary with the size of the plant's output, though this was just an approximation since overtime work and extra shifts required more electricity when the plants' output became unusually large; and at zero output the lights were turned off. Nevertheless, for normal operations the intensity of use of electricity for such purpose was considered relatively constant. But electricity required by industries to use various machines, and in some industries for electro-chemical processes, varied with output.

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[48] F.M. Fisher and C. Kaysen, op.cit.

With this background they tried to model electricity demand for industrial use, by fitting functions of the form,

$$D_{it} = A_i + B_i X_{it} + U_{it} \quad \ldots\ldots\ldots\ldots\ldots\ldots(3.7)$$

where,
D_{it} = total electricity used by the i^{th} industrial establishment,
X_{it} = the total output of that plant,
A_i and B_i are constant parameters and U_{it} is a random disturbance with the usual properties.

They found this analysis to be incomplete since it ignored the effect of the electricity price on output size and on the composition of output among various products. They tried to overcome the problem of aggregation over products of multi-product firms and felt the need to look at fairly broadly defined commodity groups. They also considered the problem of valuation arising from the industrial establishment having its own generating equipment: which was the result of a rise in the price of public electricity supply. After considering these issues, they tried to study the electricity demand for a single establishment using the following model:

$$D_{it} = A_i + B_i (X_{it}\ P_{it})^{\pi i} + U_{it} \quad \ldots\ldots\ldots\ldots\ldots(3.8)$$

where,
D_{it} is understood to mean all electricity used by the i^{th} establishment (i.e., self generated and the public supply),
P_{it} = the real price of electricity to the establishment,
X_{it} = output index,
π_i is a parameter.

They extended the above model to a set of establishments, I. They considered the minimum size of plant -minimum Ai- in all the data on plants with the same technology and products. They thought of I as consisting of many plants of this size; that number at time t denoted as N_{It} and taking minimum Ai = A; for all establishments in I, they derived,

$$D_{It} = N_{It}A + BX_{It}P_{It}^{\pi} + U_{It} \qquad \ldots\ldots\ldots\ldots(3.9)$$

where, (all summations being over all i in I),

$D_{It} = \Sigma D_{it}$; $\qquad B = B_i$,

$X_{It} = \Sigma X_{it}$; $\qquad \pi = \pi_i$,

$U_{It} = \Sigma U_{it}$; $\qquad P_{It} = P_{it}$ for all i in I.

Allowing the capacity output of the minimum size plant be x and the capacity output of I at time t be X_{It} then,

$$N_{It} = \overline{X}_{It} / \overline{x},$$

With fixed technology (i.e., fixed B and fixed Ai for given plant size); the long-run demand function for electricity from I would be:

$$D_{It} = (A/\overline{x} + BP_{It}^{\pi})\, X_{It} + U_{It} \qquad \ldots\ldots\ldots\ldots(3.10)$$

as capacity could be adjusted to output in long run (so that $X_{It} = \overline{X}_{It}$).

But changes in technology were far more important in determining long-run electricity input requirements, they considered this problem extensively and thought that a non-linear model was the best suited,

$$D_{It} = KX^{\beta}_{It}\, P^{\alpha}_{It} + V_{It} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(3.11)$$

where,

K = constant,

X_{It} = index of output,

α and β are parameters.

Price was taken as average cost per kilowatt hour of purchased electricity. The analysis was performed for two digit industries over the states for the year 1956.

There was a significant negative price effect in six out of ten industries, and a non-significantly negative effect in two more. Values of β were all positive and were significant in all but two industries. They found α to be non-significantly different from unity in seven industries and significantly different in the remaining three. They observed an elastic price effect in six industries.

A study by Baxter and Rees[49] focused on the industrial demand for electric power. The authors explicitly rejected the aggregate energy approach. This involved a two-stage procedure in which output was first related via a conventional production function to capital, labour and "energy" as inputs. Once the total input of energy was determined, this total was then allocated among the various fuels according to their relative prices. This approach of Baxter and Rees was to include the several fuels individually along with capital and labour as arguments in the production function.

In particular, Baxter and Rees considered alternative models, the first of which related output to capital, labour, oil, gas, coal and electricity. A Cobb-Douglas production function was assumed with no restrictions on the parameters. The desired demand function for electric power than took the form,

$$X_6 = \beta_0 P_1^{\beta 1} P_2^{\beta 2} \ldots\ldots P_6^{\beta 6} Q^{\beta 6+1} \quad \ldots\ldots(3.12)$$

where,

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[49] R.E. Baxter and R. Rees, "Analysis of the Industrial demand for Electricity", Economic Journal, vol.78, (June 1968), pp.277-298.

X = electricity,
$P_0 \ldots P_6$ = parametric prices,
Q denotes output.

The second model considered by Baxter and Rees laid emphasis on the effects of changes in fuel technology. In this model, electric power consumption was related to output and a surrogate for technology in place of input prices. Since during the period studied, most of the substitution in energy had been against coal, coal consumption was employed as the surrogate.

Finally, their third model was designed to test the hypothesis that there was a proportional relationship between changes in total output and in electricity consumption and that deviations from this relationship were explained by changes in relative prices and changes in labour and capital intensity. Thus, in this model it was assumed that,

$$D_t = \tau(y)Q_t \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.13)$$

where,
D_t = measures electricity demand,
Q_t = denotes output and
y = vector representing relative prices and labour and capital intensities.

Baxter and Rees fitted their models to 16 industry groups (most of them in manufacturing) for the United Kingdom; using 44 quarterly observations over the period 1954 to 1964. Seasonal effects were allowed for through the use of dummy variables. The authors concluded that relative price changes were not unambiguously an important determinant of growth in industrial electricity consumption. The chief determinants were growth in output and changes in technology. Taken at face value, the results for the relative price variables suggested that in at least

9 out of the 16 industry groups, price elasticity of demand was zero; in a further two it was relatively inelastic; and only in five, did there appear to be a marked responsiveness of demand to relative price changes. They avoided many of the aggregation problems that could occur if the variation in electric power use among different industry types was not accounted for. However, the authors themselves were careful to qualify their results, noting that poor data quality and statistical problems required that their estimated elasticities be considered as a first approximation only.

Mount, Chapman and Tyrrell[50] (MCT) analysed both the short-run and long-run demand for electricity for three classes of consumers: residential, commercial and industrial. Their procedure was to estimate a model, using a pooled cross-section and time-series data set consisting of annual observations on 47 contiguous states of U.S.A. from 1947 to 1970. This method allowed elasticities to vary both geographically (i.e. state to state; or region to region) and over time. They used an autoregressive model. The study was noteworthy primarily because it was the only one to use a functional form that allows for non-constant elasticities. The dependent variable, total quantity consumed, was explained by the average price of electricity, income, the lagged average price of gas, population, lagged price of appliances or machinery and nine regional dummy variables.

A major deficiency in MCT's study of residential demand for electricity was their use of average revenue as a measure of the price of electricity, without correcting for the simultaneity problem. Further bias was introduced

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[50] T.D. Mount, L.D. Chapman and T.J. Tyrrell, <u>Electricity demand in the United States: An Econometric Analysis</u>, Oak Ridge National Laboratory (ORNL-NSF-49), Oak Ridge, (Tenn, June 1973).

by their failure to include demographic and geographic variables as causal factors. Their commercial and industrial estimates should be considered as a rough approximation of the true elasticity values. In addition to the average revenue bias in the model, there were several other sources of error that hinder the interpretation of the derived results. First, the "commercial" and "industrial" classifications used by utilities were based on voltage and volume levels -- not on consumers' actual characteristics. Thus, a master-meter apartment building or an office building may be classified as an "industrial" customer and small manufacturing firms may pay "commercial" rates. Further, MCT's model was clearly mis-specified. Income, which was used as a proxy for output, could not adequately capture the influence of output changes on electric power consumption, especially in the industrial sector. Furthermore, the price of gas was the only alternative fuel price included, and that was found not to be significant. Finally, because different industries had different power needs and because industry mix varies from state to state, there are severe aggregation and simultaneity biases in studies such as this, which aggregate across all industry types. For example, since power-intensive industries concentrate in regions where rates were low, average price elasticity from a cross section of all states would not be descriptive of actual conditions in any given state.

Anderson[51] analysed the producers' demand for energy by the U.S. primary metals industry. Anderson's analysis was based on the methodology of Fisher and Kaysen with some extensions. First, the study focused on the total producers' demand for energy, not just the demand for

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[51] K.P. Anderson, Residential Energy Use: An Econometric Analysis, The Rand Corporation, (R-1297-NSF), (October 1973).

electric power. Second, allowance was made for quantity discounts in the purchase of energy inputs. Third, allowance was made for the effects of the supply equation on the demand equation. In addition to the direct effect on demand of the price of the input itself, allowance was made for the effects of competing or related input prices. The following demand function was used.

$$\ln E = \alpha_0 + \alpha_1 \ln Pc + \alpha_2 \ln Pk + \alpha_3 \ln Po + \alpha_4 \ln Pe + \alpha_5 \ln W \quad \ldots.(3.14)$$

where,
E = (KWHs electricity purchased)/(value added),
Pc = price of coal,
Pk = price of electricity,
Po = price of heating oil,
Pe = price of gas,
W = average wage-rate of production workers in primary metals.

Using cross-section data from 1958 and 1963, the result showed a substantial and highly significant negative price elasticity of demand.

Lyman's[52] study based on his doctoral dissertation in 1973, analysed the demand for the three major consumer classes: residential, commercial and industrial. He used firm (as opposed to national) data and non-linear demand functions of the type considered by Box and Cox.[53] Still another innovation was the inclusion of an income variable describing the income distribution, which allowed for income and price elasticities to vary with the level of

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[52] R.A. Layman, Price elasticities in the electric power Industry, Department of Economics, University of Arizona, (Arizona, October, 1973).

[53] G.E.P. Box and D.R. Cox, "An Analysis of Transformations", Journal of the Royal Asiatic Society, Series B, Vol.26, No.2, (1964), pp.211-243.

income.

Lyman assumed that demand was related to a list of predictor variables as follows,

$$q = H(PE,PG,PI,M,Z,u) \quad \ldots\ldots\ldots\ldots\ldots\ldots(3.15)$$

where,

q = purchase of electricity per consumer,

PE = price of electricity,

PG = price of gas,

PI = index of other prices,

M = vector of economic and demographic variables,

Z = vector of climatic variables,

u = random error term.

Lyman suggested a linear semi-logarithmic function for residential demand and a linear double-logarithmic function for commercial and industrial demand. He found that demand was typically price elastic for each of the consumer classes and for residential demand. He also found the income elasticity of residential demand weak in general and zero or negative in the southern regions. However, for most regions considered, the size of the income elasticity varied inversely with the level of income.

III.2.2 Studies after 1973.

After 1973, in the literature of energy economics, the emphasis moved from electricity demand studies to that of the possibility of fuel substitution for different groups of consumers. The residential consumer group continued to be the most interesting one for the researchers and a long list of studies on residential demand for electricity can be listed. But studies for the aggregate demand for electricity, industrial demand for electricity and agricultural demand for electricity were very few.

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McFadden et al.[54] parameterised a model in which three price measures were assumed to summarise the rate schedule faced by each household: (i) marginal price at an intermediate consumption level; (ii) rate of decline of marginal price; (iii) average price. The model was fitted to monthly data on individual households using a stratified random sample of a survey of 3,249 households. The prices were determined from typical electric bill rates. Typical bill rates for 1975 at consumption levels of 100, 250, 750 and 1,000 KWH per month were collected for each city occurring in the sample. The marginal price was defined to equal marginal price between typical electric bills at 500 and 750 KWH per month. The rate of decline of marginal price was defined to equal marginal price between typical electric bills at 750 and 1,000 KWH per month, divided by marginal price between 500 and 750 KWH per month. The average price was defined as the measured average monthly consumption of the household, with cost obtained by linear interpolation between adjacent typical electric bills. Using about 1,600 cross-sectional units, a reasonable explanation of the demand for electricity was obtained ($R^2 = 0.559$). The price parameters possessed the correct, negative sign, though the parameter on average price was not statistically significant.

The paper by Michael Murray, Robert Spann, Lawrence Pulley and Edward Beauvais[55] presented a demand study of the Virginia Electric Power Company (VEPCO). Residential, commercial and industrial demands were analysed using

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[54] D. McFadden, C. Puig and D. Krishner, "Determinants of the long-run demand for electricity", Proceedings of the Business and Economic Statistics Section, Part 2, American Economic Association, (1977), pp.109-117.

[55] P. Michael, Murray, Robert Spann, Lawrence Pulley and Edward Beauvais, "The demand for Electricity in Virginia", Review of Economics and Statistics, (November 1978), pp.585-600.

monthly data from each of VEPCO's nine Virginia billing districts over the period 1958-1973. Seasonal variations in the kilowatt hour demand coefficients were permitted and the structure of VEPCO's monthly kilowatt peak demand was estimated to allow some conclusions to be drawn about VEPCO's peak load problems. The study gave more careful attention to the two-part tariff nature of commercial and industrial electricity price schedules. They tried to account for seasonal variation in demand coefficients, and for the dynamics of consumer demand. They integrated the analysis of kilowatt hour demand (KWH) with the analysis of the system wide kilowatt (KW) peak demand. Major conclusions were: both growth in income and growth in real price of electricity tend to induce load factor deterioration because the long run KWH demand income elasticity (about (0.8)) and marginal price elasticities for both energy and demand charges (between -0.9 and -0.5 and between -0.64 and -0.14 respectively) were less than the corresponding KW peak demand elasticities (about 1.27 for income, -0.44 for energy charges and -0.08 for demand (KW) charges). This finding suggested that, in periods of rising real incomes and rising real electricity prices, electric utilities would increasingly feel the need for means, such as time of day pricing, to alleviate peak load problems. They also concluded that the prices of alternative fuels should be considered in forecasting electricity demand, since industrial customers seem responsive to these prices.

According to Studness[56] both energy consumption and electricity demand in U.S. had been growing faster than real gross national product before 1973, but energy consumption had grown more slowly than real GNP since then,

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[56] Charles M. Studness, "Electric demand and aggregate U.S. energy consumption", Public Utilities Fortnightly, July 31, (U.S., 1980), pp.38-39.

while electricity demand continued to grow more rapidly than real GNP. The continuing rise of electric generation's share of energy consumption stems from the structure of energy prices encouraging a shift to electricity usage, as electric rates had increased less since 1973 than the prices of other forms of energy.

L.D Taylor,[57] noted a major shortcoming in the econometric literature dealing with the residential demand for electricity, namely the failure to deal adequately with decreasing block pricing. Motivated by this comment, Timothy Roth[58] made an attempt to estimate the residential demand function employing both average and marginal price. He found that the coefficient on marginal price was "right" and significant, that is he found the expected inverse relationship between the quantity of electricity demanded and the marginal price it obtains. On the other hand, the positive sign on average price was counter-intuitive. Because average price in that case was exactly the same concept as the intra-marginal payment, a change in average price is exactly same as a change in real income. The positive sign on average price according to him implies that a reduction in real income (equivalent to an increase in average price) causes an increase in electricity demand; that is electricity is an inferior good. This result was anomalous because it contradicted most existing empirical studies of electricity demand, i.e., studies which show positive income elasticities.

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[57] L.D. Taylor, "The demand for Electricity: A Survey", Bell Journal of Economics, 6, (1975), pp.74-110.

[58] T.P. Roth, "Average and Marginal Price changes and the demand for Electricity: An Econometric Study", Applied Economics, V.3, (September 1981), pp.377-388.

Christopher Garbacz[59] criticised Roth's model. The model relied on strong assumptions i.e., "white goods" are fixed, the level of aggregation is appropriate and supply is given.

A study by Maddigan et al[60] employed econometric modelling to estimate price elasticities and the pattern of inter-fuel substitution for the irrigation use of electricity. They used pooled U.S. state-level data for the period 1969-79. They assumed a log-linear form and the average-usage equation was specified as,

$$\ln(E/N)_{jt} = \alpha_0 + \alpha_1 \ln(PE/I)_{jt} + \alpha_2 \ln PK_{jt} + \alpha_3 \ln(PL/I)_{jt} + \alpha_4 \ln ARID_{jt} + \alpha_5 \ln IPI_{jt} + \alpha_6 D_{jt} + e_{jt} \ldots\ldots (3.16)$$

where,

j is state and t is year; t= 1969,...1979,

E = quantity of irrigation electricity sales (MKWH),

N = number of irrigation customers,

PE/I = average price of electricity in the irrigation sector deflated by the cost of living index I($/MKWH),

PK = interest rate on farm real estate debt (%),

PL/I = hourly wage rate of field workers PL, deflated by the cost of living index I($),

ARID = aridity index,

IPI = irrigation production index,

D = regional set of state dummy variables,

e = disturbance term, and

α_0, to α_6 are the parameters to be estimated.

The inclusion of the interest rate and the wage rate

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[59] C. Garbacz, "Electricity demand and the Elasticity of Intra-marginal Price", Applied Economics, V.15, n.5, (October 1983), pp.699-701.

[60] Ruth J. Maddigan, W.S. Chern and C.G. Rizy, "The irrigation demand for electricity", American Journal of Agriculture Economics, (November 1982), pp.673-680.

reflected the fact that electricity is combined with equipment and labour as input factors for irrigation. According to the authors, in the selection of irrigation systems capital and electricity are substitutes. This relationship appears in the average-usage equation because new irrigation customers are added every year. Once the units are in place, however the equipment and energy combine to irrigate the fields. Equipment costs include depreciation and maintenance, which depend on the intensity of equipment use. It is an empirical question whether the net impact of these effects will result in a positive or negative value for α_2.

This analysis of irrigation demand for electricity sheds light on one of the major components of energy demand in agriculture. This demand varies widely from region to region, reflecting the great diversity in natural conditions and farming practices across the United States. The empirical results highlighted the North-West as the region in which changing electricity prices will have the strongest immediate impact on demand because of its relatively high short-run price elasticity. The significant price elasticities estimated in this study imply that (a) the cost of electricity is a factor in determining the amount of irrigation employed and (b) farmers will conserve electricity should energy prices continue to increase.

Charles M. Studness[61] analysed the total electricity sales in U.S.A for the years 1952-82. He found that the estimates of the demand elasticity of real electric rates were about -0.6 in both the first difference and distributed lag regressors, although the two regression forms differed on how quickly demand responded to a change in electric rates. In the electricity estimates, the value

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[61] C.M. Studness, "The long term Outlook for electric demand", Public Utilities Fortnightly, (September 15, 1983), pp.47-48.

of the coefficient for the real GNP variable was 0.4 in the first-difference regression, but 1.3 in the distributed lag regression. Despite the difference in the real GNP elasticity between the two regression equations, the demand growth implied by the two regression equations was similar over likely ranges of real GNP growth and real electricity rate changes. Specifically, the elasticity estimates and the constant term derived from both the first-difference and the distributed-lag regressions imply that electricity demand would grow between 4.5 and 5% per year if real GNP grows at 3% per year and electricity rates rise roughly 2% per year in real terms.

Sutherland[62] examined the temporal stability of electricity demand functions with distributed lags over the 1961-80 period. Demand functions were estimated for residential, commercial and industrial sectors and tested for stability in the pre- and post- oil-embargo period. Most of the demand functions estimated were statistically unstable over these periods. Although a partial adjustment specification of the industrial demand equation appeared to be stable, the income, price, and cross elasticities were significantly different over the sub-periods for the residential and commercial demand equations.

A demand for electricity model was specified for sector j in general form as,

$$EC_{jt} = f(\hat{P}E_{j,t-1}, GNP_{t-1}, PNG_{j,t-1}, D1, D2, D3) \quad ....(3.17)$$

where,

EC_{jt} = electric consumption in sector j during time t,

$\hat{P}E_{jt}$ = predicted average price of electricity in sector j during time t (in 1972 dollars),

[62] R.J. Sutherland, "Instability of electricity demand functions in the post oil-embargo period", Energy Economics, (4 October 1983), pp.267-272.

GNP = gross national product (in 1972 dollars),
PNG_{jt} = price of natural gas in sector j during time t (in 1972 dollars),
D1, D2, D3 = seasonal dummy variables.

The above equation is in general form but was estimated assuming a double log specification. Two-stage least-squares was used to purge the price variable of its correlation with the error term. The instrumental variables were total electric utility operating costs, the price of natural gas, GNP and the three seasonal dummy variables. A hat (^) is used on the price of electricity variable to denote that the predicted value from this equation was used as an instrumental variable. The Cochrane-Orcutt procedure was used to adjust for first-order serial correlation. In the subscript t-i, the i denoted the length of lag and it could differ for each independent variable.

The above equation was estimated with aggregate quarterly data. The sets of regression coefficients were examined for statistical stability over the pre-embargo and post-embargo sub-periods, and in general the models were estimated to be unstable over these periods. One implication of this result could be that the econometric models estimated with pre-embargo data are likely to be unreliable in the post-embargo period. Second, models estimated with data over the entire period are likely to be biased due to temporal changes in the parameters. The author suggested that the future econometric estimates of electricity demand functions should consider the stability of the model during the pre- and post-embargo period.

Gordon Spangler and Vincent P Wright[63] felt that forecasts offered by many economic analysts differ markedly in their assessment of future demand for electricity.

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[63] Gordon Spangler and Vincent P Wright, "Another look at growth in demand for electricity", Public Utilities Fortnightly, (April 26, 1984), pp.25-26.

Hence, they returned to a very basic model and analysed the relationship between electric power sales and the gross national product. Their analysis indicated that despite some structural changes in the U.S. economy, sales of electricity remain positively correlated to GNP, and consequently to industrial production. Moreover, the contribution of the goods-producing segment of the economy to GNP had diminished only slightly in recent decades, despite apparent growth of the service industries.

It is important to notice the difference in the problems of electricity demand in developed countries and developing countries. For example, the substitutes of electricity in some sectors of the economy are different in developing nations compared to developed nations. Also the effect of the oil crisis of the early 1970s would be different in developing countries compared to developed nations, since the effect of the oil crisis would directly depend upon the energy intensities of production processes and dependency on oil from OPEC countries. Unfortunately there are very few studies on electricity demand in developing nations.

Glenn D Westley[64] studied electricity demand in Paraguay. He analysed the residential and commercial demand for electricity in ten regions in Paraguay for 1970-77. Models that were both linear and nonlinear in the parameters were estimated. The non-linear model took advantage of prior information on the nature of the appliances being utilised and simultaneously dealt with the demand discontinuities due to appliance divisibility. Three dynamic equations, including a novel cumulative adjustment model, all indicated rapid adjustment to desired appliance stock levels. Also, the multiproduct surplus loss obtained

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[64] Glenn D. Westley, "Electricity demand in a developing country", Review of Economics and Statistics, (Netherlands), V.66, n.3, (August, 1984), pp.459-467.

from an estimated demand equation was used to measure the welfare cost of power outages.

Van Helden, et al[65] estimated residential demand functions for electricity employing different price variables, and, in contradiction to Roth's[66] findings of a positive coefficient on average price and a negative coefficient on marginal price, they found the coefficients on average price were "right": the negative signs reflected the expected inverse relationships between the quantity of electricity demanded and the average price. On the other hand, non-significant but positive signs on marginal price were obtained. Evidence was given for the inclusion of the average price as the only price variable in the demand function for electricity. After trying the model that included both: average price and marginal price, they tried the model which eliminated the marginal price. This led to a model with highly significant parameters. Hence, it was preferred above the other model that included both average and marginal price, though the elimination of the marginal price variable gave a decrease in absolute value of the parameter on average price. It appeared that the parameter on average price in a model with average price as the only price variable was approximately equal to the sum of the parameters of the marginal price and the average price in a model containing these variables.

A Pouris[67] examined the effects of price on the demand for electricity in South Africa over the period 1950-83. Emphasis was placed on estimation of the long-run own-price

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[65] Van Helden, G. Jan, Leaf Lang, S.H. Peter, Serker, Elmer, "Estimation of the Demand for Electricity", Applied Economics, V.19 n.1, (January 1987), pp.69-82.

[66] Timothy P. Roth, op.cit.

[67] A. Pouris, "The price Elasticity of Electricity demand in South Africa" Applied Economics, V.19, n.9, (September 1987), pp.1269-1277.

elasticity of electricity demand. An unconstrained distributed lag model was used and the elasticity (over the period of 12 years) was estimated to be -0.90. More than 70% of the electricity in South Africa was consumed by the industrial and mining sectors.

As we can observe from the above discussion of the studies in the period under study, emphasis was laid on the possibility of forecasting the long-term demand for electricity rather than observing the effects of prices on electricity demand over the period. In the long term the distributed lagged models are deficient since the environment keeps changing. For example, with increasing electricity prices, the omission of price from the set of determining variables will cause overestimation of the long-term demand by the model. Hence, even for forecasting purposes, models that exclude the price effects could be useful only under the restrictive assumptions of a stable or slowly changing environment.

III.3 Electricity demand analysis in India.

Electricity authorities in the developed countries carry out detailed studies of past demand for the purpose of load growth projections. Some of them resort to studying past demand in relation to other economic variables. In Italy, for example, the government authorities employ rates of increase in population and consumption per capita as the basis for demand forecasts.[68] They also use input-output matrices for estimating the demand for electricity. In Belgium, simple econometric models are used to study the demand for electricity and the index of industrial output is considered an appropriate explanatory variable for this purpose.

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[68] Ralph Turvey and Dennis Anderson, Electricity Economics: Essays and Case studies, A World Bank Publication, Second Edition, (Washington D.C., 1981).

In contrast, except for some ad hoc attempts by government agencies connected with the electricity industry and planning, no serious efforts seem to have been made in India to link electricity demand to its own price, to the price of its substitutes like coal, oil, or gas, to income or to any other relevant economic variable. The Central Electricity Authority, Planning Commission, Ahemedabad Electric Company, Calcutta Electric Supply Company and such other bodies have conducted demand studies with a view to forecasting future load growth. The techniques adopted by them were generally simple and crude. A study of demand for energy in India has been conducted by the National Council of Applied Economic Research where projections on the basis of certain "norms" are given. The report of the Fuel Policy Committee[69] of the government of India gave forecasts of demand for electricity at the all-India level for the years 1978-79, 1983-84 and 1990-91, based on the end use method.[70] The Annual Power Surveys of the Central Electricity Authority are other government documents which give projections of power demand at the states and all India levels. The only academic attempt at the state level in India is that of Prof.Pachauri[71] who estimated econometric models of demand for electricity in Andhra Pradesh. A study by Nirmala Banerjee for the Calcutta Electricity Supply Company tried to observe the

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[69] Report of the Fuel Policy Committee, Ministry of Energy, Government of India, (New Delhi, 1974), Also Known as Chakravarty Committee report.

[70] The end-use method breaks down demand for power into its component end uses, and then on the basis of norms for each one of the end-uses, the demand for the years to come is projected. It does not take into account the effects of prices and technological changes etc.

[71] R.K.Pachauri, Energy and Economic Development in India, Praeger Publishers, (New York, 1977), pp.145-178.

elasticities of demand for that particular region.[72] In 1980, P.P.Pillai studied the demand for electricity for Kerala for the period 1967-68 to 1977-78.[73] These studies are all discussed in this section.

The Fuel Policy Committee[74] was appointed by the Government of India in 1974 with the objective of surveying fuel resources and the regional pattern of their distribution; studying the trends in exploitation and use of fuels; estimating demand by sectors (in particular the transport, industry, power generation industry and domestic fuel and by regions); and studying the efficiency of use of fuel.

A statistical regression of energy consumption on the activity levels of the economy as a whole and on the sectoral level was attempted. A linear regression model relating energy from coal, oil, electricity and total commercial energy, to i) national income, ii) income for mining and manufacturing, and iii) the index of industrial production, was developed for the years 1953-54 through 1970-71. A set of log-linear models was also developed.

It was found that there was significant correlation between total commercial energy and income from mining and manufacturing sectors and the index of industrial production. The regression of total commercial energy on national income indicated that a high proportion of the total variation in energy consumption could be explained by national income. The results with the log-linear model were not presented since the Committee found the results with

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[72] Nirmala Banerjee, Demand for Electricity, A monograph published for Centre for studies in social sciences, (Calcutta, 1979).

[73] P.P. Pillai, Dynamics of Electricity Supply and Demand in Kerala-A macro econometric Analysis, Agricole Publishing Academy, (New Delhi, 1981).

[74] Report of the Fuel Policy Committee, op.cit.

linear models more reliable (in terms of $\bar{R}^2$) as compared to the results with the log-linear model. Some multiple regressions using national income, population and index of industrial production were also attempted. The results were not given, but it was mentioned that,

"... while the models explained the past trends slightly better; they could not be used for projection purposes..."[75]

Since the objective was to forecast, the restricted models were used and the effects of prices were completely ignored.

In 1979, the Government of India set up a Working group on Energy Policy[76] in order to estimate the prospective energy demand in the different sectors of the economy and regions of the country by 1982-83 and a decade thereafter, to survey the prospective supplies of energy, to recommend measures for optimum use of available energy resources and to outline a national energy policy and a longer term conservation policy.

The Committee studied regression models correlating energy consumption with activity levels of the economy as a whole and in individual sectors. One of the aims of the Group was to forecast energy needs; therefore they examined various forecasting methods and models. During the 1970s the price of different energy forms had undergone a sea-change and the basic directions of technological innovations were re-examined. The Group felt that data relating to the past might not provide a reliable guide to the future. Therefore, they developed a two stage methodology wherein first, using the conventional methodologies, a Reference Level Forecast of energy demand

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[75] Ibid., p.136.

[76] Report of the Working Group on Energy Policy, Planning Commission, Government of India, (New Delhi, 1979).

was attempted. This was obtained by averaging the forecasts obtained by different methodologies. The second stage of the exercise was to set out the best level and composition of energy demand that could materialise if the policy prescriptions suggested by the Group were adopted and the assumptions made by the Group of the likely developments in the international energy system actually materialised.[77] This was referred to as the Optimum Level Forecast.

The exercise showed that, with the adoption of policy prescriptions of the type suggested, it might be possible to achieve the same rate of economic growth with a substantially lower level of energy inputs.

The Committee on Power[78] was appointed in 1980 by the Government of India in the Ministry of Energy with the objective "to examine all aspects of the functioning of State Electricity Boards and Central Organisations engaged in electricity generation transmission and distribution,

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[77] The assumptions were, (i) The annual average compound growth of GDP was assumed to be 4.7% for the period 1977-78 to 1982-83, 5.5% for the period 1982-83 to 1987-88, 6.0% for the period 1987-88 to 1992-93 and 6.0% for the period 1991-92 to 2000-01. (ii) The average annual compound rate of growth of agricultural sector was assumed to be 3.92% in the period 1982-87, 3.72% in the period 1987-92 and 3.93% in the period 1992-2000. Similarly the annual average compound rate of growth of industrial sector was assumed to be 6.81%, 7.23% and 7.23% for the respective periods. The growth of the transport sector was assumed to be 6.5%, 6.8% and 6.72% per annum for the respective periods. And the rest of the sectors were expected to grow at the annual average rate of 6.27%, 7.23% and 6.74% in the respective periods. (iii) The population was assumed to be 697.2 million in 1982-83, 760.5 million in 1987-88, 823.3 million in 1992-93 and 920.9 million in 2000-01. (iv) The relative prices of different fuels were assumed to be of the same order as in 1978. (v) The rate of substitution of non-commercial fuels and animal energy by commercial fuels was assumed to follow the same trend in the future as in the past 25 years.

[78] Report of the Committee on Power, Department of Power, Ministry of Energy, Government of India, (New Delhi, 1980), Also known as Rajadhyaksha Committee Report.

including organisational structure, management practices, planning systems, efficiency of operations, financial performance, tariff structure and legislative framework and make recommendations for improving them."[79]

The report took into consideration the need for long-term electricity demand forecasts for planning installed capacity in future. The Committee referred to the Annual Power Surveys for their forecasts[80] The surveys are conducted by the Power Survey Committee which was set up by the Department of Power with representatives drawn from the power industry, consuming sectors and the Planning Commission, and the Power Survey Directorate of the Central Electricity Authority (CEA) acts as the secretariat for the Committee.

The methodology adopted for forecasting medium term electricity demand in the Annual Power Surveys has been modified from time to time, the present method is a combination of the end use[81] method and past trends for individual states. But here again the effects of factors like income and price on the demand in the past were not given any importance; rather the past trends of electricity consumption were extrapolated.

In their study[82] of May 1985, the Advisory Board on

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[79] Ibid, p.1.

[80] The Annual Power Survey started in the early sixties by the Central Electricity Authority, Government of India, New Delhi, on the pattern of the semi Annual Power Surveys of Edison Electric Institute of the U.S.

[81] Please refer to footnote 70.

[82] Towards a perspective on Energy demand and supply in India in 2004/05, Advisory Board on Energy, Government of India, (New Delhi, May 1985).

Energy[83] (ABE) in their made an attempt to project future energy consumption in four major sectors i.e., 1) Household, 2) Agricultural, 3) Industrial, 4) Transport. Their approach was to project demand for energy on the basis of the likely developments in the factors affecting the demand for energy in each of the sectors. Here again price as one of the factors was neglected and the effects of electricity price on demand in the past was not considered.

Professor Pachauri studied the domestic, commercial, industrial and agricultural sectors of Andhra Pradesh.[84] The models for each of the mentioned sectors within the Andhra Pradesh region were specified and estimated in two parts. The first related to the relationship between numbers of customers for electricity in each sector and the second to average consumption in kilowatt hours per customer in each of these sectors. Hence, the dependent variables regressed were numbers of customers and kilowatt hours per customer in each case against a number of alternative sets of independent variables. The models were estimated both in the simple linear and log-linear forms.

For the industrial sector, a first order autoregressive model was considered for the analysis of the number of industrial consumers, whereas the electricity demand by the industrial consumer group was considered to be a function of the electricity demand in the previous year as well as a time trend. The income and the price variables were not included as the variables affecting electricity sale to industrial consumers. Hence, income and price elasticities were not estimated.

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[83] The Advisory Board on Energy was set up in 1984 to make energy demand and supply projections for the next twenty years.

[84] R.K. Pachauri, Energy and Economic Development in India, Praeger Publishers, (New York, London, 1977).

For the agricultural sector the number of consumers was considered to be a function of the number of villages electrified and average price of electricity, whereas the kilowatt hour consumption was considered to be a function of a seasonal factor, average rainfall, kilowatt hour consumption in the previous year and a time trend.

The models for agricultural consumers lacked significance due to a high degree of multicollinearity in the data set. The models were used to project demand up to the year 1990/91, based on a set of "reasonable assumptions" regarding the growth parameters for the future.

Nirmala Banerjee studied the domestic demand by state for the period 1951-1971; industrial demand for electricity was studied in detail i.e., electricity demand by all industries to-gather as well as the demand for electricity by each industry.[85]

The industrial demand for electricity was the dependent variable, with industrial production, and the ratio of prices of electricity in coal equivalent terms and coal as independent variables. The cyclical influence on electricity use was also considered. The industrial demand for electricity was modelled as,

$$Y_t = AX_t^{b1} P_t^{b2} U_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.18)$$

where,

Y_t = total consumption of electricity by industries in t^{th} year,

X_t = industrial production in t^{th} year,

P_t = ratio of prices of electricity in coal equivalent terms and coal in t^{th} year,

U_t = error term,

[85] Nirmala Banerjee, op.cit.

$t = 1,2, \ldots n$.

The relative price of electricity was found to be of little relevance in explaining the overall demand for electricity.

P.P.Pillai[86] studied electricity demand in relation to economic development in a southern state of India, namely Kerala; for the period, 1957-58 to 1976-77. The aggregate demand for electricity was examined in terms of linear, log-linear simple equations and simple, first order, autoregressive process models. A model depicting the dynamic growth paths of demand for electricity was also tried. The dependent variable was the total electricity demanded during the t^{th} year (Em_t) in the following model,

$$\text{Log}(Em)_t = \beta_0 + \beta_1 \log X_t + \beta_2 \log Pt + \beta_3 \log(Em)_{t-1} + \beta_4 \log T + U_t \ldots (3.19)$$

where,

Em_t = total electricity demanded in t^{th} year in million KWH,

X_t = net domestic product at constant prices (1960-61),

P_t = the average price in paise per unit (KWH) of electricity in the t^{th} year,

T = time trend variable.

Electricity demand by different sectors of the economy was also studied on the basis of electricity demand by different sectors, their respective income and price data.

The long-run income and price elasticities were found to be higher than short-run income and price elasticities in case of total, residential and commercial, industrial and agricultural demand. The long-run income elasticity for different consumers ranged between 1.048 to 2.103, and in the short-run it ranged between 0.68 to 1.3. The long-run price elasticity ranged between -0.156 to 0.818 and in the short-run it ranged between -0.115 and -0.633.

[86] P.P. Pillai, op.cit.

The analysis ignored both demographic variables like the number of consumers and also, the pattern of economic growth in the state. Seasonal factors such as the rainfall were also ignored.

III.4 Summary of results: The literature.

As noted earlier there were various studies for different categories of consumers and in the earlier section the studies of industrial demand have been explained in detail, but various studies have been made also of the residential demand for electricity. Except for Ruth's study, I have not included studies of residential electricity demand in the literature in this chapter.[87] Also, this study does not include analysis of residential electricity demand in India.

Both long-run and short-run elasticities have been estimated by some of the studies. Table III.1 also contains a list of variables (other than price) used in each of the studies as well as a column describing the type of data used in each study.

III.5 Elasticities.

III.5.1 Long-run elasticities.

Studies so far have shown as expected, that for all classes of consumers the price elasticity of demand for electricity and the income elasticity of demand were much larger in the long run than in the short run.

The econometric literature on industrial demand consisted of few studies. The implications of decreasing block pricing, and peak demand verses non-peak demand, i.e. separating demand according to the time of the day, need more attention. Also, a distinction between short-run and

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[87] The references on residential electricity demand analysis are given in the Bibliography.

long-run demand analysis for industrial consumers was indicated. The industrial demand for electricity in the long run was linked with capital formation and technological change.

Table III.1
Results of various studies.
Industrial Demand

	SR	LR	P	Other Important Variables
Fisher and Kaysen	NE	-1.25	A	
Baxter and Rees	NE	-1.50	A	Capital, Labour inputs.
Mount, Chapman & Tyrrell	-0.22	-1.82	A	Population, Income, Gas price, Temperature.
Anderson	NE	-1.94	A	Coal price, Coke price, Oil price, Manufacturing wage rate.
Lyman	NE	(-1.40)	A	Gas price, Price Index, Income, Temperature.
Michael Murray, Robert Spunn et el.	-0.9	-0.5	M	Seasonal variations, KW demand.
Sutherland	NE	-1.13	A	Price of natural gas, Seasonal variations.
Banerjee Nirmala (India)	NE	(-0.013)	A	Industrial Production, Ratio of prices of electricity in coal equivalent and coal
Agricultural Demand				
Maddigan	-1.1	-2.12	A	Number of Consumers, Cost of living Index, interest rate on real estate Irrigation production.
Total demand				
Pouris (South Africa)	NE	-0.9	A	-
Pillai P.P. (India)	-0.6	-1.56	A	-

Note: NE =Not Estimated, SR =Short-run, LR =Long-run, P =Proxy for price variable, A =Average Price, M =Marginal price.

The long-run price elasticity of demand was indicated to be elastic. All of the studies support this for industrial demand. The evidence on the magnitude of the long-run income elasticity was much more mixed. Estimates ranged from 0 to 2 and clearly depend upon the type of model employed.

Perhaps the most important implication to be drawn from the long-run studies was that the magnitude of price-induced demand changes varied significantly from one system to another. The significance of this finding ran the risk of being underemphasised by its simplicity. In fact, the underlying reasons were often subtle and complex. Other demographic characteristics of the residential sector also played an important role in determining price responsiveness. For example, housing characteristics, the mix of urban, suburban and rural populations varied significantly. The importance of this regional variation for a specific utility was, of course, that elasticities calculated from a cross-section of statewide data might not reflect residential customers' price responses if the aggregation process had eliminated (or ignored) important characteristics of a particular service area. The same conclusion holds for non-residential demand and was intensified by two additional factors which operate on price elasticity. The price response of a utility's industrial class of customers would be seriously affected by the industrial composition of its service area; and this characteristic probably demonstrated greater regional variation than did many residential characteristics. Further, the long-run industrial demand response to changes in the price of electric power was likely to be far greater in a single service area than at the national level. Many power-intensive industries (e.g., aluminium production) responded to price level changes not only by altering their energy inputs, but also by locating and expanding production in areas that have lower energy price levels.

III.5.2 Short-run elasticities.

Developing a synthesis of the results of the KWH demand models which estimated short-run price elasticities was a considerably easier task than dealing with long-run results. All of the studies found short-run (one year or less) responses to changes in the price of electricity and other fuel prices to be relatively small for both residential and nonresidential consumers. The estimated elasticity coefficients tended to fall in the neighbourhood of -0.15 to -0.30 for electricity price, and somewhat lower for the price of gas. As a general proposition, however it was expected, on the basis of consumption studies, that the short-run effects of price changes would be small in both residential and non-residential sectors. In a sense these conclusions suggested multifaceted implications for the electric utility industry. On the one hand low short-run elasticities indicated that changes in rate structure, which effectively increase the price of electric power to the consumer, may have taken some time significantly to reduce KWH demand (as compared to what it would have been if no rate alterations occurred). On the other hand, the relative slowness of these responses to price changes would have eased the electricity industry's financial burden stemming from altered rate structures. If responses were too rapid, higher electricity rates might have led to serious erosion of revenues while cost of service remained high due to the high fixed costs reflecting capital development programs of earlier years. The slower the demand responses to higher prices, the more time could be provided for the electricity industry to adjust capacity.

One more issue needs to be mentioned, relating to both long-run price response and especially to price responses in the short-run. Although observed changes in electricity consumption due to changes in equipment utilisation and efficiency have been relatively small, this does not imply that time-of-day pricing will have only a negligible impact on the rate of consumption. Even if electric power rates have only a small impact on decisions regarding the utilisation rates of these appliances, rate design may still have a large effect on when equipment is used. This remains the question to be raised in the consideration of KW demand models.

III.5.3 Cross elasticities.

The results concerning the cross elasticities of demand can be summarised briefly as,

(1) There was little evidence of any cross elasticity at all in the short-run. Mount, Chapman and Tyrrell found, for residential demand, the cross elasticity with respect to the price of natural gas was only 0.02. Houthakker found a somewhat higher value for the U.K. namely 0.21.

(2) Though the evidence for the long run was not clear cut, it definitely suggested that electricity demand responds to the prices of other types of energy. Anderson found a positive cross elasticity with respect to the price for coke, for electric power consumption in the primary metals industries, but negative cross elasticities with respect to the prices of coal and fuel. Finally, Mount & Chapman and Tyrrell found cross elasticities with respect to natural gas of 0.19 for residential demand, 0.06 for commercial demand and 0 for industrial demand.

CHAPTER IV

ELECTRICITY DEMAND ANALYSIS: CASE STUDY I.

Electricity demand analysis at all-India level.

Electricity demand in India has been growing since Independence. One of the aims of this study is to understand the pattern of electricity demand in India after Independence and the factors that might have affected it. In order to know the pattern of electricity demand it is important to know the growth-rate of electricity demand. And, in order to understand the reasons for the observed growth-rate, we need to observe the effects of different explanatory variables on electricity demand. Since the available information on the "electricity demand" is electricity sales (KWH), it may be more appropriate to consider it as electricity sales rather than demand.

IV.1 Growth of aggregate electricity sales in India.

To begin with, the process of growth of past electricity sales was examined in terms of two alternative models.

First, a simple linear trend in electricity sales enabled us to describe the change in electricity sales over the period of time. It assumes an arithmetic growth rate. The second, a semi-log model with time as the explanatory variable, assumes a geometric (compound) growth rate of KWH sales. These models have been used for "demand"[88] forecasting by extrapolation using the estimated trend equations by the electric utility companies in India.[89]

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[88] The data on electricity sales are considered as a good proxy for electricity demand in Indian electric utilities.

[89] In interviews with the officials in the Planning Department of Gujarat Electricity Board, Baroda and Maharashtra State Electricity Board, Bombay, I was told (continued...)

IV.1.1 Models.

The simple linear trend in the KWH sales was estimated using the form;

$$ITSALE_t = \alpha_{01} + \alpha_{11}t + \epsilon_{t1} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(4.1)$$

where,

$ITSALE_t$ = index of the quantity of electricity sold in the t^{th} year; (1962 was taken as the reference year),

t = time variable.

ϵ = random disturbance term.

Second, a semi-log model with time as the explanatory variable in the following form was used;

$$lITSALE_t = \alpha_{02} + \alpha_{12}t + \epsilon_{t2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(4.2)$$

where,

$lITSALE_t$ = logarithmic transformation of the index of electricity sales to all consumers in t^{th} year.

t = time variable.

Similar models were also tried for per capita electricity sales.[90]

IV.1.2 Results.

From the estimated relationships depicting the growth paths, it was observed that the electricity sales to all consumers and per capita electricity sale were better explained with the help of a semi-log growth model than with the simple linear growth model. From the data on the

[89](...continued) that electricity demand in the state was forecast on these models. This forecasted demand was then used for the purpose of planning the supply.

[90] All the data used in this Chapter are explained in the Appendix to Chapter IV.

index of electricity sales to all consumers and the index of per capita electricity sale, it appeared that there was a difference in the growth pattern over time and hence we derived growth-rates for two sub-periods using the semi-log growth model. The results of the semi-log growth model can be observed from Table IV.1.

Table IV.1
Annual average growth-rates of electricity sales and per capita electricity sale using the semi-log growth model. (model (4.2))

Period	Growth-rates (in percentages).	
	ITSALE	IPCSe
1947-86	9.7	7.18
SE	(0.0021)	(0.002)
1947-72	11.7	9.0
SE	(0.0018)	(0.0017)
1973-86	5.8	4.8
SE	(0.002)	(0.002)

Note: ITSALE = Index of total electricity sales.
IPCSe = Index of per capita electricity sale.

The estimates refer to the period mentioned in the first column. The equations were estimated by ordinary least squares. This suggested that in the period 1947 and 1986, the index of electricity sales to all consumers increased at the compound rate of 9.79% per annum, whereas the index of per capita electricity sale increased at the compound rate of 7.18% per annum. Between the years 1947 and 1972 the index of electricity sales grew at the annual rate of 11.7% and between the years 1973 and 1986 the index of electricity sales grew at the annual average rate of 5.82%. The growth-rates for the two sub-periods are different from each other. Similarly the growth-rates of per capita electricity sale in two sub-periods are also different i.e., 9.0% in the first sub-period and 4.8% in the second sub-period. This slow down in the growth-rate of electricity sales may be either due to higher transmission and distribution losses or/and lack of capacity to generate electricity. Thus it may reflect the problem of failure to supply.

IV.2 Econometric models of electricity demand.

The analysis of the growth-rates of electricity sales to all consumers failed to explain why the consumers were consuming at a higher growth rate in the first sub-period compared to the second sub-period; and it is important to understand the reasons for the observed changes in electricity sales. As observed in the previous Chapter, micro-economic theory suggests that demand for any commodity is affected by the income of the consumer (i.e. the ability of the consumer to pay) and the price of the commodity. While the availability (and the increasing usefulness) of electricity set an immediate limit to requirements in a region, the actual level of demand at any given time depends on a number of socio-economic factors. The demand for electricity in India after Independence might also have been affected by economic variables like the price of the alternative resources, the reliability of supply, population growth, political factors like the attitude of the political party in power towards modernisation, institutional changes in regulating the industry, social factors like adaptability in the society etc, and also exogenous shocks like the war and the oil crisis. Any consumer would be interested in using a commodity that satisfies his needs and/or gives him comfort and/or facilitates his economic activity, but this is only if the consumer could afford to pay for the commodity. Thus, though the effects of the price of substitutes and other social and political factors on electricity demand would be interesting to study, the analysis in this and the following Chapter is restricted to the study of the effect of variables like consumers' ability to pay, the cost of electricity to the consumer and population growth, on electricity demand.

IV.2.1 Models.

Electricity demand was expected to be affected by the consumers' ability to pay and the price of electricity. An increase in the level of income increases the ability of the consumer to pay for electricity and as a result electricity demand is likely to increase. Therefore, a positive sign was expected for the income coefficient.

An increase in price on the other hand makes electricity more expensive for the consumer and may discourage electricity demand. At the same time, new potential consumers may find electricity so expensive that they may be discouraged from starting to use electricity even for their basic needs. Thus, a negative response to increase in price may be expected. But in most uses of electricity, once the consumers have substituted from any other source of energy to electricity, it is difficult and very expensive to switch back. For example, the decisions regarding consumer durables are taken among households in the longer run. Since the capital cost involved is high, once the appliances are in use, consumers may not stop using them just because the price of using them has gone up, or may not refrain from purchasing the durable goods which happen to be electricity intensive, just because electricity prices have changed (though the extent of use of some appliances, (e.g., air conditioners) may be affected by an increase in prices). It is quite likely that initially, consumers who substitute from alternative sources of energy to electricity are keen to enjoy the benefits of using electricity and take less notice of the costs of using it. After substituting for another energy source, they may find it more difficult and expensive to switch back and such "lock in" effect might be reflected in the coefficient of price. It is also possible that the electricity consumers might ignore prices in deciding their level of electricity demand. Hence it is interesting to observe empirically the price effect on electricity demand.

In order to incorporate the effects of population growth, one can include data on population as an independent variable. To avoid the problem of multicollinearity between the income and population, (if population is included as a independent variable along with income and price), one can incorporate the population growth by studying the per capita electricity sale. Thus, we studied the effects of per capita income and average price (per unit of electricity) on the per capita electricity sale (PCSe).

An econometric model that explained the growth path of per capita electricity sale was tried where the dependent variable used was the per capita electricity sale. The main explanatory variables were income and price.

All the variables were transformed into logarithmic form to give the following model;

$$\log(IPCSe_t)=\log\beta_{03} + \beta_{13}\log(IPCI_t) + \beta_{23}\log(RIAPe_t) + \epsilon_{t3} \quad \ldots(4.3)$$

where,

$IPCSe_t$ = index of per capita electricity sale in t^{th} year,

$IPCI_t$ = index of per capita income at constant (1970-71) prices,

$RIAPe_t$ = index of the average price (in paise per unit of electricity) of electricity to all consumers deflated by the wholesale price index.

It was observed earlier that the per capita electricity sale grew at different rates: in the first sub-period i.e. 1953-72, the growth-rate was found to be higher than the second period. In a growing economy, that already has a growing electricity sales and so a more or less nonsubstitutable source of energy by the year 1972, it is hard to believe that electricity sales were growing at a lower rate than the rate at which it grew before 1972. Technological change had already affected the economy to some extent by 1973 and the strategy adopted in the Second Five Year Plan boosted the electricity demand from industries as well, so it is all the more surprising to observe that in the second period electricity "demand" (KWH) did not grow at the same rate as it did in the first period, especially since the economy had not yet reached a level where there was no further scope for using electricity. One possibility is that the effects of changes in the price were different in two sub-periods. Another possibility is that consumers found more avenues for fuel substitution as a result of growing income in the first period compared to the possibility of substitution in the second period, and hence, the effect of income might be different in the two sub-periods. Thus, it was also important to observe whether the effect of above mentioned variables on electricity demand was different in the two sub-periods.

The oil crisis of 1972-73 may not have affected the electricity industry in India directly due to the low share of oil consumption in the production of electricity (due in turn to official discouragement after Independence), but it made the electric utilities in India aware of the increasing scarcity of energy. On the other hand, the increasing demand (KWH) for electricity from industries and other users helped the utilities to utilise their capacity but did not generate enough resources to enable the electric utility to create the capacity that was required to fulfil the projected demand for power (KW). This led to shortages in electricity supply and a rise in electricity prices particularly for industries after 1972. But whether the increase in prices led to any negative effects on electricity demand by the industries or not is yet to be seen. In order to analyse the difference in the effects of independent variables in two periods, dummy variables were used:

$$\log(IPCSe_t) = \beta_{04} + \beta_{14}D + \beta_{24}\log(IPCI_t) + \beta_{34}\log(PCI_t{*}D) + \beta_{44}\log(RIAPe_t) + \beta_{54}\log(RIAPe_t{*}D) + \epsilon_{t4} \quad \ldots(4.4)$$

where,
$IPCSe_t$, $IPCI_t$, $RIAPe_t$ are the same as defined earlier,
D is the dummy variable such that D=0 for the period 1953-1972, (period without electricity shortages, and D=1 for the period 1973-1986 (period during which electricity shortages were experienced).[91]

IV.2.2 Results.

The effects of variations in the (real) average price of electricity (RIAPe) and the index of (real) per capita income (IPCI) on the index of per capita electricity sale (IPCSe) (i.e., model 4.3) are presented in the Table 4.1 in Appendix to Chapter IV .

The coefficients of income and price were statistically significant. The coefficient of income was found to be positive as expected. The coefficient of price was found to be negative as expected. From the numerical values of the coefficients, a 1% increase in the index of per capita income, increases the index of per capita electricity sale by 3.83% in the period 1953-86. The income elasticity was found to be more than one. Also a 1% increase in real prices led to a decrease in electricity consumed of 0.62%. Unfortunately, as can be observed from D-W statistic, there was a problem of auto-correlation and this makes the statistical significance of the coefficients

[91] For explanation of the data used please refer to the Appendix to Chapter IV.

less trustworthy.

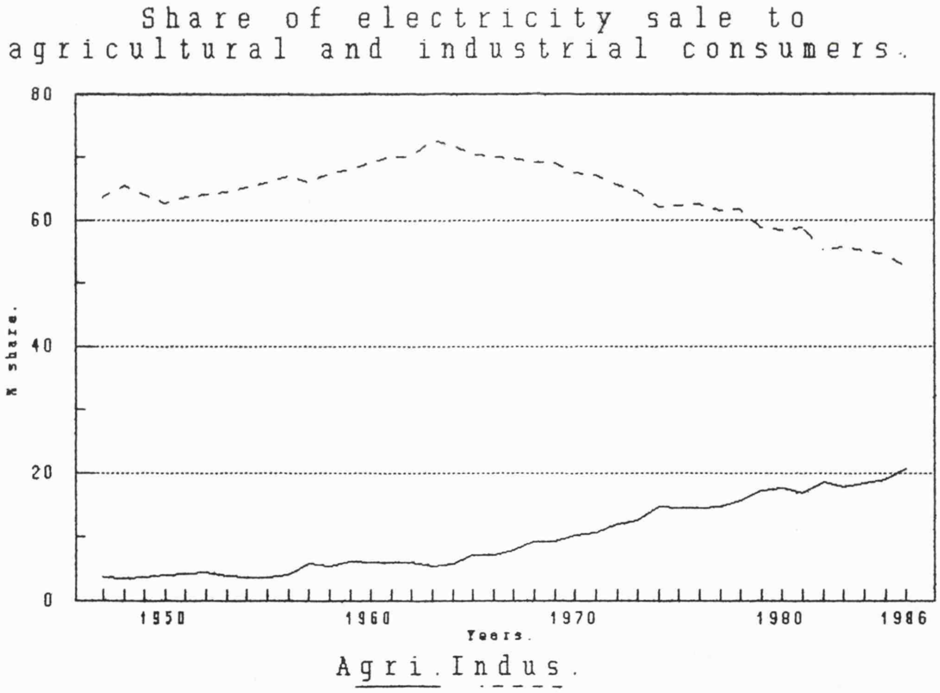
When comparing the model without the dummy variable (i.e., model 4.3) with the model including the dummy variable (i.e., model 4.4) on the basis of their F-statistic, we gathered that the variations in per capita electricity sale were better explained by the model with the dummy variable. This would mean that the model without the dummy is not stable over the whole period. The result of the model with the dummy is presented in the Table 4.1a in the Appendix to Chapter IV and the method to derive coefficients for the two sub-periods is also explained below the Table 4.1a. From the t-statistics of the coefficients in the model with the dummy variable, we gather that the coefficients of income and price in the second period are statistically different from the coefficients in the first period. Further, the model with the dummy did not have any other problems, like auto-correlation, that we had in the model without the dummy.

The income coefficients (Table 4.1b) in both the sub-periods are significantly different from zero and positive as expected. The coefficient of price in the first sub-period was significantly different from zero, whereas in the second period it is not significantly different from zero. Though the coefficients of price had a negative sign in both the sub-periods. As far as the numerical value of the coefficients are concerned, it was found that a 1% increase in the index of per capita income led to a 5.57% increase in the index of per capita electricity sale in the period 1953-72, but only a 2.25% increase in the period 1973-86. Similarly in the period 1953-72, a 1% increase in the index of real electricity prices, led to decrease in the index of per capita electricity sale by 1.06%, and by 0.01% in the second period.

Despite the increase in the (nominal) average price of electricity after 1972-73, the effects of prices on electricity sales were found to be insignificant in the second period. In the case of industries, the fuel cost may/may not be a major component of costs and hence the decision regarding electricity demand may not necessarily depend upon electricity prices. As explained earlier, after substituting other fuel by electricity it was difficult to go back to the fuel used earlier or stop using the appliance. Thus, the "locked in" effect was found in the second period.

IV.3 Electricity demand by different consumer groups.

Graph IV.1



As can be seen from Graph IV.1, the share of electricity sales to different consumer groups in the total electricity sales changed over a period of time. It is important to know the growth rate of the electricity sales to different consumer groups. Though the electric utilities in India distinguish their consumers in 8 different groups[92] the analysis in the following section covers the analysis of electricity sales to industrial users, agricultural users and "other" consumers in a single category.

IV.3.1 Models.

The simple and semi-log growth models explained in section IV.1.1 were used.

IV.3.2 Results.

The indices of electricity sales to industrial, agricultural and "other" consumers were better explained by the semi-log model. The growth-rates of electricity sales to the three consumer groups are presented in Table IV.2.

Table IV.2
Annual average growth-rates of electricity sales to industrial consumers, agricultural consumers and "other" consumers using the semi-log growth model.

Period	Growth-rates of consumer groups in percentages.		
	Industrial	Agricultural	Other.
1947-86	9.37	14.44	9.0
1947-72	12.08	16.44	9.67
1973-86	5.82	9.6	8.6

Electricity sales to industries were encouraged after independence. The annual average growth rate of electricity

[92] The 8 consumer category as mentioned earlier are 1) Domestic, 2) Commercial, 3) Industrial (high tension), 4) Industrial (low tension), 5) Agricultural, 6) Public water supply, 7) Public lighting, and 8) Railways.

sales to industrial consumers was 9.37%, it was 14.44% for agricultural consumers, and 9.0% for "other" consumers. Agricultural consumers experienced the highest growth-rate.

But like the growth of electricity sales to all consumers, the annual average growth rate of electricity sales to industries grew faster between the period 1947-72, at 12.08%, than between 1973-86, at 5.82%. In the first sub-period the index of electricity sales to agricultural consumers grew at the annual rate of 16.47% and in the second sub-period it grew at the rate of 10.46%. The annual average growth-rate of electricity sales to "other" consumers in the first sub-period was 9.67%, and 8.68% in the second sub-period. The growth-rates in the first sub-period for all consumer groups were significantly different from the growth-rates in the second sub-period for all respective consumer groups.

IV.4 Models for electricity demand by the industrial consumer group.

IV.4.1 Models.

The energy requirement by different sectors depends on the growth of that sector and its relative importance in the economy. For example, if the industrial sector was growing faster, the energy requirement by industries is likely to grow faster. Or if agriculture was the main economic activity of the nation, the growth of agriculture may lead to faster growth of the energy requirement by the agricultural sector.

Electricity is a convenient and usually an inexpensive input for Indian industries. The effect of the price on electricity demand by industries depends upon 1) the importance of electricity in the process of production and the substitutability of electricity in the process of production and 2) the share of electricity cost in the total cost of production. It is important to know the importance of electricity cost in the industry's total costs. Table IV.3 shows the cost of electricity as a percentage of gross value of output in some of the more electricity-intensive industries for 1966. For all industries taken together, the total cost of electricity consumed by industries, whether purchased or generated in their own plants, at the average market price of industrial electricity supplies,[93] in 1966 came to only about two per cent of the gross value of output of the manufacturing sector. For some industries, of course, electricity costs were of greater importance than this.

Table IV.3
Cost of electricity consumed at market prices as a percentage of total value of output for selected industries in 1966: all-India.

Name of the Industry	Cost of electricity as a percentage of gross value of output.
1	2
Textiles	2.70
Iron and Steel	3.85
Basic Industrial Chemicals	9.40
Paper and Paper Pulp	6.82
Non-ferrous Basic Metals	12.64
Cement	9.27
All Industries	2.26

Source: Quantity of Electricity consumed by each industry and the gross value of output of industry from Annual Survey of Industries, Central Statistical Organisation, Government of India, 1966.

The Table IV.4 shows the "year to year elasticity" of the all-India industrial consumption of electricity with respect to the all-India industrial production for the period 1948-1986. This elasticity measures the relative change in electricity demand vis-a-vis the change in

[93] Public Electricity Supply - All India Statistics, Central Electricity Authority, Government of India, (New Delhi, 1965-66).

industrial production.

Table IV.4
Income elasticity of industrial demand over the period 1947-1986.

Year	Elasticity	Year	Elasticity
1947	none	1967	-29.54
1948	0.39	1968	1.95
1949	-0.18	1969	1.28
1950	0.03	1970	0.83
1951	4.77	1971	1.65
1952	1.38	1972	0.33
1953	6.58	1973	0.44
1954	1.85	1974	0.31
1955	1.81	1975	3.15
1956	1.6	1976	3.47
1957	1.09	1977	0.2
1958	2.27	1978	1.73
1959	2.06	1979	-3.23
1960	1.22	1980	1.49
1961	2.22	1981	1.2
1962	1.39	1982	-0.04
1963	2.51	1983	1.44
1964	1.13	1984	1.79
1965	0.93	1985	0.766
1966	-19.72	1986	0.178

$$\text{Elasticity} = \frac{\text{\% change in electricity sale to industries}}{\text{\% change in industrial production.}}$$

For most years, between the years 1947-86, this ratio was positive and greater than one, although it varied widely from year to year from 4.09 in 1957 to -29.54 in 1967. From the two time series of industrial production and of industrial use of electricity, it appears that in years of steadily growing industrial production, electricity demand also increased steadily at a somewhat higher rate. However, in the two years of a sudden setback to industrial production in this period, (1966-67) electricity demand did not decrease correspondingly and increased in absolute terms. Thus the relevant elasticity figures for these two years were found to be negative and very large.

These wide variations in the year-to-year figures of elasticity of electricity demand appear to suggest that cyclical variations in the trend of industrial production affect industrial use of electricity over and above the changes due to the secular trend of industrial production. In other words, the actual use of electricity would be affected not just by the long-term trend in industrial production, but also by the movement of industrial production around this trend. This might be caused by the fact that electricity was not always a variable input strictly related to the production level alone. It might, to a certain extent, also be a fixed input because electricity was required for overheads such as lighting of office buildings, industrial townships, etc., none of which uses were affected by the actual industrial production level in the short run. Partly also, the indivisibilities of electrically operated machines were reflected in industry's electrical consumption. Provided that an industry produced some non-zero level of output, its machines required some power for the initial triggering off, and this amount of power was the same whether the machine runs at full capacity or not. The cost of this power supply was a fixed cost to the industry so long as it was in operation. The electricity required thereafter to keep the machine going would be a variable cost. If the machine works at full capacity, the total electricity demand per unit would be much less than if it works less than full capacity or for less than the set time. Therefore, in periods of fast growing industrial production, electricity demand would grow more slowly than in periods of slow growth. At a time of an absolute fall in the industrial production, it might fall drastically. It is then possible that the generally greater than unity values of this elasticity might be a result of some fast and drastic cyclical changes in industrial output during this period. Its secular value might be one or less than one.

This would imply that apart from the cyclical variations, electricity demand would have increased proportionately or even less than proportionately to industrial production.

In order to estimate this secular value of the elasticity of industrial demand of electricity, we assumed that the changes in electricity requirements of industries were determined by the changes in industrial production and the price of electricity. We need to calculate a variable which measures the variations in the time series of industrial production from its secular trend. This was called the "pressure of demand variable", since it represented the influence of cyclical variations in production due to changes in demand for industrial goods. A model for this was:

$$\log(IISALE_t) = \log\beta_{05} + \beta_{15}\log(IIP_t) + \beta_{25}(PD) + \epsilon_{t5} \quad ....(4.5)$$

where,

IIP_t = index of industrial production at 1970 prices,

$IISALE_t$ = index of industrial electricity demand,

PD = pressure of demand variable (explained in the Appendix to Chapter IV, page 146).

The growth of industrial production is likely to affect the electricity demand by industries. The growth of electricity demand by industries also depends on the nature of the industries. The modern production process in industries is more energy-intensive than the production process in agriculture. The flexibility of time for electricity demand is less in the continuous process industries compared to small scale industries and agriculture. Also, if the economy is primarily agricultural and if the agro-based industries are important in the industrial sector, the electricity demand by industries is more likely to be affected by the income in the economy as a whole rather than industrial production only. Thus, it is important to observe the relationship between total income and the electricity demand by industries. The price charged to different consumer groups is different. Hence it is important to observe the effects of the price on their electricity demand. The effects of income and price on electricity demand can be analysed using the model:

$$\log(IISALE_t)=\log\beta_{06} + \beta_{16}\log(IGDP_t) + \beta_{26}\log(RIIAR_t) + \epsilon_{t6} \quad ..(4.6)$$

where,

$IISALE_t$ = index of electricity sales to industries,

$IGDP_t$ = index of gross domestic product in India at constant prices,

$RIIAR_t$ = deflated index of electricity prices to industrial consumers.

In order to observe whether the effects of income and price remained the same in two sub-periods or not the following model, using dummy variables, was also tried.

$$\log(IISALE_t)=\log\beta_{07} + \beta_{17}D + \beta_{27}\log(IGDP_t) + \beta_{37}d*\log(IGDP_t) + \beta_{47}\log(RIIAR_t) + \beta_{57}D*\log(RIIAR_t) \quad .....(4.7)$$

where $IISALE_t$, $IGDP_t$, $RIIAR_t$ are the same as defined earlier and D is the dummy variable defined such that D=0 for the period 1953-72 and D=1 for the period 1973-86.

<u>IV.4.2 Results.</u>

The results are presented in Table 4.2 in the Appendix to Chapter IV. The coefficient of the pressure of demand variable (model 4.5), i.e. the difference between the estimated and the actual level of industrial production, was negative and greater than one in the first sub-period. This could be interpreted to mean that, in any particular year, changes in the requirements of industrial electricity depended not only on the changes in industrial production but also negatively, on how industrial production that year had moved vis-a-vis the secular trend.

If production grew at a rate less than its expected growth rate, then electricity requirements also grew slowly, but at a rate faster than the rate of growth of industrial production; whereas in the second period, a negative coefficient of the pressure of demand variable was observed, but it was found to be less than one. Thus, in this period, when industrial production increased faster than the expected or secular rate, electricity requirements grew at a rate much slower than the one indicated by the influence of changes in industrial production. This seems to support the contention that, to a certain extent, electricity was a fixed cost for industries and in years of better utilisation of capacity, its requirements per unit of production were considerably less than proportionate. In other words, electricity requirements of industries had been increasing at a rate faster than the rate of growth of industrial production. This increase in electricity intensity could not be fully explained by cyclical changes in industrial production. There were possible reasons why the overall electricity demand of Indian industries might have grown faster than the total industrial production in this period.[94] To recollect the list of the reasons; i) The new industries which developed for the first time during this period fundamentally used a relatively more electricity-intensive technology. ii) Amongst older industries, the more electricity-intensive industries grew relatively faster. iii) Most existing industries were switching to a more electricity-intensive technology. In the case of India during this period, all three of these needs were realised.

The result of our attempt to study the effect of gross

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[94] Please refer to discussion in Chapter II Section II.1.5 (under Utilisation).

domestic product and price on electricity sales to industries (i.e., model 4.6), are presented in Table 4.3 in the Appendix to Chapter IV. From the t-statistics we gather that the coefficient of income and price were significantly different from zero. The coefficient of income was positive as expected. The average price of electricity to industries affected electricity sales to industries negatively, as expected. Despite the fact that the proportion of electricity costs in the total costs of the industries was low as seen earlier, in the period 1953 to 1986, the industrial electricity demand was price elastic.

Observing the numerical value of the coefficients, we gather that coefficient of income i.e. IGDP, is way above 1%: a 1% increase in the index of GDP raised electricity sales to industries by 2.81%. This high income elasticity shows the underdeveloped state of the economy. There was much scope for electricity use in existing and new industries. The coefficient of price indicates that a 1% increase in the index of <u>real</u> price led to a decrease in the index of electricity sales of 1.05% in the period 1953-86. Thus, both the variables had the sign that we expected, and the effects of income and electricity price for industries were significant in the period 1953-86.

The results of the model with the dummy variable (model 4.7) that allowed for effects of electricity shortages on electricity sales are presented in Table 4.3a in the Appendix to Chapter IV. From the F-statistic comparing model without the dummy (model 4.6) and with the dummy (model 4.7), we gather that the model without the dummy is not structurally stable over the whole period. The effects of income and price in the first sub-period were significantly different from their respective effects in the second sub-period. The results on the t-statistics of the coefficients of income and price (in Table 4.3a in appendix) prove this point.

Calculating the coefficients in the first and second sub-period (Table 4.3b) we gather that coefficient of income in the first and second period were significantly different from zero and had a positive sign as expected. The price coefficient in the first period was significantly different from zero and had a negative sign, but the price coefficient in the second period was not found to be significantly different from zero and did not have a negative sign. This again might be an indicator of the "lock in" effect in the second period.

Observing and calculating (from the formulas given with Table 4.1a and the calculated coefficients are presented in Table 4.3b) the numerical values of the coefficients we gather that income elasticity in the first sub-period was higher than in the second sub-period. A 1% increase in index of gross domestic product in the country led to a 3.25% increase in the index of electricity sales to industries in the period 1953-72, whereas in the period 1973-86, a 1% increase in the index of gross domestic product in the country led to a 1.37% increase in the index of electricity sales to industries. A 1% increase in the index of real price led to a decrease in the index of electricity sales of 0.65% in the period 1953-72; whereas in the second sub-period, electricity demand was found to be price inelastic. Thus, we observe a remarkable difference in the effects of the independent variables on the dependent variable in the two sub-periods.

IV.5 Models for electricity demand by the agricultural sector.

IV.5.1 Models.

The second Five Year Plan (1955-56 to 1959-60) gave a lot of emphasis to the heavy, basic, capital goods industries which were energy-intensive. Electricity sales to industries grew strongly as a result. But after the disturbed years in the mid sixties it was realised that agriculture continued to be dependent on irregular rainfall. The technology of the high yielding variety of seeds needed assured water supply. It therefore seemed important to provide the farmers with an assured water supply and this in turn meant the need for irrigation facilities in the country. Since studies had shown that electrified pumpsets had benefits for the economy has a whole,[95] the government offered subsidies on electrified pumpsets. The electric utilities provided the incentive to install electrified pumpsets by keeping electricity prices low, instead of the oil based pumpsets for which the fuel was more expensive. It was expected that the increase in the number of pumpsets would lead to increases in the number of agricultural consumers, thus affecting the electricity demand by the agricultural sector positively.

The ability of an agricultural consumer to install an electrified pumpset depended upon his income and the government's subsidy on the electrified pumpsets. The incomes of the farmers were usually generated not only from farm produce but also from other hand-crafts, services and other small business. Hence in a study of agricultural demand, it was important to take total income in the country rather than the income from agricultural production only.

The government encouraged the electrification of villages to provide an infrastructure facility and thereby raise the standard of living in general. The effect of this policy of electrification could be captured by taking the number of consumers. The effect of the number of "new villages electrified" on the electricity demand by the

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[95] V.N. Kothari and M.M. Dadi, Economic Benefits of Rural Electrification in Gujarat, Department of Economics, M.S. University of Baroda, (Baroda, 1979).

agricultural sector was expected to be positive. Including this effect would not reflect the electricity demand solely by the agricultural sector, for in the case of India, agricultural activities are mainly centred in the rural areas and it is very difficult to separate electricity supplied to households in rural areas from the electricity supplied specifically for agriculture purposes.

The need for electricity by agricultural consumers also depends on seasonal factors. For example in the years during which there was no or less than optimal rainfall, the need for pumpsets was higher. The period of use of the pumpsets depended also on the level of rainfall. But such seasonal factors were difficult to model due to the diversity in a vast country like India. Though electricity became an important input (to decrease agriculture's dependency on nature), agricultural consumers were flexible in their time of use of electricity.

Since the cost of using the pumpset, i.e., the electricity cost, forms an important element in the total cost of production for a farmer, the average price charged per unit of electricity was also an important factor that affected the level of electricity demand by the agricultural consumers. In contrast to the index of nominal average price for industrial consumers (which showed a very sharp rise after 1973), the index of nominal average price of electricity to agricultural consumers seems to have grown faster before 1973. But even after the policy to subsidise pumpsets and provide low electricity prices came in, it was still expensive for many small and marginal farmers to install electrified pumpsets. It was the group of rich farmers who benefited the most and these were capable of forming pressure groups, which in many states were successful in forcing the electric utilities to keep electricity prices for agricultural consumers low.

Thus, the agricultural demand for electricity was studied using the model:

$$\log(IASALE_t) = \log\beta_{08} + \beta_{18}\log(IGDP_t) + \beta_{28}\log(RIAPA_t) + \beta_{38}\log(IANC_t) + \beta_{48}\log(IV_t) + \epsilon_{t8} \quad .....(4.8)$$

where,

$IASALE_t$ = index of electricity sale to agricultural consumers in t^{th} year,

$IGDP_t$ = index of gross domestic production at constant prices in t^{th} year,

$RIAPA_t$ = index of real average price from agricultural consumers; i.e 1961-62 = 100,

$IANC_t$ = index of number of electricity consumers in agriculture,

IV_t = index of number of villages electrified.

In order to observe the structural stability of this model over the whole period, and to observe whether the effects of independent variables were the same in the period after 1972, the following model was tried:

$$\log(IASALE_t) = \log\beta_{09} + \beta_{19}D + \beta_{29}\log(IGDP_t) + \beta_{39}D*\log(IGDP_t) + \beta_{49}\log(RIAPA_t) + \beta_{59}D*\log(RIAPA_t) + \beta_{69}\log(IANC_t) + \beta_{79}D*\log(IANC_t) + \beta_{89}\log(INV_t) + \beta_{99}D*\log(INV_t) + \epsilon_{t9} \quad ....(4.9)$$

where $IASALE_t$, $IGDP_t$, $RIAPA_t$ are the same as defined earlier and D is the dummy variable defined such that D=0 for the period 1953-72 and D=1 for the period 1973-86.

IV.5.2 Results.

In our attempts to model electricity sale to agricultural consumers, it was found that the gross domestic product is a good proxy for income. The results of model without the dummy (i.e., model 4.8) are presented in Table 4.4 in the Appendix to Chapter IV. The results show that variation in independent variables like income, number of villages electrified, number of consumers and price explained the variations in electricity sale to agricultural consumers significantly. The coefficient of income had positive effects on electricity sales to agriculture as expected. The effects of the number of consumers, which included the number of electrified pumpsets, was also positive in the period 1953-86. The number of villages electrified increased in the period 1953-86, and it affected the electricity demand positively. Thus, the government's programme to offer a subsidy on electrified pumpsets (as can be seen from the effects of the number of consumers, as a proxy), and to promote electrification of villages in India, seemed to have positive effects on electricity sales to agricultural consumers in India in the period 1953-86. Though the extent of subsidy may differ in different states. The coefficient of price had a negative sign as expected. In reality, the actual electricity tariff schedules for different consumers in any region are designed by the State Electricity Boards, which were expected to follow the central government's policy.

Observing the numerical value of the coefficients, we gather that the coefficient of income is below 1 (unlike the coefficient of industrial consumers), a 1% increase in the domestic product led to a 0.66% increase in electricity sales to agricultural consumers. Also the coefficients of the number of villages electrified and number of consumers were below 1. As a result, a 1% increase in the number of agricultural consumers increased electricity sales by 0.37%, whereas a 1% increase in the number of villages electrified, led to a 0.43% increase in the electricity consumed by agricultural consumers. A 1% increase in the index of <u>real</u> prices led to a decrease in electricity sales to agricultural consumers of 0.42%. The coefficients on income, real price, number of consumers and villages electrified were all found to be statistically significant at 1% the significance level.

Using the F-statistic to compare the model without the dummy variable (i.e, model 4.8) and the model with the dummy variable (i.e., model 4.9) that allows for the difference in the effect of the independent variables on the dependent variable in the two sub-periods, we gather that the model without the dummy (model 4.8) explained the variations in the dependent variable in a better way. The model without dummy was stable over the whole period. And the coefficients in the two sub-periods were not significantly different from each other.

IV.6 Models for electricity demand by "other" consumers.

IV.6.1 Models.

Sales in this consumer group included the electricity sales to railways, public lighting, public water works, commercial and domestic consumers. The demand for electricity by railways would more or less depend upon the technical relationship between fuel required, the speed, distance travelled, the efficiency, number of years for which the traction was used and the traction policy of the Department of Railways. Electricity demand from public water works and public lighting was not expected to be constant over time, as in the developed countries. Much of India was not served by electricity at Independence, and as the nation developed, the ability of the state to provide basic facilities increased and more people and larger areas gained this basic facility. Thus, electricity demand was expected to grow over time alongside the steady growth of the nation, and the nation's policy on such welfare measures. Electricity demand by domestic and commercial consumers was also expected to increase over time and was also subject to the influence of a number of other factors[96] like the seasonal differences, the size of the house, the working pattern of the members living in the house and the number of appliances. Electricity demand by commercial consumers became very important in the Indian context only from early eighties, when the tertiary sector in the Indian economy seemed to be growing very fast. The production services - activities linked intimately to production like transportation, trade, repair and maintenance; business services like banking, insurance, advertising, accountancy, market research, computers for data processing and so on: and the consumer services - education, health, travel and tourism, leisure and entertainment and media, have been growing very fast and played a very important role in the economy. But much of electricity demand from these commercial consumers was found to be difficult to separate from electricity demand from the domestic consumers. This was because the location of offices were not pre-planned and located away from the residential area. Small offices were found in residences.

Thus, it was found to be difficult to list various factors affecting this consumer group. Nevertheless, electricity demand by this consumer group was expected to respond to changes in national income, the average price of electricity charged and the number of consumers. To study the effects of income and price the following model was used:

$$\log(IOSALE_t) = \log\beta_{010} + \beta_{110}\log(IGDP_t) + \beta_{210}\log(RIOAR_t) + \beta_{310}\log(IONC_t) + \epsilon_{t10} \quad \ldots\ldots\ldots(4.10)$$

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[96] There are number of studies on the residential demand for electricity and factors affecting it. Since the main purpose of the study is not to study residential demand for electricity the references are not reviewed here.

where,

$IOSALE_t$ = index of electricity sale to all the consumers except to the industrial and agricultural consumers; (1962 =100),

$IGDP_t$ = index of gross domestic product at (1970) constant prices; with the reference year 1962,

$RIOAR_t$ = index of real average price charged to "other" consumers - all the consumers except the industrial and agricultural consumers, i.e., the index of average prices to this consumer group was deflated by the wholesale price index for all India,

$IONC_t$ = index of number of "other" consumers.

In order to find out whether the coefficients in the two sub-period are different from each other or not the following model was tried:

$$\begin{aligned}\log(IOSALE_t) = &\log\beta_{011} + \beta_{111}D + \beta_{211}\log(IGDP_t) + \beta_{311}D*\log(IGDP_t) \\ &+ \beta_{411}\log(RIOAR_t) + \beta_{511}D*\log(RIOAR_t) \\ &+ \beta_{611}\log(IONC_t) + \beta_{711}D*\log(IONC_t) + \epsilon_{t11} \quad ..(4.11)\end{aligned}$$

where $IOSALE_t$, $IGDP_t$, $RIAPR_t$ and $IONC_t$ are the same as defined earlier and D is the dummy variable defined such that D=0 for the period 1953-72 and D=1 for the period 1973-86.

IV.6.2 Results.

The results of the model without the dummy (i.e., model 4.10) are presented in Table 4.5 in Appendix to Chapter IV. The coefficients of income and the number of consumers were found to be statistically different from zero at the 1% significance level. But the coefficient of price was statistically different from zero only at the 10% significance level. In our attempts to explain the electricity sales to "other" consumers we observe that the coefficient of income was found to be positive, as expected. The index of number of consumers also had positive effects on electricity demand. The coefficient of price had a negative sign, as expected.

From the results we gather that the coefficient of income was below 1. A 1% increase in the index of gross domestic product increased the index of electricity sales by 0.65%. Also, a 1% increase in the index of number of consumers led to a 0.7% increase in the index of electricity demand. The non-deflated index of average price charged to "other" consumers was rising till 1977 but it fell after 1977 till 1983. A 1% increase in the index of real price of electricity led to a decrease in the index of electricity sales by 0.028%. Thus we can see that in the period 1953-86, electricity sales to all other consumers except agricultural and industrial were mainly affected by the gross domestic product and the number of consumers.

Comparing the model without the dummy (i.e., model 4.10) and the model with the dummy (i.e., model 4.11), we gather that model without the dummy (i.e. model 4.10) is stable over the whole period. From the results of model 4.11 we also gathered that the coefficients in two sub-periods were not significantly different from each other.

IV.7 Summary.

A perusal of the results mentioned brings out interesting features. The growth of electricity sales to the three consumer groups as well as for all taken together were better explained by the semi-log models. The t-statistics comparing the growth-rates of sub-periods show that the growth-rates for respective consumer groups are different in two periods. The effects of the explanatory variables were found to be significantly different in the first sub-period compared to the second sub-period, only for industrial electricity demand and per capita electricity sale; whereas in the case of agricultural consumers and "other" consumers the independent variables did not affect the electricity demand differently in the two sub-periods.

IV.7.1 Price and income elasticities.

Generally, the effects of income was found to be significantly different from zero in all consumer groups. Since all the models were log-linear, the coefficients of income in the restricted model, that did not allow for the difference in the effect of independent variables in the two sub-periods, show the income elasticities for the respective consumer groups. The income elasticities are summarised in Table IV.5.

Table IV.5
Income and price elasticities: (All-India).

Consumer group	Income elasticities Period 1953-86	1953-72	1973-86	Price elasticities. Period 1953-86	1953-72	1973-86
Per capita electricity sale.	3.83	5.57	2.25	-0.616	-1.05	(-0.01)
Industrial consumers.	2.81	3.25	1.37	-1.05	-0.65	(+0.099)
Agricultural consumers.	0.663	-	-	-0.415	-	-
"Other" consumers.	0.651	-	-	-0.028@	-	-

Note: Income elasticities for all consumer groups and Per capita sale are statistically significant at 1% significance level. Figures in the brackets are statistically insignificant at 10% significance level.
@ Significant only at 10% significance level.

As can be seen from Table IV.5, the income elasticities for the agricultural consumers and "other" consumers in the period 1953-86 are below 1, and there was hardly any difference in the numerical value of the income elasticities of these two groups. The income elasticities of all sectors taken together and the industrial consumers were above one. Also, for per capita electricity sale and the industrial electricity demand, the income elasticity was higher in the period 1953-72 compared to income elasticities in the respective consumer groups in the period 1973-86. The difference in the income elasticities of industrial consumers and agricultural consumers is very large. This indicates that the income elasticity of electricity demand aggregated over different consumer groups can be very misleading and so disaggregation of electricity demand by consumer group is important for both the explanation and any consideration of policy implications. Similarly, aggregation of electricity demand by any consumer group over different regions could also be misleading and it is important, if possible, to observe the effect of income in a particular region on electricity demand in that region.

From the restricted models for respective consumer groups, the price elasticities can be observed directly by observing the coefficient of price. The price elasticities are also summarised in Table IV.5.

In the case of price elasticities we observe that in the period 1953-86, the numerical value of the price elasticities of the four groups is very different. The absolute value of the price elasticity was the highest in the case of the industrial consumer group and it was the lowest in the case of the "other" consumers. For the period 1953-72, the price elasticities for industrial consumers and per capita electricity sale were significantly different from zero, but in the period 1973-86 the price elasticities for these two groups were not significantly different from zero.

Thus, it was difficult to generalise the possible reasons for the observed growth-rate in electricity sale to different consumers. But there are some similarities in the response of all consumers and individual consumer groups (three in our sample) to the independent variables like income and price. High and significant income effects on one hand and on the other low or negligible price effects indicate that electricity sale may continue to grow. And to fulfil growing electricity demand, the utilities may have to plan higher capacity.

Appendix to Chapter IV.

Explanation of the data.

The index of total electricity sale:($ITSALE_T$), index of electricity sales to industrial consumers:($IISALE_t$), index of electricity sales to agricultural consumers:($IASALE_t$), and index of electricity sales to "other" consumers:($IOSALE_t$).

The index of electricity sales to all consumers included electricity sold to domestic and commercial consumers, agricultural consumers, low tension and high tension industrial consumers. It also included the electricity used by railways, public water supply, public lighting and electricity sold to bulk purchasers. It covered only electricity distribution by the public sector i.e., the electricity boards and the municipalities.

The annual data on electricity sales in million KWH to respective consumer groups were taken as dependent variables in the models for respective consumer groups. Electricity sales to industrial consumers included sales to the high tension as well as low tension industries. The data included electricity distribution by the public sector, and did not include electricity generation and distribution by the captive power plants owned by the industrial groups.

The electricity sales for agricultural purposes was very difficult to measure. Usually, in the rural areas the connection given for a strictly agricultural purpose i.e., an electrified pumpset-used for irrigation, was found to be used for domestic lighting as well, hence, it was very difficult to separate the electricity sales for domestic purposes in the rural areas from the electricity sales for agricultural purposes. Thus, electricity sales to agricultural consumers also had some element of domestic demand.

The data on the electricity sales to "other" consumers were derived by deducting the sum of electricity sales to agricultural and industrial consumers from the total (aggregate) electricity sales.

The data on electricity sales were taken from various reports published by Central Electricity Authority in their annual publication: Public Electricity Supply-All India Statistics. The data on electricity sales to different consumer groups were converted into indices, taking 1962 as the reference year.

Index of per capita electricity sales:(IPCSe).

The data on per capita electricity sales were taken from various reports published by Central Electricity Authority in their annual publication: Public Electricity Supply-All India Statistics. According to the reports, the data regarding the per capita electricity sale were derived by dividing electricity sales to all consumers by the total population. Electricity sales to all consumers included the electricity supply by not only the public utilities but also the private sector i.e., the electric companies. These data were converted into an index taking 1962 as the reference year.

Index of per capita income:($IPCI_t$).

Per capita income (PCI) refers to the per capita income in the country at 1970-71 (constant) prices. The data were taken from the Economic Surveys of various years. Data on PCI were converted into an index taking 1962 as the reference year. Like the IPCSe, the IPCI has a lower growth-rate compared to the Index of Gross domestic product.

Index of Industrial Production:(IIP_t).

The index of industrial production was derived with the help of the data on industrial production at constant prices i.e., 1969-70 prices, and the data were then converted into an index taking 1962 as the reference year. The data on industrial production were taken from the Economic Survey for the period 1947 to 1986. The index of industrial production has been growing steadily except for disturbances in the late sixties and in last two years of the seventies. It grew the fastest in the year 1985-86.

Gross Domestic Product:($IGDP_t$).

The data on gross domestic product depicts the value of gross domestic product in India at 1970-71 prices. The series was converted into an index taking 1962 as the reference year. The data on gross domestic product includes agricultural production and industrial production. The data on gross domestic production were taken from the Economic Survey for the period 1947 to 1986.

"Pressure of demand variable":(PD_t).

First, the estimated log(IIP) was calculated by making IIP a function of time, and then the fitted values of IIP were taken. We find log(IIP) = 3.0671 + 0.0661t. (R^2 = 0.97). The fitted values of the index of industrial production were deducted from the actual values of the index of industrial production to get the "pressure of demand" variable. i.e.[log(IIP_t - estimated IIP_t].

The Index of average price of electricity to all consumers:($RIATRe_t$).

Since the electricity prices differ for each state and union territories, and within the state for each consumer group, it was difficult to calculate the price charged per unit of consumption. Hence, the average revenue i.e., total revenue divided by the total electricity sales, was taken as a proxy for the price of electricity. This in fact represented the weighted average of the prices paid by different classes of consumers. Since electricity in this category was also an input in the process of production, the price index was deflated by the wholesale price index. The wholesale price index (all commodities) for all India, with 1962 as reference year, was used to deflate the index of the average price of electricity and the index reflects the real average price of electricity that the consumer had to pay. The index of the (nominal) average price of electricity charged to all consumers followed an upward path. A sharp increase in the nominal price was observed after 1981. The increase in the average electricity price was less than the increase in the prices of all commodities.

The data on the total revenue earned were given by the Central Electricity Authority in their reports till the year 1977-78. After 1977-78 the information was available from the Central Electricity Authority though it was not published in their annual reports.

Index of real average price for the industrial consumers:($RIIAR_t$), index of real average price for the agricultural consumers:($RIAAR_t$), index of real average price for "other" consumers:($RIOAR_t$).

To avoid one of the aggregation problems i.e. aggregation of revenues over the consumer categories, average revenue by each consumer group was calculated. The average revenue was taken as the proxy for the average price.

The data on average price charged to industrial consumers were converted into an index taking 1962 as a reference year. This index was then divided by the price index of industrial production. The outcome was the deflated index of average price charged to industrial consumers which was taken as a proxy for electricity prices for industrial consumers.

The data on real average prices charged to agricultural consumers were derived by dividing the index of average revenue from agricultural consumers by the price index of agriculture products in the economy.

The revenue earned from electricity sales to "other" consumers was derived by deducting the revenue earned from electricity sales to industrial and agricultural consumers from the total revenue earned. The average price charged to "other" consumers was derived by dividing the revenue earned from electricity sales to "other" consumers by electricity sales to "other" consumers. The index of the average price charged to "other" consumers was derived by taking 1962 as the reference year, and was deflated by the wholesale price index for all commodities in all India.

The data on revenue earned from respective consumer groups were also given by the Central Electricity Authority in their reports till the year 1977-78. After 1977-78 the information was available from the Central Electricity Authority though it was not published in their annual reports. The data on wholesale price index and price indices of agricultural and industrial production were collected from the Planning Commission in New Delhi.

Number of agricultural consumers: ($IANC_t$), number of "other" consumers: ($IONC_t$).

The number of agricultural consumers include all the consumers connected by the electricity boards for agricultural purposes, though electricity boards would come to know about the purpose only if the consumer informs the board and requests to be billed on the basis of agricultural tariffs.

The number of "other" consumers include the consumers connected by electricity boards where the electricity is used for commercial, residential, public lighting, public water works and railways. There are geographical areas in India that have electricity but are not legally connected by electricity boards and therefore do not have electricity meters. For example the slums in the cities do not have electricity meters and thus are not connected legally by electricity boards, but the population living in the slums do use electricity for various purposes including entertainment facilities (e.g. T.V. sets). However these consumers were not included in the number of "other" consumers. And to that extent it is an underestimation of the actual number of consumers using electricity.

The data on number of consumers were taken from the Public Electricity Supply-All India Statistics, a yearly publication by the Central Electricity Authority.

Number of villages electrified:(INV_t).

The Government of India in its objectives in all Five Year Plans included the objective of electrifying as many villages as possible. Therefore every year, many new villages were electrified. The data on the number of villages electrified include all the villages electrified, not just the new villages electrified in that year. These data were taken from the unpublished records of the Central Electricity Authority at New Delhi. The number of villages electrified does not necessarily reflect the number of potential consumers in the village. Sometimes even if only one connection was given to the village (for example to the Gram-Panchayat office for light and sometimes a fan during village council meetings) that village was considered as if the whole village was electrified.

Results.

Table 4.1

Model (4.3):
$\text{Log}(IPCSe_t) = \log b_{03} + b_{13}\log(IPCI_t) + b_{23}\log(RIATR_t) + e_{t3}$
Result:

Period	b_{03}	b_{13}	b_{23}	$\bar{R}^2$	D-W statistic
1953-86					
	-16.86	3.83	-0.6164	0.9103	0.62238
SE	(3.53)	(0.38)	(0.29)		
T-stat.	-4.7	9.9	2.1		

RSS1 = 1.28

Table 4.1a

Model (4.4):
$\text{Log}(IPCSe_t) = \log b_{04} + b_{14}D + b_{24}\log(IPCI_t) + b_{34}D*\log(IPCI_t) + b_{44}\log(RIATR_t) + b_{54}D*\log(RIATR_t) + e_{t4}$
Result:

Period	b_{04}	b_{14}	b_{24}	b_{34}	b_{44}	b_{54}	$\bar{R}^2$	D-W statistic
1953-86								
	-25.85	16.71	5.57	-3.31	-1.05	1.04	0.9575	1.9
SE	(4.24)	(5.2)	(0.47)	(0.64)	(0.4)	(0.51)		
T-stat.	-6.09	3.21	11.7	-5.16	-2.63	2.02		

RSS2 =0.5158

F-statistic: $\dfrac{\text{RSS1 - RSS2/no. of restrictions}}{\text{RSS2/(no. of obs.- no. of explanatory variables).}}$

$$= \frac{1.28-0.5158/3}{0.5158/28}$$

$$= 13.93$$

In order to observe the sign of the coefficients and whether they are significantly (statistically) different from zero or not, we can calculate the coefficient of income and price in the second period and their respective standard errors (from which t-statistic can be calculated) in the following manner.

(i)Coefficient of income in the second period $=(\beta_{24} + \beta_{34})$

(ii)Coefficient of price in the second period $=(\beta_{44} + \beta_{54})$

The $SE(i) = [Var(\beta_{24}) + Var(\beta_{34}) + 2Cov(\beta_{24}, \beta_{34})]$

and $SE(ii) = [Var(\beta_{44}) + Var(\beta_{54}) + 2Cov(\beta_{44}, \beta_{54})]$

Alternatively, one can estimate the model in the following form,

$$Log(IPCCe_t) = \beta_{03a}(D1) + \beta_{13a}(D2) + \beta_{23a}D1*log(IPCI_t) + \beta_{33a}D2*log(IPCI_t) + \beta_{43a}D1*log(RIAPe_t) + \beta_{53a}D2*log(RIAPe_t) + \epsilon_{t3a} \ldots (4.3a)$$

where $IPCCe_t$, $IPCI_t$ and $RIAPe_t$ are same as defined earlier and D1 and D2 are the dummy variables such that D1=1 for the period 1953-72, and D1=0 for the period 1973-86. D2 is such that D2=0 for the period 1953-72 and D2=1 for the period 1973-86. β_{23a} and β_{43a} refers to the coefficients of income and price respectively in the first period whereas β_{33a} and β_{53a} are the coefficients of income and price respectively in the second period. If the t-statistic is statistically significant the coefficients are significantly different from zero, otherwise not. Both methods yield the same result but this method reveals the statistical significance of the coefficients more readily.

Table 4.1b
Calculated coefficients for two period and their respective T-statistics.

	PCI	RIATR
Period 1 (1953-72)	5.57	-1.056
T-st.	11.72	-2.6
Period 2 (1973-86)	2.25	(-0.011)*
T-st.	5.24	-0.033

* Insignificant coefficient.

Table 4.2
Model (4.5):
$Log(IISALE_t) = logb_{05} + b_{15}log(IIP_t) + b_{25}log(PD) + e_{t5}$
Result:

Period	b_{05}	b_{15}	b_{25}	$\bar{R}^2$	D-W.
1947-72	-4.5	2.00	-1.35	0.992	1.14
S.E	(0.19)	(0.044)	(0.23)		
T stat.	-23.7	45.2	-5.66		
1973-86	(0.40)*	0.99	-0.87	0.975	1.6
S.E	(0.26)	(0.04)	(0.17)		
T stat.	1.5	20.5	-4.96		

* Insignificant coefficient.

Table 4.3

Model (4.6):
$Log(IISALE_t) = logb_{06} + b_{16}log(IGDP_t) + b_{26}log(RIIAR_t) + e_{t6}$
Result:

Period	b_{06}	b_{16}	b_{26}	$\bar{R}^2$	D-W Statistic
1953-86					
	-3.6	2.8	-1.05	0.9823	1.67
SE	(0.44)	(0.073)	(0.11)		
T-stat.	-8.24	38.7	-9.15		

RSS1 =0.4282.

Table 4.3a

Model (4.7):
$Log(IISALE_t) = logb_{07} + b_{17}D + b_{27}log(IGDP_t) + b_{37}D*log(IGDP_t) + b_{47}log(RIIAR_t) + b_{57}D*log(RIIAR_t) + e_{t7}$
Result:

Period	b_{07}	b_{17}	b_{27}	b_{37}	b_{47}	b_{57}	$\bar{R}^2$	D-W Statistic
1953-86								
	-7.35	5.61	3.25	-1.87	-0.65	0.75	0.9906	1.72
SE	(1.4)	(1.6)	(0.12)	(0.4)	(0.21)	(0.35)		
T-stat.	-5.14	3.3	26.2	-4.6	-3.1	2.1		

RSS2 = 0.2059

F-statistic : $\dfrac{\text{RSS1 - RSS2/no. of restrictions}}{\text{RSS2/(no. of obs.- no. of explanatory variables)}}$

$$= \frac{RSS1-RSS2/3}{RSS2/28}$$

$$= \frac{(0.4282-0.2059)/3}{0.2059/28}$$

$$= 10.08.$$

Table 4.3b
Calculated coefficients for two period and their respective T-statistics.

	IGDP	RIIAR
Period 1 (1953-72)	3.25	-0.65
T-st.	26.3	-3.1
Period 2 (1973-86)	1.37	(0.099)*
T-st.	3.52	0.357

* Insignificant coefficient.

Table 4.4

Model(4.8):

$Log(IASALE_t) = logb_{08} + b_{18}log(IGDP_t) + b_{28}log(IANC_t) + b_{38}log(INV_t) + b_{48}log(RIAAR_t) + e_{t8}$

Result:

Period	b_{08}	b_{18}	b_{28}	b_{38}	b_{48}	$\bar{R}^2$	D-W Statistic
1953-86							
	-0.248	0.663	0.37	0.431	-0.4151	0.9974	1.739
SE	(0.99)	(0.20)	(0.08)	(0.11)	(0.09)		
T-stat.	-0.24	3.28	4.29	3.67	-4.3		

RSS1 = 0.1640.

Table 4.4a

Model (4.9):

$Log(IASALE_t) = logb_{09} + b_{19}D + b_{29}log(IGDP_t) + b_{39}D{*}log(IGDP_t) + b_{49}log(IANC_t) + b_{59}D{*}log(IANC_t)$
$+ b_{69}log(INV_t) + b_{79}D{*}log(INV_t) + b_{89}log(RIAAR_t) + b_{99}D{*}log(RIAAR_t) + e_{t9}$

Result:

Period	b_{09}	b_{19}	b_{29}	b_{39}	b_{49}	b_{59}	b_{69}	b_{79}	b_{89}	b_{99}
1953-86										
	7.2	-9.4	-1.3	1.8	0.63	0.32	0.5	-0.4	-0.4	0.15
SE	2.3	3.3	0.62	0.95	0.10	1.12	0.5	1.19	0.1	0.31
T-Stat.	3.1	-2.8	-2.1	1.9	6.1	0.28	5.0	-0.3	-3.6	0.5

R^{-2} = 0.9982

D-W statistic =1.559

RSS2 = 0.0933

F-Statistic $\dfrac{\text{RSS1 - RSS2/no. of restrictions}}{\text{RSS2/(no. of obs.- no. of explanatory variables)}}$

$$= \frac{RSS1-RSS2/5}{RSS2/24} = \frac{0.164-0.0933/5}{0.0933/24}$$

= 3.6.

Table 4.5

Model (4.10):

$$\mathrm{Log}(IOSALE_t) = \log b_{010} + b_{110}\log(IGDP_t) + b_{210}\log(IONC_t) + b_{310}\log(RIOAR_t) + e_{t10}$$

Result:

Period	b_{010}	b_{110}	b_{210}	b_{310}	$\bar{R}^2$	D-W Statistic
1953-86						
	-1.53	0.651	0.703	-0.028	0.9988	1.2
SE	(0.58)	(0.16)	(0.05)	(0.02)		
T-stat.	-2.6	3.97	12.49	-1.1		

RSS1 =0.0298.

Table 4.5a

Model (4.11):

$$\mathrm{Log}(IOSALE_t) = \log b_{011} + b_{111}D + b_{211}\log(IGDP_t) + b_{311}D*\log(IGDP_t) + b_{411}\log(IONC_t) + b_{511}D*\log(IONC_t) + b_{611}\log(RIOAR_t) + b_{711}D*\log(RIOAR_t) + e_{t11}$$

Result:

Period	b_{011}	b_{111}	b_{211}	b_{311}	b_{411}	b_{511}	b_{611}	b_{711}
1953-86								
	-0.8	-1.0	0.33	0.48	0.81	-0.1	0.03	-0.09
SE	(0.6)	(1.0)	(0.2)	(0.4)	(0.1)	(0.2)	(0.04)	(0.07)
T-stat.	-1.3	-1.0	1.6	1.22	12.5	-0.7	0.76	-1.2

$\bar{R}^2 = 0.9994$

D-W statistic = 1.76

RSS2 =0.0168

F-statistic :

$$\frac{RSS1 - RSS2/\text{no. of restrictions}}{RSS2/(\text{no. of obs.} - \text{no. of explanatory variables})} = \frac{RSS1-RSS2/4}{RSS2/26} = \frac{0.0298-0.0168/4}{0.0168/26} = 5.0.$$

The data

Table 1

Year	Dependent variables		Independent Variables	
	ITSALE	IPCSe	IPCI	RIATR
(1)	(2)	(3)	(4)	(5)
1947	17.97	21.03	n.a	n.a
1948	19.92	24.74	n.a	n.a
1949	21.4	25.77	n.a	n.a
1950	22.25	32.16	83.24	n.a
1951	25.66	36.7	83.61	n.a
1952	26.79	39.17	84.99	n.a
1953	29.96	43.09	88.87	94.12
1954	33.47	47.42	89.44	91.47
1955	38.06	52.98	90.69	100.69
1956	42.61	54.43	93.74	101.12
1957	50.03	57.52	89.9	103.48
1958	57.38	63.29	95.42	108.01
1959	66.42	71.75	95.08	103.5
1960	74.09	78.76	99.82	104.7
1961	88.05	89.89	100.73	97.72
1962	100.0	100.0	100.00	100.0
1963	116.67	112.16	102.96	98.47
1964	129.66	118.55	108.57	98.0
1965	143.13	126.59	99.82	93.86
1966	155.93	136.49	98.51	95.14
1967	174.99	147.62	104.91	83.01
1968	199.97	160.61	105.23	77.23
1969	219.82	172.16	109.43	82.13
1970	234.08	185.15	113.04	95.78
1971	251.95	193.4	111.93	84.66
1972	262.79	198.55	107.91	89.28
1973	268.99	200.99	110.96	85.28
1974	281.77	204.10	110.32	74.17
1975	322.53	226.7	118.09	61.97
1976	356.59	246.14	116.02	65.51
1977	370.76	257.73	123.82	67.11
1978	413.79	269.97	127.86	66.72
1979	418.03	269.05	118.34	69.77
1980	440.96	272.86	124.74	62.29
1981	483.14	291.28	128.52	54.36
1982	511.74	303.19	128.88	65.14
1983	547.91	318.32	136.44	73.97
1984	610.67	347.46	138.37	75.85
1985	658.48	366.96	142.49	74.3
1986	728.52	393.79	145.03	79.9

ITSALE (2) = Total electricity sales in million units. (i.e., GWH, or million KWH.)
IPCSe (3) = Electricity sale per consumer in Kilowatt hours.
IPCI (4) = Index of per capita income at 1970-71 prices.
RIATR (5) = Index of real average price charged to electricity consumers.

Table 2

Years	Dependent Variable	Independent Variables		
	IISALE	IIP	RIIAR	IGDP
(1)	(2)	(3)	(4)	(5)
1947	16.28	35.19	n.a	56.27
1948	18.57	47.64	n.a	59.62
1949	19.59	33.19	n.a	62.6
1950	19.86	45.34	n.a	65.1
1951	23.3	46.98	n.a	66.48
1952	24.46	48.67	n.a	68.87
1953	27.56	49.6	128.92	73.26
1954	31.09	53.03	125.12	75.24
1955	35.84	57.5	130.67	77.71
1956	40.6	62.28	115.7	81.94
1957	47.04	64.7	116.89	80.46
1958	55.1	69.57	126.69	87.25
1959	64.5	75.3	125.69	88.7
1960	73.1	83.48	121.88	94.74
1961	88.06	91.15	93.14	97.98
1962	100.0	100.0	100.0	100.0
1963	120.84	108.29	99.36	105.12
1964	132.56	117.6	88.19	113.28
1965	143.98	128.43	92.12	107.29
1966	155.54	127.9	100.37	108.37
1967	174.31	127.38	102.82	117.72
1968	197.49	136.04	102.32	120.96
1969	216.46	146.24	105.72	128.63
1970	225.62	153.68	107.6	135.84
1971	241.32	160.13	107.18	137.88
1972	245.95	169.35	106.55	136.39
1973	247.76	172.12	101.57	143.14
1974	249.35	175.66	117.83	144.8
1975	286.56	183.95	115.54	158.64
1976	317.36	189.64	127.45	159.87
1977	325.21	212.54	126.93	174.08
1978	364.05	227.14	142.24	174.47
1979	350.54	229.75	155.44	175.15
1980	366.66	236.82	139.02	189.19
1981	404.76	257.26	129.96	189.3
1982	404.02	267.25	149.01	199.25
1983	435.5	281.69	190.94	204.48
1984	480.7	297.98	192.52	220.83
1985	510.9	322.42	193.83	228.91
1986	545.35	444.12	214.66	240.67

IISALE (2) = Electricity sales to industrial consumers in million kilowatt hours,
IIP (3) = Index of industrial production at 1970-71 prices.
RIIAR (4) = Average revenue earned from electricity sales to industrial consumer group (in paise).
IGDP (5) = Index of gross domestic product at 1970-71 prices. reference year 1970 = 100.

Table 3

Years	Dependent Variable	Independent Variables		
	IASALE	RIAAR	INV	IANC
(1)	(2)	(3)	(4)	(5)
1947	11.35	n.a.	7.21	n.a.
1948	11.02	n.a.	9.52	n.a
1949	13.06	n.a	10.27	n.a
1950	14.65	n.a.	12.68	8.17
1951	18.4	n.a.	13.93	10.32
1952	19.5	n.a	14.3	12.15
1953	19.4	76.32	16.19	13.51
1954	20.97	69.12	19.09	15.24
1955	23.09	83.32	20.64	19.74
1956	28.65	76.94	24.01	26.6
1957	49.35	64.16	30.01	31.85
1958	52.87	73.22	43.19	37.1
1959	68.32	63.8	62.95	44.92
1960	75.48	67.12	78.86	57.67
1961	89.82	75.15	82.45	82.92
1962	100.00	100.0	100.0	100.0
1963	104.5	113.55	103.54	108.48
1964	126.57	99.29	127.45	138.74
1965	171.44	85.22	141.04	169.0
1966	190.89	81.67	155.31	215.27
1967	234.28	68.9	187.54	262.05
1968	314.04	68.69	215.14	344.32
1969	342.01	81.2	253.67	456.27
1970	405.09	77.06	305.58	566.4
1971	453.61	75.76	361.01	646.93
1972	536.3	82.16	420.03	791.57
1973	571.83	73.07	480.1	909.52
1974	703.46	60.33	539.16	1012.1
1975	790.3	59.53	596.97	1109.9
1976	871.83	67.4	639.2	1160.7
1977	915.93	68.69	696.1	1278.7
1978	1090.0	62.73	746.03	1385.1
1979	1219.0	64.23	800.75	1507.7
1980	1313.0	62.13	859.33	1642.6
1981	1377.5	56.74	936.7	1791.7
1982	1614.6	60.25	1020.0	1928.6
1983	1652.3	61.87	1114.2	2072.1
1984	1899.5	55.19	1195.7	2209.7
1985	2122.5	53.95	1274.0	2365.6
1986	2557.1	53.39	1342.6	2567.1

IASALE (2) = Index of electricity sales to agricultural consumers,
RIAAR (3) = Index of real prices charged to agricultural consumers.
INV (4) = Index of number of villages.
IANC (5) = Index of number of agricultural consumers.

Table 4

Years	Dependent Variable	Independent Variables.	
	IOSALE	RIOAR	IONC
(1)	(2)	(3)	(4)
1947	24.56	n.a	n.a
1948	26.08	n.a	n.a
1949	28.8	n.a	n.a
1950	31.15	n.a	28.7
1951	34.39	n.a	32.03
1952	35.47	n.a	35.22
1953	39.63	68.51	38.14
1954	43.55	67.1	41.38
1955	48.32	73.29	47.8
1956	51.94	85.49	53.7
1957	58.98	89.26	57.15
1958	65.19	93.87	60.6
1959	71.6	94.77	68.3
1960	76.66	99.32	75.73
1961	87.6	102.39	88.11
1962	100.0	100.0	100.0
1963	107.46	103.49	110.19
1964	121.9	114.06	126.27
1965	133.63	108.05	142.35
1966	148.47	103.65	158.7
1967	162.34	85.25	176.83
1968	179.06	80.77	190.24
1969	199.5	83.33	210.35
1970	216.66	107.12	229.18
1971	233.35	84.16	254.84
1972	244.66	91.55	279.07
1973	256.52	88.93	307.62
1974	272.72	77.18	329.43
1975	312.54	60.96	352.12
1976	344.47	61.86	369.24
1977	369.78	68.71	403.87
1978	392.73	61.1	438.22
1979	418.23	59.5	462.08
1980	443.59	49.46	503.32
1981	492.23	37.9	550.14
1982	555.47	35.97	598.3
1983	605.0	26.86	641.79
1984	673.79	31.37	702.88
1985	729.98	28.33	759.18
1986	814.42	30.04	825.3

IOSALE (2) = Index of electricity sale to other consumers,
RIOAR (3) = Index of real prices charged to other consumers.
IONC (4) = Index of number of other consumers.

CHAPTER V

ELECTRICITY DEMAND ANALYSIS: CASE STUDY II.

Electricity demand analysis at state level.

In a vast country like India the power situation in different parts was and continues to be diverse. There were differences in the availability of resources, in the growth of installed capacity to generate electricity, in the generation from the installed plants, and in the efficiency of the plants. The differences in the level of population, economic activity, living conditions and climate lead to differences in the pattern of electricity demand. Since the differences in the level of economic activity also affect the total income/output of each region, the effect of income on electricity demand is unlikely to be the same as that observed for "all India" in the previous Chapter. Similarly, the choice of the plant mix in each region is affected by the availability of primary energy sources in that region which in turn affects generation costs. In theory these cost differences should be reflected in prices. Thus, electricity prices in different regions are unlikely to be the same. In practice, the tariffs charged to electricity consumers in different regions were found to be different, and the effect of electricity price on the level of electricity demand may also vary across the different regions in India. This Chapter aims to find the effects of independent variables like income and price on electricity demand by two important consumer groups, agricultural and industrial, in four different states in India.

V.1 Regional differences in the growth of electricity industry.

After Independence, the government of India decided to define each State's territory on the basis of language. It took quite some time for this to be achieved. By 1960-61 most of the states had well defined geographical borders and also their own state governments with their own set of energy policies. There were some states in the North and North-East region which were formed after 1960-61. Table V.1a and V.1b give data on the installed capacity, generation, peak load, system losses and per capita electricity sales in different states in India. There was considerable variation in the level of installed capacity in 1960-61, and this continued into 1970-71 and 1985-86. As can be observed from Table V.2, the average system losses, though they remained almost same in the year 1970-71 as in 1960-61, increased in the year 1985-86. On the other hand, the average peak load, installed capacity, generation and per capita electricity sales increased continuously in the period 1960-61, 1970-71 and 1985-86. The coefficients of variation measured in percentages over the states in 1960-61, 1970-71 and 1985-86 for system losses and per capita electricity sales reveal decreasing variance in per capita electricity sales, but not in system losses. Each of these indicators need to be discussed individually.

V.1.1 Installed Capacity:(IC).

Capacity is installed on the basis of the requirement of power (KW) in the region. Installed capacity at the all India level increased at an average rate of 9.74% per annum. Out of the 16 states/union territories, for which we have the data, 7 of them had higher than average growth rates per annum. These states were Andhra Pradesh, Assam, Jammu & Kashmir, Rajasthan, Madhya Pradesh, Karnataka and Uttar Pradesh. In 1960-61 these states had very low installed capacity. And as a result of government intervention the investment in generating capacity was made, and hence we observe these higher than average growth rates.

<u>Table V.1a</u>
Installed capacity, electricity generation, peak load, system losses and per capita electricity sale in different states in India in 1960-61, 1970-71 and 1985-86.

State	I.C. MW.	Genera-tion. GWH.	Peak Load MW.	System Losses % of Gen	PCSe of Elect. KWH.
A.P.					
1960-61	269.8	900.1	186.4	20.63	19
1970-71	656.9	3,244.1	660.6	24.77	55.66
1985-86	3,365.6	12,269.3	-	22.28	182.2
Assam					
1960-61	19.4	36.3	10.9	16.14	4
1970-71	179.7	369.1	92.4	17.87	21.56
1985-86	432.2	844.6	-	24.27	52.57
Bihar					
1960-61	350.9	1,596.8	307.9	10.88	41
1970-71	499.1	1,372.3	296.8	23.58	65.14
1985-86	1,594.4	3,348.1	-	15.77	94.08
Gujarat					
1960-61	333.3	1,271.2	251.5	16.1	52
1970-71	696.8	2,967.5	597.9	16.59	138.02
1985-86	3,316.2	12,934.2	-	25.09	303.57
J.& K.					
1960-61	13.0	43.5	8.5	21.84	14
1970-71	40.4	168.2	36.9	21.49	37.53
1985-86	205.5	877.7	-	38.97	128.85
Karnataka					
1960-61	191.1	1,058.0	184.3	14.6	44
1970-71	863.7	4,690.6	844.6	14.28	104.26
1985-86	2,529.8	7,597.7	-	24.24	189.08
Kerala					
1960-61	137.3	581.8	131.1	19.99	29
1970-71	548.1	2,137.0	523.9	12.1	75.54
1985-86	1,309.0	5,362.1	-	25.78	139.29
Madhya Pradesh					
1960-61	267.5	477.0	132.7	14.1	20
1970-71	995.6	3,594.9	805.6	14.35	54.13
1985-86	2,943.8	11,478.6	-	19.55	168.32
Maharashtra					
1960-61	759.5	3,267.9	619.0	11.76	52
1970-71	2,329.4	10,343.0	2,117.6	13.1	158.43
1985-86	6,883.9	26,440.3	-	15.68	313.9
Orissa					
1960-61	136.3	489.6	83.5	15.87	43
1970-71	529.8	1,522.9	351.9	5.48	95.68
1985-86	1,234.7	3,677.7	-	23.95	134.15

Table V.1b
Installed capacity, electricity generation, peak load, system losses and per capita electricity sale in different states in India, in 1960-61, 1970-71 and 1985-86.

State	I.C. MW.	Generation GWH.	Peak Load MW.	System Losses % of Gen.	PCS of Elect. KWH.
Punjab					
1960-61	277.1	1,003.6	245.9	23.2	33
1970-71	1,272.0	4,468.0	1,085.0	35.46	158.62
1985-86	2,449.3	10,688.9	-	18.27	423.23
Rajasthan					
1960-61	70.7	108.4	25.8	24.24	11
1970-71	88.7	166.6	34.0	11.91	49.8
1985-86	1,229.9	4,746.6	-	26.18	142.98
Tamilnadu					
1960-61	517.5	2,213.7	453.6	19.29	51
1970-71	1,965.5	5,038.0	1,739.7	17.21	129.53
1985-86	2,528.9	8,632.2	-	18.5	218.18
U.P					
1960-61	397.4	1,252.3	267.3	17.33	15
1970-71	1,351.2	5,724.7	1,259.7	23.63	60.24
1985-86	4,354.7	12,326.8	-	21.12	117.29
W.B.					
1960-61	753.7	2,318.7	567.3	7.21	84
1970-71	1,212.1	4,055.9	872.7	8.3	117.6
1985-86	2,694.4	8,004.1	-	19.32	131.33
Union Territories.					
Delhi					
1960-61	76.3	310.7	66.1	10.12	188
1970-71	314.3	1,353.3	283.4	9.62	285.5
1985-86	256.6	1,158.2	-	23.7	516.32
All India:					
1960-61	4,579.1	16,937.1	3,545.9	14.67	38.2
1970-71	14,708.9	55,827.6	12,532.9	17.5	89.76
1985-86	46,769.3	17,0350.1	-	21.74	177.98

Source: Public Electricity Supply: All India Statistics, op.cit.

V.1.2 Generation.

The amount generated (column 2 in Table V.1a and V.1b) depends mainly upon three factors. i) percentage of installed capacity available, ii) average capability of the available plants, iii) water availability affecting hydro-electric plants and iv) load curve of the region. The first three factors affect the ability of the system to generate electricity at any time and the fourth factor allows the supply system to decide what the actual generation should be. Whichever is lesser of what can be generated and the demand for electricity is the amount actually generated. Due to technical reasons, what is actually generated is always less than the generation when installed capacity is fully utilised. At the "all India" level, generation increased at the average rate of 9.67% per annum.

Table V.2
Mean, Standard Deviation, Coefficient of Variation of installed capacity, electricity generation, peak load, system losses and per capita electricity sale in India; in 1960-61, 1971-72 and 1985-86.

	I.C.	Generation	Peak Load	System Losses	PCSe of Electricity.
N	16	16	16	16	16
Mean(1960-61)	285.7	1,058.1	221.4	16.45	43.7
1970-71	846.5	3,201.0	725.2	16.85	100.45
1985-86	2,333.1	8,149.2	n.a.	22.67	203.46
Standard Deviation					
1960-61	-	-	-	4.75	42.2
1970-71	-	-	-	7.29	63.23
1985-86	-	-	-	5.35	121.45
Coefficient of Variation.					
1960-61	-	-	-	0.28	0.96
1970-71	-	-	-	0.432	0.629
1985-86	-	-	-	0.236	0.597

n.a. = not available, - = not calculated.
Source: Calculated on the basis of the data presented in Tables V.1a and V.1b.

Out of the 16 states, only five states had high annual average growth rates, these states were Andhra Pradesh, Assam, Jammu & Kashmir, Rajasthan and Madhya Pradesh which had all experienced high growth in capacity as well. But in states like Karnataka and Uttar Pradesh, though the annual average growth-rate of installed capacity was high, the annual average growth-rate of generation is very close to 9.0% which is slightly below average.

V.1.3 Peak load.

The rate of growth of peak load reflects the behaviour of consumers: whenever the demand for electricity by most of the consumers tends to increase at a particular hour, the peak load increases at a fast rate. Pricing policy can play a very important role here. A differential rate structure depending upon the time of demand can avoid the fast rising peak and thereby economise on the investment in creating additional capacity to meet the additional peak load demand (KW) and also spread load, with better utilisation of the capacity at off-peak times.

The electricity tariff policy in each state depends upon the State Electricity Board (SEB), for the consumers do not have a choice to select their supplier: there prevails a "natural monopoly" in each state. If peak load pricing was tried and was effective, then, other things being equal, the peak load should have grown more slowly than installed capacity. The available data for peak load after 1972-73 may not represent the true peak demand (KW), since after 1972-73 only the restricted peak load was reported. So the actual rise in peak load is unknown to us. Nevertheless, after the early nineteen seventies oil crisis, the demand for electricity seems to have gone up in parallel with the restricted peak load of the system as a whole.

V.1.4 System losses.

In the process of production and distribution of electricity it is technically inevitable that some portion of electricity is lost. The difference between the electricity available in a system and the quantum of electricity sold to the consumers (within the state and outside the state) is the amount of loss incurred by the system in the process of transmission, transformation and distribution.[97] System losses also included the electricity unaccounted for. However the extent of loss can be controlled and kept to an optimum level by proper planning and a technically sound distribution system. Apart from the loss due to technical reasons such as leakages, overloading of lines, lack of maintenance, lack of improvement of lines etc., there are other social reasons for such unaccounted loss of electricity in the course of its distribution. Unmetered or unauthorised use of electricity, theft of electricity by consumers (especially in the large and growing areas of slums in the large cities), use of energy by some of the staff of the electricity department without metering it, are just some of the other reasons for the difference between the quantum of electricity generated and sold. Part of such losses could be wiped out if proper vigilance is introduced and strict discipline is maintained.

The loss of electricity in the course of transmission and distribution causes loss in revenue to the State Electricity Boards. The system losses as a percentage share of generation at the "all India" level has increased at the average rate of 1.58% per annum. Out of 16 states, 10 states experienced a rise at a higher rate than observed for India as a whole. In states like Orissa, Rajasthan and the union territory of Delhi, the system losses decreased till 1970-71, but it increased after 1971.

From the data on percentage loss of energy available in different states in India, it is very difficult to generalise the reason for decreasing/increasing system losses. System losses depend upon geographical location of despatch centres and load centres, economies of scale (for example, over long distances it is cheaper to transmit

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[97] Energy Available = (generation by SEB + from the public utilities in adjoining states) - energy used by power station auxiliaries.

electricity at high voltage) etc. These characteristics do vary across states. Therefore, though it is important to optimise the system losses in every state, it is not possible to generalise the possible reasons for high system losses.

V.1.5 Per Capita Sale of electricity:(PCSe).

Per capita electricity consumption is taken as one of the indicators of development by the World Bank. Per capita electricity sales in India as a whole increased at an annual average growth rate of 6.34%. In India, since Independence, one of the national objectives has been balanced regional growth. The coefficient of variation for per capita sale of electricity reveals that, though the disparity has decreased over the period, i.e. the coefficient of variation in per capita sale of electricity over the states was 96% in 1960-61, 63% in 1970-71, and was still as high as 59% in 1985-86 (Table V.2). In the states of Andhra Pradesh, Assam, Jammu and Kashmir, Madhya Pradesh, Uttar Pradesh, Rajasthan, Kerala and Punjab, the per capita sale of electricity was lower than at the all-India level. Of these, Assam, Jammu and Kashmir, Madhya Pradesh, Uttar Pradesh and Kerala continued to have lower per capita sale of electricity even in the year 1985-86. There were three other states (Orissa, Bihar and West Bengal) that joined the group of states having lower than average per capita sale of electricity in the year 1985-86. Thus, the situation between states changed over the period under study but did not necessarily improve in all states over the same period.

In order to study the demand pattern and the effects of price and income on electricity demand in more detail, I have chosen four states from four different regions of India; Maharashtra from the Western region, Kerala from the Southern region, Bihar from the Eastern region and Punjab from the Northern region.[98]

V.2 A Study of four States in India: Maharashtra, Kerala, Bihar, Punjab.

Bihar has a total geographical area of 1.74 lakh square Kilometres and ranks sixth in the country in terms of area. It is the second most populated state in the country. Even though the state is endowed with water resources, much of it has remained untapped. The cropping pattern in Bihar is dominated by food-grains. Rural electrification and agricultural activities have received increasing attention in recent years but, according to the Reserve Bank of India (RBI),[99] the power supply situation is a major constraint to the efficient utilisation of tube-wells. Even though several large-scale industrial units are located in the state, it largely remains a backward state. Apart from the large scale demand for power by the heavy engineering and steel units located in South Bihar, the per capita power demand in Bihar as a whole remained quite low. Two agencies look after the generation of power and its distribution in Bihar. These are the Bihar State Electricity Board (BSEB) and the Damodar Valley Corporation (DVC). The latter was established in 1948 and is responsible for the unified development of the Damodar Valley, covering an area of 2,423,559 Square Kilometres in the states of Bihar and West Bengal. Thus, the power supply in Bihar comes not only from the power plants under the BSEB, but also from its share in DVC.

Kerala is the smallest of the four Southern states. It

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[98] Consistent data were not available for long periods from the states in North-Eastern region, hence it was not possible to include any state from the North-Eastern region.

[99] "Agriculture productivity in Eastern India", Report of the Committee on Agricultural productivity in Eastern India, Reserve Bank of India, Volume II, (1984), p.251.

has the advantage of abundant rainfall from the South West monsoon. It has the highest population density and the highest literacy rate in India. In 1976-77, the state government of Kerala completed a programme of rapid industrialisation. Nearly 10,000 small scale units, manufacturing a variety of products were started involving a total investment of around Rs. 150 crores (i.e. 1,500 millions). The state government also accelerated the tempo of electrification of irrigation pump-sets; 97% of its villages were electrified by the year 1986-87.

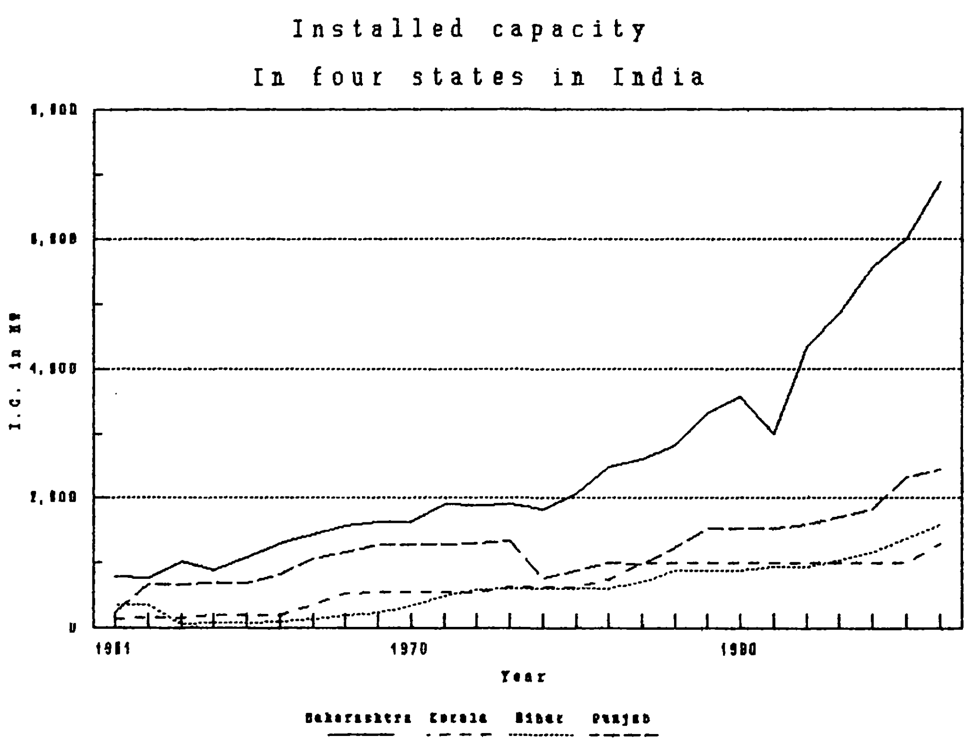
Maharashtra is the third largest state in India, both in area and population. It has the highest installed capacity and generation of electrical energy in the country. It accounts for one fourth of the industrial production and one-sixth of power demand by the industrial sector in the country. Since Maharashtra has attached special importance to the electrification of agricultural activities in order to wipe out its food deficit; demand for electricity from agriculture has been growing fast.

The present state of Punjab has shrunk in size by nearly half in terms of population, and more than half in terms of area since its reorganisation in 1966. But the compact state that was left after the formation of Haryana and enlargement of Himachal Pradesh, proved to be a prosperous one, with a high level of per capita income. The industrial advancement that has taken place in Punjab has so far been oriented towards small-scale and medium-sized industry. The hosiery and textile units in Amritsar, sports goods in Luthiana, the mini steel plants and engineering units all over the state contributed to the growth in industrial load in Punjab. Energy supply to agriculture has also been a top priority in Punjab, which is the first State to have achieved the green revolution in India.

<u>V.2.1 Installed capacity, plant mix and generation in the four states in the period 1961-86.</u>

Installed capacity increased at the fastest rate (annual average rate), of 10%, in the state of Bihar. In Kerala the installed capacity increased at the rate of 9% per annum, in Maharashtra at 7.9% and in Punjab it increased by 5.9%. It is important to remember that the level of installed capacity for each one of the four states was not the same in 1960-61.

Graph V.1



From Graph V.1, we can observe that the installed capacity was growing steadily in Kerala but in the year 1961 Kerala had only 137.3 MW of installed capacity. In the remaining states the total installed capacity has also been growing steadily; but for various purposes the categorisation of the installed capacity under different ownership was changed. Hence we find that the installed capacity as reported under the ownership of the public sector did not have a steady but a misleading irregular increase. For example, Maharashtra had a fairly steady increase in installed capacity after 1964. The states of Maharashtra and Gujarat were combined states till 1960 but in May 1960 Maharashtra was separated from Gujarat. The power stations located in the region of Gujarat were counted as the property of the Gujarat Electricity Board and likewise for Maharashtra. The Tata Electric Company's (TEC) share of installed capacity was counted in the Maharashtra State Electricity Board (MSEB)'s total installed capacity till 1963 but not after 1963. After 1963, TEC's share of installed capacity was considered as a part of the installed capacity of private undertakings. In Bihar for that matter, it was only after 1963 that the Damodar Valley Corporation (DVC) was considered as a corporation separate from the Bihar State Electricity Board (BSEB), and hence in 1963 BSEB started with only 50 MW of installed capacity. Central Electricity Authority (CEA), decided to compare the maximum demand with the installed capacity but they could not split the data on maximum demand (KW) of such stations hence the reports[100] till 1972-73, reported the installed plant capacity and generation of jointly owned projects under the state that had the maximum share.[101] In the case of Punjab, the installed capacity of the joint hydro-electric plant was counted in the installed capacity of the Punjab State Electricity Board hence, the installed capacity appears to have decreased in the year 1974.

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[100] Public Electricity Supply: All India Statistics, Central Electricity Authority, Department of Power, Ministry of Energy, Government of India, New Delhi, (annual publication).

[101] From the interviews with CEA officials in April 1989, New Delhi, (India).

Table V.3a
Plant mix in the four states; i.e., Maharashtra, Kerala, Bihar and Punjab. Percentage share of hydro-electric plants and coal based thermal plants in the total installed capacity.

Year	% share of hydro plants.				% share of thermal plants.			
	Mahar-ashtra	Kerala	Bihar	Punjab	Mahar-ashtra	Kerala	Bihar	Punjab
1961	37.1	96.5	12.5	91.1	58.3	0	82.2	2.8
1962	36.7	96.5	12.5	96.5	57.5	0	81.5	1.0
1963	51.7	97.5	0	96.3	43.6	0	61.3	1.6
1964	59.1	99.4	0	94.9	34.6	0	72.1	2.6
1965	48.6	99.5	0	94.8	46.7	0	74.9	2.6
1966	45.9	97.7	0	93.6	50.0	0	79.1	3.9
1967	52.1	99.0	0	95.0	45.0	0	88.6	3.1
1968	52.4	99.7	0	98.1	44.8	0	91.1	1.3
1969	51.5	99.7	0	98.3	47.0	0	93.1	1.1
1970	51.9	99.7	1.4	98.4	47.3	0	93.8	0.2
1971	44.2	99.7	2.0	98.4	55.0	0	94.7	1.1
1972	44.4	99.7	1.6	97.6	54.8	0	95.6	1.1
1973	44.0	99.7	2.3	95.2	55.8	0	94.8	1.1
1974	46.3	99.5	2.4	91.9	53.5	0	94.7	0.6
1975	41.3	99.5	2.4	80.6	58.7	0	94.8	12.9
1976	47.4	99.6	2.4	71.8	52.6	0	94.7	22.5
1977	45.2	99.8	2.1	73.5	54.8	0	95.9	23.0
1978	42.4	100	9.5	71.7	57.6	0	89.0	26.8
1979	38.4	100	9.5	70.1	61.5	0	88.9	28.9
1980	36.5	100	9.5	70.2	63.5	0	88.9	28.5
1981	33.0	100	15.9	70.4	67.0	0	82.7	28.6
1982	30.5	100	15.9	71.3	66.7	0	82.8	27.7
1983	27.1	100	14.2	66.4	67.9	0	84.6	25.8
1984	23.6	100	12.9	75.3	72.0	0	86.0	24.0
1985	22.0	100	10.9	62.4	73.9	0	88.6	37.1
1986	19.7	100	9.4	64.4	70.5	0	90.2	35.1

Source: Public Electricity Supply-All India Statistics, op.cit.

From Table V.3a and V.3b we can gather information regarding the plant mix in the four states.

The installed capacity in hydro-electric plants increased by 9.1% per annum in Kerala, by 5.7% per annum in Maharashtra and by 4.3% per annum in Punjab. The installed capacity in the coal-based plants increased at an average annual rate of 10.7% in Bihar, 9.5% in Maharashtra, 20.1% in Punjab. Bihar was a dry state and continues to be one.

Table V.3b

Plant Mix in the Four states; i.e., Maharashtra, Kerala, Bihar and Punjab. Percentage share of gas plants and oil plants in the total installed capacity.

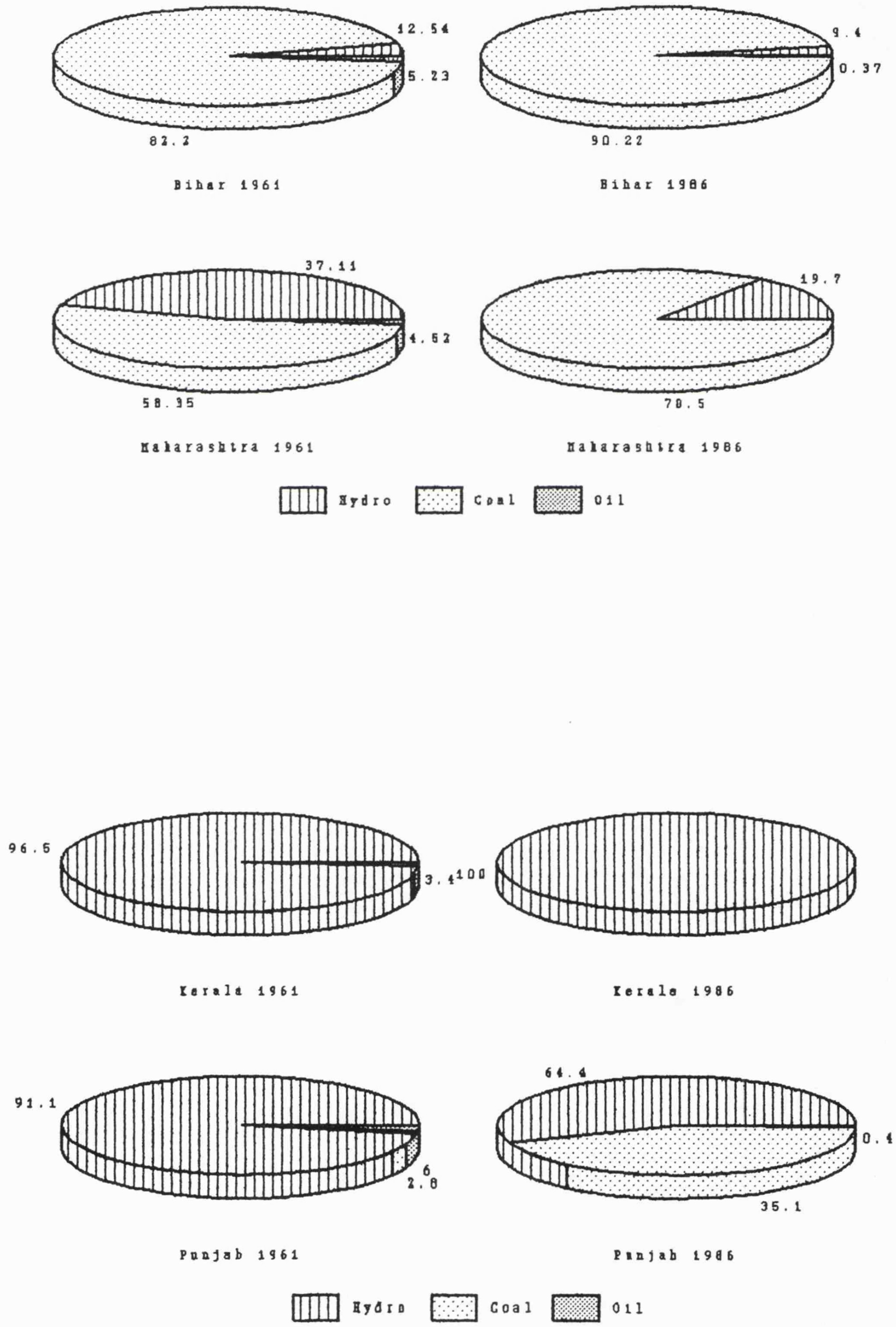
Year	% share of gas plants. Mahar-ashtra	Kerala	Bihar	Punjab	% share of oil plants. Mahar-ashtra	Kerala	Bihar	Punjab
1961	0	0	0	0	4.5	3.4	5.2	6.0
1962	0	0	0	0	5.7	2.5	5.9	2.4
1963	0	0	0	0	4.5	2.5	38.6	2.1
1964	0	0	0	0	6.1	0.6	27.8	2.4
1965	0	0	0	0	4.6	0.5	25.1	2.5
1966	0	0	0	0	4.0	2.3	20.9	2.3
1967	0	0	0	0	2.9	0.9	11.4	1.8
1968	0	0	0	0	2.6	0.3	8.8	0.5
1969	0	0	0	0	1.4	0.3	6.8	0.5
1970	0	0	0	0	0.7	0.3	4.7	0.3
1971	0	0	0	0	0.7	0.3	3.3	0.3
1972	0	0	0	0	0.7	0.3	2.7	1.1
1973	0	0	0	0	0.1	0.2	2.7	3.6
1974	0	0	0	0	0.1	0.5	2.7	7.4
1975	0	0	0	0	0.0	0.5	2.7	6.4
1976	0	0	0	0	0.0	0.4	2.7	5.6
1977	0	0	0	0	0.0	0.1	1.9	3.4
1978	0	0	0	0	0.0	0.0	1.4	1.3
1979	0	0	0	0	0.0	0.0	1.5	0.9
1980	0	0	0	0	0.0	0.0	1.5	0.9
1981	0	0	0	0	0.0	0.0	1.4	0.9
1982	2.7	0	0	0	0.0	0.0	1.3	0.8
1983	4.9	0	0	0	0.0	0.0	1.1	0.6
1984	4.3	0	0	0	0.0	0.0	1.0	0.6
1985	4.0	0	0	0	0.0	0.0	0.4	0.4
1986	9.7	0	0	0	0.0	0.0	0.4	0.4

Source: <u>Public Electricity Supply-All India Statistics</u>, <u>op.cit</u>.

From the pie charts (Graph V.2) for two different years i.e., 1961, and 1986 we can observe that the installed capacity in Kerala has been predominantly in hydro-electric plants, whereas in Bihar the coal-based plants have dominated the scene.

Graph V.2

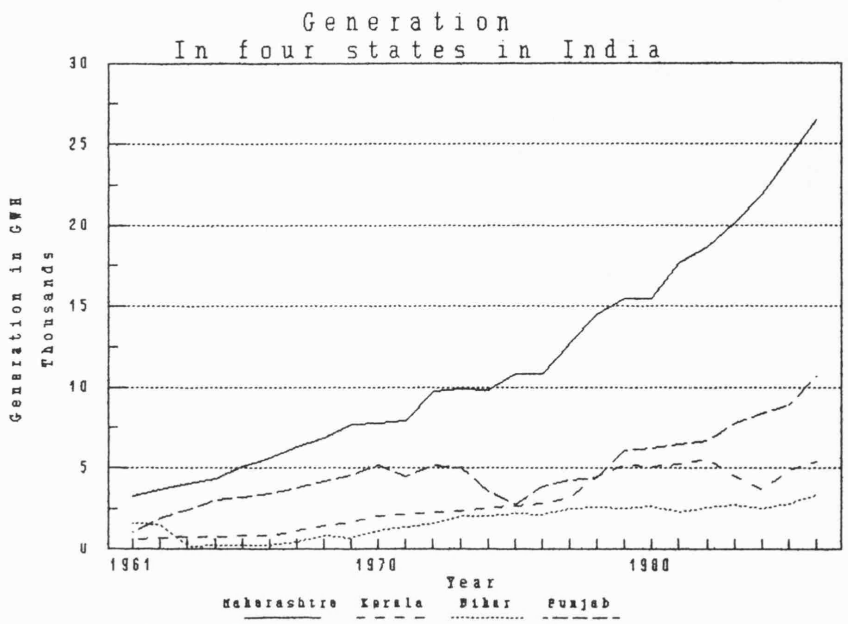
Plant mix in four states in India
1961 and 1986



Punjab in fact had very low (7.27 MW) capacity in coal-based plants in 1960 hence the high growth rate. Kerala did not have coal-based plants at all, while Bihar had few hydro-electric plants. The availability of coal led Bihar to concentrate its plant capacity in coal-based plants. Oil-based plants have never been important except in Bihar in the sixties but their share in the total installed capacity declined rapidly till 1973. Punjab had a major share of its installed capacity in hydro-electric plants but its share declined after 1973. This could be due to more expensive unit costs of generating electricity from any incremental hydro-electric plants. This could be due to either capital intensive hydro-electric projects or the potential sites for the hydro-electric plants may have been on those rivers where the flow of water was not expected to be flowing at a constant force in all seasons. In Maharashtra the share of hydro plants in the total installed capacity has been fluctuating between 20 to 50 per cent of the total installed capacity until 1977, and has since been continuously declining as new investment has been mainly in the coal based plants. Except for Maharashtra (and there only after 1982), gas based plants have not been installed in any of the four states during the whole sample period.

As can be seen from Graph V.3, generation of electricity has been growing steadily in four states though at different rate. Generation of electricity has been growing at an annual average rate of 9.6% in Kerala. In Bihar, generation was growing by 8.4%, at 6.5% per annum in Maharashtra and at 6.5% per annum in Punjab. The installed capacity reflects the planned generation of electricity but as discussed in Chapter II, the ability to generate electricity depends upon the percentage availability of installed capacity, average capability of the plant and the amount of water coming down to hydro-electric plants. While

Graph V.3



the actual generation depends upon these three factors and the load curve. When there is no excess demand, generation reflects the characteristics of demand. Over a period of time the fuel used in different final activities gets replaced by electricity; and if there is excess demand, the full utilisation of the plants becomes possible and the generation reflects the availability of electricity supply. It is quite likely that economic activities in Maharashtra and Bihar led to increases in the peak load i.e., maximum demand (KW), rather than just increase in total energy supplied and that this led to fast increases in installed capacity.

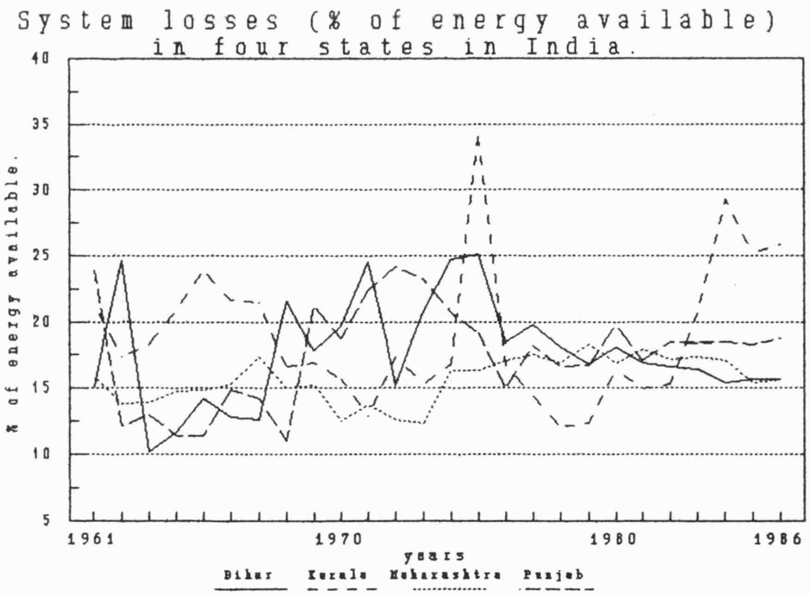
V.3 Intensity of plant utilisation in the four states.

The supply of electricity from the electricity system depends very much on technical efficiency in production and distribution. The important parameters that are commonly used in discussing technical efficiency of the electricity generating plants are the "load factor", "plant factor" and "diversity factor". As discussed in Chapter II, it is important to recognise the fact that one can not compare these parameters in absolute terms and these parameters do not reflect technical efficiency unless compared with planned values of these parameters. Hence, we will discuss only system losses as a measure of technical efficiency and observe if optimising system losses would lead to any increase in social gain.

V.3.1 System losses.

As discussed in Section V.1.4, it is not possible to avoid system losses completely in any system. And it is difficult to generalise the reasons for the high system losses. But from Table V.4, we observe that the system losses in four states in India were very marked.

Graph V.4



From Graph V.4, we can observe that except in Bihar after 1977, and Maharashtra over the whole period, the rest of two states have not been successful in either optimising the losses or in maintaining a constant level of system losses.

Table V.4
System Losses in absolute terms and as percentage share of generation, in four states; i.e., Maharashtra, Kerala, Bihar and Punjab.

Year	System Losses In MKWH. (absolute terms)				System Losses as a percentage of energy available in the state.			
	Mahar- ashtra	Kerala	Bihar	Punjab	Mahar- ashtra	Kerala	Bihar	Punjab
1961	520.5	134.7	272.5	240.5	15.9	21.3	15.07	23.9
1962	503.8	130.2	390.8	225.3	13.8	17.3	24.6	12.1
1963	561.7	140.5	145.9	310.0	13.9	18.3	10.2	13.0
1964	625.1	169.4	121.4	312.0	14.7	20.9	11.7	10.4
1965	754.1	213.5	175.5	365.0	14.8	23.9	14.2	11.4
1966	863.2	207.3	174.2	507.8	15.3	21.6	12.8	14.8
1967	1,098.7	248.9	200.6	541.8	17.3	21.4	12.6	14.2
1968	1,024.5	239.2	425.7	459.6	15.0	16.6	21.5	11.0
1969	1,124.5	274.9	343.6	527.7	15.2	16.9	17.8	21.2
1970	1,019.0	321.3	453.1	587.6	12.5	15.7	19.7	18.7
1971	1,213.3	278.0	559.3	631.9	13.7	12.9	24.5	22.4
1972	1,276.1	394.1	652.1	756.2	12.6	17.3	15.2	24.2
1973	1,253.6	358.2	997.3	701.7	12.3	15.3	20.8	23.2
1974	1,737.9	428.1	932.6	725.3	16.3	16.8	24.7	20.7
1975	1,835.0	908.9	1,134.3	534.5	16.3	34.5	25.1	19.1
1976	1,978.2	464.1	908.1	625.8	17.1	16.7	18.4	15.0
1977	2,384.8	452.5	1,064.5	835.7	17.5	14.4	19.8	18.2
1978	2,568.6	534.9	963.5	758.3	16.9	12.0	18.1	16.6
1979	2,986.3	637.8	957.4	1,019.7	18.3	12.3	16.8	16.7
1980	2,679.0	844.7	931.5	1,240.3	16.9	16.4	18.1	19.8
1981	3,147.3	783.8	836.8	1,070.3	17.9	14.9	16.9	17.1
1982	3,185.3	848.5	963.9	1,219.2	17.2	15.3	16.6	18.5
1983	3,411.9	939.2	972.1	1,340.2	17.3	20.6	16.4	18.4
1984	3,729.3	1,104.7	933.4	1,498.0	17.1	29.3	15.4	18.5
1985	3,713.6	1,256.4	978.7	1,479.0	15.4	25.2	15.7	18.3
1986	4,254.4	1,435.6	1,089.7	1,859.7	15.7	25.8	15.7	18.7

Source: <u>Public Electricity Supply-All India Statistics</u>, <u>op.cit</u>.

States like Punjab had system losses (as percentage of generation) as low as 11% in 1968, which shows the possibility of keeping the system losses to that low level, but a conscious effort and coherent policy to optimise system losses and maintain that level seem to be missing in these states.

In Section V.1.4, it was also discussed that there are technical as well as social reasons for system losses. From an economic point of view the losses due to social reasons could be regarded as transfer payments because the real unmetered electricity is still used for productive/consumable purposes. But the loss of electricity in the course of distribution causes loss in the revenue to the State Electricity Board and this revenue loss should be optimised.

It would be interesting to know, if the State Electricity Boards were successful in their efforts to optimise the system losses, what would be the effect on the social gain from using electricity?

In order to get an idea about the effects on social gain if system losses were reduced by for example 33% (or 1/3), we need to know what would have been the extra supply of electricity as a result of reduction in system losses by one third.[102] Table V.5 shows the extra supply as a result of reducing system losses by one third. This indicates the extent to which electric utilities in the respective states would have reduced electricity shortages. Using the nominal price of electricity in respective states over the years, we can calculate the gain in revenue of respective State Electricity Boards. This shows that the State Electricity Boards would be able to reduce the shortages in supply and also increase their earnings.

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[102] Usually electricity generated in any state is less than the electricity available in any state. This is so because different states get their respective share of electricity from the centrally owned power stations. But we can assume that the system losses as a percentage of energy available was the same as the system losses as a percentage of energy generated.

Table V.5
Extra supply of electricity (in MKWH) in four states and the nominal price of unit electricity in four states; i.e., Maharashtra, Kerala, Bihar and Punjab.

Year	Extra Supply as result of reduction in System losses by one third. In MKWH. (absolute terms)				Price charged per KWH in each State. (Paise per unit.)			
	Bihar	Kerala	Maharashtra	Punjab	Bihar	Kerala	Maharashtra	Punjab
1961	80.21	44.9	173.2	80.17	14.95	11.95	14.54	9.5
1962	124.64	43.4	167.4	75.1	14.95	11.95	14.54	9.5
1963	5.00	46.8	187.9	103.33	14.95	10.3	15.96	9.5
1964	6.87	53.11	214.1	119.92	16.0	10.3	15.96	9.5
1965	10.21	71.17	250.7	121.67	19.9	13.4	15.96	9.5
1966	8.84	69.1	287.4	169.27	19.9	13.46	16.26	10.23
1967	17.57	82.97	365.2	180.6	19.9	13.46	13.13	10.23
1968	55.88	79.73	341.2	153.2	21.2	16.68	13.13	10.23
1969	37.22	91.63	388.3	175.9	21.24	16.68	17.62	10.23
1970	71.51	107.10	322.2	195.87	22.76	17.51	17.62	10.23
1971	112.07	92.67	361.9	210.63	22.76	17.51	17.62	10.23
1972	77.83	131.37	408.2	252.07	23.53	17.51	14.58	10.23
1973	142.18	119.4	405.8	233.9	23.53	17.82	18.56	10.16
1974	163.87	142.7	533.7	241.77	23.76	17.82	18.56	10.16
1975	180.17	302.97	586.5	178.17	30.4	18.42	20.7	19.19
1976	130.94	154.7	614.9	208.6	34.48	18.41	22.67	23.88
1977	162.71	150.83	741.6	278.57	34.32	19.46	22.67	23.88
1978	155.55	178.3	815.8	252.77	34.32	19.46	22.67	23.88
1979	138.48	212.6	944.9	339.9	34.32	23.23	32.82	28.41
1980	159.35	281.57	873.4	413.43	40.07	23.23	32.82	28.41
1981	128.48	261.27	1,054.0	356.77	51.85	29.7	38.67	32.11
1982	142.91	282.83	1,071.1	406.4	65.0	29.7	46.91	42.33
1983	150.51	313.07	1,161.3	446.73	65.5	33.45	52.0	45.28
1984	126.22	368.23	1,249.0	499.33	77.93	34.02	54.57	48.28
1985	145.36	418.8	1,215.4	493.0	77.93	35.18	57.64	48.28
1986	175.99	478.54	1,381.9	619.91	77.93	35.18	71.98	59.09

Source: Extra Supply in four states is calculated on the basis of the data presented in Table V.4. The data on price charged in four states were collected from unpublished sources of respective State Electricity Board.

The consumers would value each extra unit of electricity supply more than the price that they pay for one unit of electricity. This would be the case since the consumers would not have been able to get what they want at the price that they paid during shortages. So, the social gain of each extra unit of electricity would be more than the revenue earned by the SEBs for each extra unit of electricity supplied. Thus, the revenue gain as a result of reduction in system losses by one third gives us lower estimate of social gain.

Table V.6
The revenue gain to the State Electricity Boards in four states; i.e., Maharashtra, Kerala, Bihar and Punjab. (in million Rupees).

Year	Extra Revenue as a result of reduction in system losses by one third. Bihar	Kerala	Maharashtra	Punjab
1961	11.99	5.36	25.18	7.62
1962	18.63	5.19	24.33	7.13
1963	0.75	4.82	29.99	9.82
1964	1.1	5.47	34.16	11.39
1965	2.03	9.57	40.01	11.55
1966	1.75	9.3	46.73	17.31
1967	3.49	11.17	47.95	18.47
1968	11.86	13.29	44.8	15.67
1969	7.9	15.28	68.42	17.99
1970	16.27	18.75	56.76	20.04
1971	25.5	16.22	63.77	21.55
1972	18.31	23.00	59.52	25.78
1973	33.45	21.28	75.32	23.76
1974	38.94	25.43	99.05	24.56
1975	54.77	55.8	121.42	34.19
1976	45.15	28.48	139.39	49.81
1977	55.84	29.35	168.11	66.52
1978	53.39	34.69	184.95	60.32
1979	47.53	49.39	310.14	96.56
1980	63.85	65.41	286.64	117.46
1981	66.61	77.6	407.57	114.56
1982	92.9	84.00	502.45	172.03
1983	98.58	104.72	603.88	202.28
1984	98.36	125.27	681.56	241.1
1985	113.28	147.33	700.56	238.02
1986	137.16	168.35	994.72	366.3

Source: Calculated from Table V.5.

Even if the reduction in system losses is achieved only by reducing electricity theft, the revenue to SEBs would increase. And the social gain would still be higher than the revenue gain, if the marginal value of electricity to thieves is less than the marginal value of electricity to those consumers who suffer from electricity shortages. Usually the marginal value of electricity would be more than zero. Whereas the marginal value of electricity to those who want to buy it, would be at least the price per unit that they are expected to pay. Thus, reduction in system losses by reducing theft would mean transferring electricity to those to whom it is worth at least the price they were expected to pay, from those to whom it is worth less than the price they were expected to pay.

Thus, irrespective of whether the utilities are able reduce system losses by reducing theft or by optimising losses while transmitting and distributing, there is bound to be some social gain. And the lower limit of this social gain is approximated by the revenue gain as shown in Table V.6. Our examination of four states can now be summarised. The plant mix in the sample of four states was different and hence the cost of generation and distribution was also different. Also, the level and combination of economic activities were different leading to differences in the pattern of demand in each state. Hence, we find differences in the rate at which generation was increasing compared to the rate at which installed capacity was increasing. There were also some common features among the four states. The high and fluctuating system losses was the main common feature though the rate at which system losses were fluctuating was found to be different. This indicates the possibility of achieving a higher level of generation and reduce power shortages with the existing capacity by optimising system losses. This can be achieved by conscious and vigorous efforts by the State Electricity Boards.

V.4 Time-series analysis of electricity demand for the four States.

V.4.1 Growth of electricity sales to industrial and agricultural consumers.

In any large and diverse country like India, it is difficult to imagine uniformity in her regions. It is quite likely that industrial activity dominates the economy of one state and not the other. For example as can be observed from Table V.7, the share of electricity sales to industrial consumers declined over the period though it remained quite high in all four states, whereas the share of electricity sales to agricultural consumers increased over a period of time in all the four states, but at different rates.

Table V.7
Share of electricity sale to industrial consumers and agricultural consumers in total electricity sale in the four states; i.e., Maharashtra, Kerala, Bihar and Punjab.

Year	% share of Industrial consumers.				% share of agricultural consumers.			
	Mahar-ashtra	Kerala	Bihar	Punjab	Mahar-ashtra	Kerala	Bihar	Punjab
1961	68.1	81.5	89.2	61.3	0.5	3.7	1.7	12.8
1962	69.4	83.6	82.5	80.0	0.4	3.0	1.9	7.2
1963	69.9	82.2	78.4	81.1	0.5	3.0	1.5	6.4
1964	77.0	83.4	79.8	86.7	0.7	2.3	1.3	5.0
1965	69.7	81.1	74.9	86.3	1.0	3.3	1.3	5.2
1966	69.9	80.4	77.4	81.5	1.8	3.2	1.5	8.9
1967	69.6	83.2	70.7	80.6	2.1	3.4	2.3	10.0
1968	67.3	84.6	68.3	84.9	2.6	2.6	4.2	6.7
1969	70.2	84.6	67.4	81.2	3.6	3.3	4.2	8.8
1970	69.4	83.9	67.5	74.5	4.3	2.8	4.2	14.6
1971	69.4	82.5	69.7	65.3	4.6	2.7	4.0	22.0
1972	67.3	81.4	75.4	63.1	4.8	4.3	2.0	24.0
1973	67.9	80.4	73.8	59.8	5.1	4.5	2.7	27.2
1974	69.0	78.2	74.7	59.9	5.5	5.1	2.7	25.6
1975	66.9	76.2	75.9	53.7	7.1	5.6	2.6	31.3
1976	62.5	74.9	69.0	60.6	8.4	6.0	12.0	26.5
1977	62.1	74.6	71.3	59.3	8.5	4.8	10.9	25.8
1978	61.2	76.2	73.5	51.9	8.9	3.4	7.1	31.7
1979	60.4	74.9	78.0	50.5	10.7	3.4	4.6	35.4
1980	59.1	70.8	71.4	47.3	10.4	3.4	11.2	38.5
1981	57.9	70.1	71.4	47.1	12.2	2.9	11.5	37.0
1982	57.4	64.5	73.2	46.3	12.5	3.5	10.9	36.6
1983	53.4	61.1	71.0	46.1	15.2	3.6	13.0	36.4
1984	54.9	58.8	71.6	47.7	15.0	3.7	12.9	34.7
1985	52.5	62.2	72.4	45.0	17.6	2.9	11.9	34.3
1986	53.1	60.4	70.1	47.1	17.5	2.6	14.2	35.9

Source: Calculated on the basis of the data on electricity sales to different consumer groups.

Therefore it is important to observe the growth rate of electricity sales to different consumer groups.

V.4.2 Models.

The growth-rates of the electricity sales to different consumer group were calculated using the simple and semi-log growth models. As explained in Chapter IV, Section IV.1.2, the following two models were used,

$$Isale_{it} = \alpha_{i01} + \alpha_{i11}t + \epsilon_{it1} \quad \text{....(from 4.1)}$$

$$lIsale_{it} = \alpha_{i02} + \alpha_{i12}t + \epsilon_{it2} \quad \text{.....(from 4.2)}$$

where,

Isale = index of electricity sales,

t = time variable, i.e 1,2,..,26 for the years 1961 to 1986, and

i refers to the state i.e. 1,2,3,4 for 4 states.

This is the general model therefore it can be used for both agricultural and industrial consumer groups.

V.4.3 Results.

Linear and semi-log time trends were fitted to the data[103] for electricity sales to industrial and agricultural consumers. From the analysis it was gathered that electricity sales to the two different consumer groups in all four states were better explained by the semi-log models. The annual average growth-rates of electricity sales to both the consumer groups in the period 1961-86, in four states can be observed from Table V.8. Punjab had the lowest growth-rate of electricity sales to industries in the period 1961-86. The annual average growth-rate appeared to be much the same in the states of Maharashtra, Kerala and Bihar: they were statistically different from each other but the economic difference is probably not significant. From the data on electricity sales to

[103] For explanation of the data used please refer to the Appendix to Chapter V.

different consumers in four states, a difference in the pattern of growth after 1973 was observed. The growth-rate in the first sub-period in the state of Bihar and Punjab was statistically not different from the growth-rate in the second sub-period in the respective states. However we observe a remarkable difference in the growth-rate between the sub-periods in the states of Maharashtra and Kerala. In both these states the growth-rate of electricity sales to industries was much higher in the period 1961-72 compared to the growth-rate in the period 1973-86.

Table V.8
Annual average growth-rates (in percentages) of electricity sales to industries and agricultural consumers in four states.

State & consumer group	Period 1961-86	1961-72	1973-86
Bihar			
Industrial	6.2	4.05	4.75
Agricultural	16.5	15.0	17.0
Kerala			
Industrial	6.3	11.4	3.13
Agricultural	8.21	11.7	(0.006)
Maharashtra			
Industrial	6.35	10.0	4.61
Agricultural	22.0	35.15	16.02
Punjab			
Industrial	3.9	6.61	6.64
Agricultural	14.93	16.6	11.7

Note: Figures in the brackets are statistically not different from zero. i.e. insignificant coefficients.

Electricity sales to agricultural consumers in the period 1961-86 also grew at different rates in all four states. The growth-rate of electricity sales to agriculture was the highest in the state of Maharashtra and the lowest in Kerala. Also, the growth rates for the two sub-periods were estimated. Except for Bihar, in all other states electricity sales to agricultural consumers grew at different rates in the two sub-periods; and in those three states the growth rate of electricity sales to agricultural consumers was found to be higher in the first sub-period compared to the second sub-period. In the case of Kerala, in the period 1973-86, the electricity sales to agricultural consumers did not grow at all.

Differences in the growth-rates of electricity sales to both the consumer groups in two sub-periods reflect the effect of power cuts in the second period. Except in Kerala, electricity sales to the agricultural consumers in all states grew at a faster rate than electricity sales to industries.

The different growth rates of electricity demand in four states may have been due to differences in the growth rate of economic activity, and other, demographic characteristics of the state. We cannot assume that the effects of income and population or number of consumers was the same in all four states. Prices charged (average and marginal price of electricity) per unit of electricity were found to be different in all states. In order to observe the effect of prices, income and the number of consumers on electricity demand the econometric models specified below were used.

V.5 Models for electricity demand by the industrial consumers.

The growth in electricity sales to industries in four different states were found to be statistically different from each other and there is no prior reason to assume that the effects of independent variables on the dependent variable will be the same in all four states.

As observed in Chapter IV, Section IV.4.2, generally, electricity demand by industrial consumers was expected to have been influenced by electricity prices and by income in the respective states.

If the data on electricity demand by different industries in different states were available, it would be ideal to study the effect of income and price on each industry in different states. Assuming that the technology in any particular industry would be similar all over India, if we study the effects of income and price on any particular industry in different states, there is no reason to suppose difference in the effects of the income variable and price on electricity demand of that particular industry in different states. This would be the case since there is no reason to suppose that a saw mill with some capitalisation in one state is particularly different from a saw mill with the same capitalisation in other state, or a freezer plant in one state is different from a freezer plant in another state. Also, we expect the behaviour of the entrepreneurs running them would be the same. Since we do not have the data on electricity demand by industry in our sample of four states, we have to study electricity demand aggregated over all industries in any state. We also have to use proxy variables.

Electricity sales to all the industries in the state is used as a proxy for the industrial demand for electricity. Similarly, either industrial production (i.e., production from all the industries in the state) or state domestic product is used as a proxy for the income variable. The proxy used for the income variable (either the gross state domestic product or the industrial production) depended on the nature of the industries in the state. It was expected that in a state where industries had already developed to a certain extent, the industrial production would be an effective income variable. If the industrial activity depended on other sectors of the state economy and had more backward linkages, (gross) state domestic product would be an effective proxy for the income variable affecting the electricity demand by industries in the state. We categorised four states in our sample on this basis. The state of Maharashtra was industrially developed; and Punjab, though not heavily industrialised, had experienced the growth of sports goods, hosiery and textile, and small steel and engineering industries which did not depend on the production of other sectors within the state. Hence, it is quite likely that in these two states industrial production might be the best proxy for the income variable in explaining electricity demand. In Bihar, a more or less a backward state, and Kerala, more of an agricultural state (except for one electronics industry, Keltron), industrial electricity demand may be better explained by the gross domestic product in the state. The proxy for the price variable in the analysis of electricity demand at state level was marginal price (i.e., the tariff charged) and not average price. The weighted average of the tariff charged to all industries in the state was used as a proxy for the price variable. The coefficients of the income variable and the price variable in different state would be different. And this would be due to the differences in the "mix of industries" in different states as well as due to imperfections of the proxy variables.

V.5.1 Models.

For the reasons explained in Chapter IV, Section IV.2.2, it is likely at state level also, that the effect of the independent variables would be different in the two sub-periods. To see whether this is the case or not, we need to test the model without a dummy that reflects power shortages (i.e., a "restricted" model that assumes that the effects were the same irrespective of power shortages, throughout the period) against the model with a dummy variable (i.e., a "general" model that allows for different effects in two sub-periods) using an F-statistic.[104] It is not necessary that all the four states will have different effects in the two sub-periods, but the possibility of the difference in the effects in two sub-periods needs to be explored by comparing the following two models for the respective states. For Bihar and Kerala, the models are:

$$\log(IIsale_{it}) = \delta_{01} + \delta_{11}\log(ISDP_{it}) + \delta_{21}\log(RIITTR_{it}) + \epsilon_{t1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5.1)$$

$$\log(IIsale_{it}) = \delta_{02} + \delta_{12}D + \delta_{22}\log(ISDP_{it}) + \delta_{32}D*\log(ISDP_{it}) + \delta_{42}\log(RIITTR_{it}) + \delta_{52}d*\log(RIITTR_{it}) + \epsilon_{t2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5.2)$$

where,

i = 1,2 for states of Bihar and Kerala,

t = reflects that the analysis of the model would be only for period t, which in this Chapter would be 1961 to 1986,

$IIsale_{it}$ = index of electricity sales to industries in state i in the t^{th} year,

$ISDP_{it}$ = index of domestic product in state i in the t^{th} year at constant prices i.e. at 1970-71 prices,

$RIITTR_{it}$ = index of electricity prices (real) in state i in t^{th} year,

D = dummy variable such that D=0 for the period 1961-72 and D=1 for the period 1973-86. To allow for a difference in the effect in the two sub-periods of both independent variables, a multiplicative dummy is used.

The following set of equations should be analysed for the states of Maharashtra and Punjab:

$$\log(IIsale_{jt}) = \delta_{03} + \delta_{13}\log(ISIP_{jt}) + \delta_{23}\log(RIITTR_{jt}) + \epsilon_{t3} \ldots (5.3)$$

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[104] The method to compare two models using an F-statistic is explained in Appendix to Chapter V and it was also used in Chapter IV.

$$\log(IIsale_{jt}) = \delta_{04} + \delta_{14}D + \delta_{24}\log(ISIP_{jt}) + \delta_{34}D*\log(ISIP_{jt}) + \delta_{44}\log(RIITTR_{jt}) + \delta_{54}d*\log(RIITTR_{jt}) + \epsilon_{t4} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(5.4)$$

where,
j = 3,4 for states of Maharashtra and Punjab,
$ISIP_{jt}$ = index of industrial production in state j in the t^{th} year at 1970-71 prices,
$RIITTR_{jt}$ = index of electricity prices (real) in state j in the t^{th} year,
D = dummy variable such that D=0 for the period 1961-72 and D=1 for the period 1973-86,

Thus, generally, electricity sales to industrial consumers were expected to be affected positively by the income variable (i.e., gross domestic product in Bihar and Kerala and industrial production in Maharashtra and Punjab), and negatively by the price variable (i.e., the electricity price charged to industrial consumers). It will be interesting to compare the effects of the independent variables over the four states.

V.5.2 Results.

Results for the states of Bihar and Kerala.

The results for the state of Bihar and Kerala are presented in Table 5.1 and 5.1a in Appendix to Chapter V.

In the state of Bihar, as indicated earlier, electricity demand was studied using two independent variables, gross domestic product in the state and electricity prices. (The number of consumers as an independent variable was also studied, but the model was no better on the basis of the F-statistic, and the number of consumers was not a significant variable that affected the electricity demand in the state). From the F-statistic we gather that the model without the dummy is better, implying that the effects of independent variables are not significantly different from each other in two sub-periods. The effects of the independent variables were statistically significant at the 1% and 5% significance level for the income variable and price variable respectively. The gross domestic product in the state seems to have affected the electricity demand positively in the period 1961-86, and the electricity price charged to electricity consumers affected electricity demand in the state negatively as expected. Observing the numerical values of the coefficients we gather that a 1% change in the index of the income variable seemed to have increased electricity sales by 2.4% in Bihar. Whereas a 1% increase in the prices led to decrease in electricity sales by 0.38%. A high coefficient on income means that if income increases which is likely to be the case, electricity sale would increase at a higher rate than the income.

From the F-statistic comparing the model without the dummy variable and the model with the dummy variable for the state of Kerala, we gather that the model with the dummy variable (i.e., model 5.2) explained the variations in electricity sales better, implying that the effects of the independent variables in the two sub-periods were different. The t-statistic from the coefficients conveyed that the effects of price and income were statistically significantly different from each other in the two sub-periods. From the results presented in Table 5.1a in Appendix to Chapter V, one has to calculate the coefficients of income and price for the two sub-periods using the method explained below the Table 4.1a. Calculating the t-statistic for the coefficients in the two sub-periods (Table 5.2b), we gather that the coefficients of income in the two sub-periods were significantly different from zero. As far as the effects of price are concerned we gather that in both the periods the effects were statistically not different from zero. The main reason for insignificant price effects may be low variation in real prices over the period under study. Income coefficients had a positive sign in both the periods as expected. The coefficient of price in the first period is positive implying that the rise in prices led to an increase in the electricity demand in the period 1961-72. Insignificant but positive price effects could be due to imperfection in the proxy variable (i.e. average revenue) for price of electricity to industrial consumers in Kerala. But in the second period the sign of price elasticity is negative, as expected.

Observing the numerical value of the coefficients of income for the two sub-periods we gather that a 1% increase in income in the period 1961-72 led to an increase in electricity sales by 2.5% and 1% increase in income in the period 1973-86 led to an increase of 1.6% in the electricity sales.

Results for industrial consumers in Maharashtra and Punjab.

As explained earlier, in Maharashtra, industrial production was thought to be a better proxy for the income variable. It was very difficult to model the electricity sales to industrial consumers in Maharashtra. The model without the dummy explained the variations in electricity sales well (results are presented in Table 5.2 and 5.2a in the Appendix to Chapter V). Also the t-statistic on the income and the price variables suggested that both the coefficients were significantly different from zero. Also, the sign of the coefficients were found as expected, but there was a problem of auto-correlation. And hence, the coefficients become less trustworthy.

When comparing the model with the dummy and the model without the dummy (using the F-statistic), we gather that the model with the dummy seemed to explain the variations in the electricity sales better. Though the t-statistics of the coefficients imply that the coefficients of price in the two sub-periods were not significantly different from each other, the coefficients on the income variable in the two sub-periods were significantly different from each other. Calculating the t-statistics for the coefficients of income in the two sub-periods (Table 5.2b), we gather that the income coefficients were significantly different from zero in both the sub-periods, whereas the coefficients of price in both the sub-periods were not significantly different from zero. The coefficients of the income variable in both the sub-periods were positive as expected (though the sign of the price coefficients in both the periods was positive which is again very surprising).

Observing the numerical value of the coefficients in the two sub-periods we gather that a 1% increase in the index of industrial production in the period 1961-72 led to a 2.2% increase in electricity demand; whereas in the period 1973-86, a 1% increase in the index of industrial production led to an increase in electricity sales to 0.78%.

The state of Punjab was formed in 1966, and reliable data are available only for the period after 1966. From the F-statistic comparing the model without the dummy and the model with the dummy, we gather that the model without the dummy explained the variations in the electricity sales better than the model with the dummy. The t-statistic for the coefficients, we gather that the coefficients of income and price were statistically different fro zero at 5% significance level. The sign of the income coefficient in that model is positive as expected, but the sign of the price coefficient is positive, which is very surprising. A 1% increase in the index of industrial production in Punjab led to a 0.18% increase in the index of electricity demand. A 1% increase in the price led to an increase (instead of a decrease) in electricity sales by 0.69%. The positive price coefficient in Punjab clearly indicates that there was something wrong. It is not possible to explain the reason econometrically but it could be due to the fact that the electricity price for industrial consumers was mis-specified in Punjab. It would be interesting to work out the extent of mis-specification of electricity prices and its implications for the financial performance of the electricity board, but due to lack of data on costs we have to restrict our study to electricity sale analysis.

Income and price elasticities for industrial consumer group.

Since the data on independent and dependent variables were transformed into logarithms (i.e., all the models are log-linear models), the coefficients can be interpreted as elasticities. Comparing the elasticities, we gather from Table V.9 that the income elasticity in the period 1961-86, was highest in the state of Bihar and lowest in the state of Punjab. As far as the price elasticity in the same period is concerned, it can be observed from Table V.9 that the pricing policy in Bihar was more successful compared to other states in discouraging electricity sales.

Table V.9

Income and price elasticities for industrial consumers.

State	Income elasticities Period 1961-86	1961-72	1973-86	Price elasticities. Period. 1961-86	1961-72	1973-86
Bihar	2.4	-	-	-0.38	-	-
Kerala	2.22	2.5	1.65	(0.13)	(0.48)	(-0.28)
Maharashtra	1.48	2.2	0.78	-0.36	(0.22)	(0.1)
Punjab (1966-86)	0.18	-	-	0.69	-	-

Note: Figures in the bracket represent statistically insignificant elasticity.

At the other extreme, any increase in the prices in Punjab led to an increase in electricity sales in Punjab.

Comparing the effects of income and prices in the sub-periods, in the state of Kerala and Maharashtra, we gather that the income elasticities in the first period were higher than in the second period in the respective states. However, the price elasticities in both states in both the sub-periods were not significantly different from zero. The numerical values in absolute terms were found to be less in the second period compared to the numerical value of the price elasticities in the first period.

V.6 Models for electricity demand by the agricultural consumers.

Electricity sales by agricultural consumers as observed in Chapter IV, Section IV.5.1, were influenced by the income of agricultural consumers and the government policy of electrifying villages and encouraging farmers to use subsidised electric pumpsets.

As with industrial consumers, there is no prior reason to assume that the effects of the independent variables on agricultural consumers will be the same in all states. Though all the four states were expected to aim at electrifying the maximum number of villages every year and at encouraging agricultural consumers to use electricity, the state electricity boards in the four states did not use the same policy measures to encourage agricultural consumers to use electricity. For example, in states like Bihar, the state electricity board tried to encourage more electricity demand by offering low electricity prices to agricultural consumers, whereas, Kerala state electricity board tried to encourage agricultural consumers by electrifying all villages. Punjab electricity board implemented a different (flat rate per pumpset) pricing policy to encourage electricity use in the agricultural sector.

At the state level, it was observed that there was a high correlation between the number of consumers, the number of villages electrified and the number of electrified pumpsets. We assumed the number of consumers to be the best proxy for the number of connections since the number of consumers includes the number of electrified pumpsets and it also reflects the number of villages electrified (i.e. unless the village was electrified, agricultural consumers could not choose to consume electricity for domestic or agricultural purposes).

As far as the income variable is concerned, as explained in Chapter IV, at state level also we assumed that the ability of an agricultural consumer to install an electrified pumpset depended not only on his income from farm produce but also on the (state) government's subsidy on the electrified pumpsets. The income of farmers was assumed to be generated not only from farm produce but also from other small business and hand-crafts. Therefore (gross) state domestic product was thought to be a good proxy for the income variable in the model for electricity demand by agricultural consumers. But in the case of Kerala, the state government subsidy on electrified pumpsets was not a successful measure in itself, since it did not provide an incentive to farmers to install an electrified pumpset. This was so because the farmer found it difficult to afford the variable cost (i.e. electricity bills and maintenance of the pumpset) of an electrified pumpset in a region where electricity supply was found to be unreliable in dry years (particularly when the farmer would need to make use of the pumpset). The availability of electricity at the time when the farmer needed electricity supply was one of the major factors affecting the decision of the farmers to install the electrified pumpset. In some of the villages that I visited in Kerala, electricity was supplied only for couple of hours during the night (i.e., from 02.00hrs to 04.00hrs). The non-availability of electricity when the farmers wanted to use electrified pumpsets discouraged the farmers from installing electrified pumpsets. Also, the incentive for a farmer to consume more electricity depended not only on his income from farm produce, for farmers on the coastline of Kerala were involved in subsistence fishing. Electricity demand by agricultural consumers in Kerala was assumed to be affected by the income from agriculture rather than state (gross) domestic product. Also, differences in the crop pattern, climate and other irrigation facilities led to differences in the irrigation requirement for electrified pumpsets. Though it was very difficult to include all these variables in the model, the difference in agricultural activities, climate and the policy of the electricity boards led to differences in the factors that affected the demand for electricity in each state.

V.6.1 Models.

For the reasons explained in Chapter IV, Section IV.2.2, at state level also, it is likely that the effects of the income variable, price variable and number of consumers in the respective states may be different in two sub-periods. To know whether this is so, we need to test the model without a dummy variable against the model with a dummy variable that allows for different effects in two sub-periods. Thus, the possibility of differences in the effects of independent variables need to be explored by comparing the following set of equations for agricultural consumers in Bihar, Maharashtra and Punjab:

$$\log(\mathrm{IAsale}_{mt}) = \delta_{05} + \delta_{15}\log(\mathrm{ISDP}_{mt}) + \delta_{25}\log(\mathrm{RIATTR}_{mt}) + \delta_{35}\log(\mathrm{IANC}_{mt}) + \epsilon_{t5} \quad \ldots\ldots\ldots(5.5)$$

$$\log(IAsale_{mt}) = \delta_{06} + \delta_{16}D + \delta_{26}\log(ISDP_{mt}) + \delta_{36}D*\log(ISDP_{mt}) + \delta_{46}\log(RIATTR_{mt}) + \delta_{47}D*\log(RIATTR_{mt}) + \delta_{56}\log(INC_{mt}) + \delta_{66}D*\log(IANC_{mt}) + \epsilon_{t6} \quad ..(5.6)$$

where,

m = 1,3,4, for states Bihar, Maharashtra and Punjab,

$IAsale_t$ = index of electricity sales to agricultural consumers in the t^{th} year,

$ISDP_t$ = index of domestic product in the t^{th} year at constant (1970-71) prices,

$RIATTR_t$ = index of electricity prices (real) in t^{th} year,

$IANC_t$ = index of number of agricultural consumers,

D = dummy variable such that D=0 for the period 1961-72 and D=1 for the period 1973-86.

In case of Kerala, we need to compare the following set of equations:

$$\log(IAsale_{kt}) = \delta_{07} + \delta_{17}\log(IADP_{kt}) + \delta_{27}\log(RIATTR_{kt}) + \delta_{37}\log(IANC_{kt}) + \epsilon_{t7} \quad ....(5.7)$$

$$\log(IAsale_{kt}) = \delta_{08} + \delta_{18}D + \delta_{28}\log(IADP_{kt}) + \delta_{38}D*\log(IADP_{kt}) + \delta_{48}\log(RIATTR_{kt}) + \delta_{48}D*\log(RIATTR_{kt}) + \delta_{58}\log(IANC_{kt}) + \delta_{68}D*\log(INC_{kt}) + \epsilon_{t8} \quad ..(5.8)$$

where,

k = (2) for Kerala state,

$IAsale_{kt}$ = index of electricity sales to agricultural consumers in the t^{th} year in Kerala,

$IADP_{kt}$ = index of agricultural production in Kerala in the t^{th} year at constant (1970-71) prices,

$RIATTR_{kt}$ = index of electricity prices (real) in t^{th} year in Kerala,

$IANC_{kt}$ = index of number of agricultural consumers in Kerala in t^{th} year,

D = dummy variable such that D=0 for the period 1961-72 and D=1 for the period 1973-86.

V.6.2 Results.

Results of agricultural consumers in Bihar, Maharashtra and Punjab.

The results for the model without the dummy and the model with the dummy for agricultural consumers in Bihar, Maharashtra and Punjab are presented in Table 5.3 and Table 5.3a respectively in Appendix to Chapter V.

In the state of Bihar, from the F-statistic we gather that the model without the dummy is better, implying that the effects of independent variables are not significantly different from each other in two sub-periods. The coefficients of income and price in the model without the dummy were statistically different from zero at the 1% significance level, whereas the coefficient of the number of consumers was statistically different from zero only at the 25% significance level. The gross domestic product in the state seems to have affected the electricity sales positively in the period 1961-86, as expected. The number of consumers in the agricultural sector also affected agricultural electricity sales positively, as expected and the electricity price charged to agricultural consumers affected agricultural consumers negatively as expected.

Observing the numerical values of coefficients we gather that a 1% rise in income led to an increase in electricity sales to agricultural consumers by 3.6%. And a 1% increase in electricity prices (real) led to a decrease in electricity sales to agricultural consumers of 0.577%.

In Maharashtra also, the F-statistic proved that the model without the dummy explained the variations in electricity sales to agricultural consumers better than the model with the dummy. It is quite likely that the variation (the increase) in the independent variables like income and number of consumers is very high in the second period which led to a sharp increase in electricity sales in the second period. All the coefficients were statistically different from zero at the 1% significance level. In the period 1961-86, the income variable and the number of agricultural consumers variable affected the electricity sales to agricultural consumers positively as expected. The price variable affected electricity sales negatively in this period, as expected. A 1% increase in the income variable in this period led to an increase in electricity sales by 1.1%. A 1% increase in the number of agricultural consumers variable led to an increase in electricity sales by 0.84%, whereas a 1% increase in <u>real</u> prices led to a decrease in electricity sales to 0.28%.

In Punjab, though agricultural electricity sales were thought to be influenced by the income in the state, the number of consumers and electricity prices for agricultural consumers, we gather that the number of consumers did not have significant effects on electricity sales and hence, the preferable model on the basis of F-statistic was the one with only two independent variables, income and price. From the F-statistic comparing the model without the dummy and the model with the dummy, we gather that the model with the dummy explained the variations in electricity sales to agricultural consumers better. This implied that the coefficients in two sub-periods are significantly different from each other in the two sub-periods, but it is difficult to trust the coefficients of the first sub-period since the first sub-period in the case of Punjab is only from 1966 to 1972. Hence we have to ignore the coefficients in the first period. The coefficient of the income variable in the second sub-period was statistically different from zero at the 1% significance level, whereas the coefficient of the price variable was not significantly different from zero.

Insignificant price effects during the period 1973-86 are not very surprising since the pricing policy in Punjab was on the basis of capacity of the pumpset and not the total energy consumed per pumpset. The coefficient on the income variable in the second sub-period had positive effects as expected and the coefficient on the price variable had negative effects as expected. A 1% increase in income in this period led to a 2.16% increase in electricity sales to agricultural consumers. High income effects are not very surprising in case of Punjab, since the effects of the green revolution were realised to a great extent and, the assured water supply was an important factor. As and when farmers, were able to consume electricity on the basis of his income, they were encouraged to use electrified pumpsets since water was essential.

Results of agricultural consumers in Kerala.

In the case of Kerala, income from agriculture in the state was assumed to be a better proxy for the income variable. The results are presented in Table 5.4 and 5.4a in Appendix to Chapter V.

From the F-statistic comparing the model without the dummy and the model with the dummy, we gather that the model with the dummy explained the variations in electricity sales to agricultural consumers better than the model without the dummy. This meant that the effects of the independent variables in the two sub-periods were significantly different from each other. But, from the t-statistic on the coefficient of income, we gather that the effects were not statistically different from each other. Similar was the case of the price coefficients. But the numerical values of the coefficients on the independent variables were very different from each other in the two sub-periods. The coefficient on the income variable in the first sub-period was significantly different from zero, but in the second sub-period it was not statistically different from zero, though the coefficients of the income variable in both the sub-periods had a positive sign as expected. In the first sub-period the coefficient on the number of consumers variable was significantly different from zero and had a positive sign. But in the second period it had a negative sign and it was not significantly different from zero. The coefficient on the price variable in the first sub-period was not significantly different from zero. And, contrary to our expectation, the coefficient on the price variable in the first sub-period had a positive sign.

On the basis of our calculation (Table 5.4b), with the help of the results of the model with the dummy, we gather that in the first sub-period, a 1% increase in agricultural production led to an increase in electricity sales to agricultural consumers by 3.0%. In the second period a 1% increase in prices discouraged electricity sales by 0.54%. A 1% increase in the number of consumers in the first sub-period led to an increase in electricity sales to agricultural consumers by 0.25%.

Comparing the coefficients of the income variable and number of consumers in the model with the dummy and the coefficients in the model without the dummy, we can say that the effects in the first sub-period dominate the effects in the whole period. For example, the model without the dummy suggests that a 1% increase in income led to an increase in electricity sales by 2.75%, and a 1% increase in the number of agricultural consumers led to an increase in agricultural electricity sales by 0.23%. The effects of the price variable in the second sub-period dominated the effects in the whole period. In the period 1961-86, a 1% increase in real prices charged to agricultural consumers led to a decrease in agricultural electricity sales of 0.56% which is similar to the effects of prices in the second sub-period in the model with the dummy.

Thus, we find that in the states of Kerala and Punjab the effects of the independent variables on electricity sales to agricultural consumers were significantly different from each other in the two sub-periods whereas in the states of Bihar and Maharashtra this was not so.

Income and price elasticities for agricultural consumers.

In case of agricultural consumers also, the coefficients of the income and price variables can be considered as income and price elasticities since the log-linear models were analysed. Comparing the income elasticities for agricultural consumers in four states from Table V.10, we gather that in the period 1961-86, the income elasticity is the highest in Bihar and the lowest in Maharashtra. As far as the price elasticities are concerned we observe that the price elasticity is the highest in Bihar in this period. Bearing in mind that Punjab is a special case, the price elasticity is minimum in case of Maharashtra. Thus, Bihar and Maharashtra represent two extreme cases in the sample of four states.

Table V.10

Income and price elasticities for agricultural consumers.

State	Income elasticities Period 1961-86	1961-72	1973-86	Price elasticities. Period 1961-86	1961-72	1973-86
Bihar	3.6	-	-	-0.57	-	-
Kerala	2.75	3.0	0.85	-0.56	(0.37)	-0.54
Maharashtra	1.1	-	-	-0.28	-	-
Punjab (1966-86)	2.99	-	2.16	(0.26)	-	(-0.01)

Note: Figures in the bracket represent a statistically insignificant elasticity.

The analysis for the sub-periods is valid only in the state of Kerala and Punjab. Due to few observations not much can be said about Punjab in the first sub-period. In Kerala, the income elasticity in the first period is higher than in the second period, whereas the price elasticity has the correct sign and is significant in the second period.

V.7 Conclusion.

Despite the differences in plant mix and in economic activities in the four states that led to differences in installed capacity and generation, we found similarities in the high and fluctuating system losses.

Similarly while comparing the income effects on industrial consumers and agricultural consumers we gather that, in the period 1961-86, except for Maharashtra, the income elasticities are higher in the case of agricultural consumers compared to industrial consumers.

Comparing the price effects on electricity sales to agricultural and industrial consumers we gather that except in Punjab the (absolute values of) price elasticities are also higher in the case of agricultural consumers compared to industrial consumers.

Keeping in mind the possible effect of electricity shortages after the early 1970s and the oil crisis of the early 1970s on electricity sales, it was important to test the structural stability of the model. We tried to check the structural stability of the models for both the consumer groups in four states in India by comparing models with and without the dummy variable (i.e. multiplicative dummy was used) for the 1973 effect. But we found that though the growth-rates in sub-periods were different for some states (for example Maharashtra and Kerala) for both the consumer groups, the effects of the independent variables were not statistically different in the two sub-periods (for example in Maharashtra especially for agricultural consumers). In this case, the effects of variations in the dependent variables due to variations in the independent variables remained the same before and after the electricity cuts and oil crisis. Thus, differences in the growth rates of electricity sales were more responsive to the price variable and the income variable in the state than any other factor.

Comparing the coefficients of the income variable and the price variable in two sub-periods where it is applicable, i.e., where the model was not found to be stable for the whole period, for example Kerala, we found that income effects in the first sub-period in both the consumer groups were higher than in the second sub-period, whereas the price effects for the industrial consumer group in Kerala were not significantly different from zero in both the sub-periods.

We can conclude that on the whole the agricultural sector in the period 1961-86 was more sensitive to changes in the income variable and the price variable compared to the industrial consumer group. Also, variations in income dominated the variations in electricity sales to both the consumer groups. The positive price elasticity (for example in the case of industrial consumers in Punjab), indicates the possibility of mispricing in the electricity industry, though the non-availability of data on costs of generation and distribution in the four states do not allow us to know the extent of mispricing and the consequences of mispricing electricity. From this analysis it is also not possible to say anything about whether the independent variables affected electricity sales differently at different times of the day or not.

Appendix to Chapter V.

A Note on Data.

There are two main sources of data regarding electricity generation, total electricity consumption and electricity consumption by consumer groups.

The State Electricity Boards (SEBs) are one of the two sources and the data that I gathered from the respective State Electricity Boards covered, 1) total electricity consumption, 2) Electricity consumption by consumer groups, 3) The revenue earned from electricity sales to different consumer groups.

The Central Electricity Authority is the second source of data. The Central Electricity Authority (CEA) publishes a report called, Public Electricity Supply; All India Statistics, every year and it includes data at the All India level and at state level on installed capacity, generation, utilisation, technical data on plants, etc., In the section on utilisation, the reports include data on the sale of electricity to different consumers in the state by the respective State Electricity Boards and also the total sale of electricity in the state. i.e., not only by State Electricity Boards.

Thus I have three sets of data on the sale of electricity to consumers:

A) Estimation of electricity sales to the consumers within the state by the respective State Electricity Boards.

B) CEA's estimation of electricity sales in the state by SEBs.

C) CEA's estimation of electricity sales to consumers in different states (i.e., not only by the State Electricity Boards).

Ideally the first and the second set of data should match exactly; not least because CEA is a central body that collects data from the individual State Electricity Boards. The data on electricity demand by major consumer categories does match exactly but the total electricity demand by SEBs as calculated by SEBs is not the same as recorded by CEA.

In the second set of data the "energy available" includes 1) Net generation in own power houses (other than jointly owned central government projects).
2) Generation from utilities within state/jointly owned central government projects except DVC and BBMB.[105]
3) Electricity from other state electricity boards (i.e., other than the one under consideration)/Electric undertaking including BBMB/ DVC and other countries.
4) Electricity generation from self generating plants.

"Energy sold" is the difference between the energy

[105] DVC: Damodar Valley Corporation, BBMB: Bhakra Beas Management Board.

available and energy losses. Energy sold includes 1) Energy sold to consumers, 2) To licensees in the states, 3) To other Boards/countries. Which means that the energy sold includes something more than the total sum of energy consumption by different consumers in the state. i.e., it includes exports for which the consumers within the state have not paid. On the supply side i.e., energy available, it includes the electricity exchanged through State Electricity Boards, from self generating plants, from outside the state and from jointly owned projects. In reality not all electricity consumption from outside gets exchanged through the SEBs hence there is underestimation of the actual energy availability in the state. And on the consumption side, the energy sold is an overestimation of the energy consumed within the state by various consumers.

The third data set [set(c)] estimates energy available as the sum of 1) Net generation in own power houses (other than the jointly owned projects and central government projects), 2) Total power supply in the state from jointly owned and central government projects, 3) total power supply in the state from the self generating industries, 4) Power supply from other states and outside the country. The energy sold to the consumers in the state is the difference between available energy and not only the losses but also the energy sent to other states.

Since the third data set appears to be closer to the supply and demand of energy for the consumers within the state, we prefer to use that data set consistently throughout the analysis.

<u>Explanation of the data used.</u>

Index of electricity sales to industrial consumers:($IIsale_t$), index of electricity sale to agricultural consumers:($IAsale_t$).

The annual data on electricity sales to industrial consumers in million KWH in each of the four states were taken as the dependent variable in the model for the industrial sector. The data included electricity sales (by electric utilities) to the high tension as well as the low tension industries. It did not include electricity generation and distribution by the captive power plants owned by the industrial groups.

The annual data on electricity sales to agricultural consumers in million KWH for respective states were taken as the dependent variable in the model for the agricultural sector. The electricity sales to agricultural consumers had some element of electricity sales to domestic consumers as well, since it is difficult to separate the KWH sales for irrigation and for domestic purposes when only one connection is used for both purposes. It has been observed that in many villages in India, even if the connection was given to only one consumer (as may be just to the Gram-Panchayat office), that village was included in the total number of villages electrified. But in reality there may be many more potential consumers in the same village. It was extremely difficult to know the unfulfilled demand for electricity from agricultural consumers.

The data were available from the respective State Electricity Boards as well as the Central Electricity Authority. To maintain consistency in the source of data we have taken the data from CEA for the period 1961-1986. Reliable data for Punjab were only available for the period 1966-1986.

Index of state domestic product:($ISDP_t$), index of industrial production and agricultural production:($ISIP_t$).

The data on state domestic product (SDP) were in lakh Rupees (i.e. 100,000) at 1970-71 prices for the period 1961-1986. The data on state domestic product were converted into an index by taking 1961-62 as the reference year, and taken as an indicator of the level of economic activity in the respective states.

The data regarding industrial production were calculated for the respective states at 1970-71 prices and were converted into an index taking 1961-62 as the reference year. Thus, data on the index of industrial production in Maharashtra and Punjab were used as an indicator of industrial activity in the respective states.

The data regarding agricultural production were calculated for the respective states at 1970-71 prices and were converted into an index taking 1961-62 as the reference year. Data on the index of agricultural production in Kerala was used as an indicator of income in that state.

The data on state domestic product, industrial production and agricultural production were taken from the publication by the Central Statistical Organisation (CSO) in India for the Planning Commission in India, known as State Domestic Product.

Electricity price for industrial and agricultural consumers: ($RIITTR_t$), ($RIATTR_t$).

Though the data on revenue earned from different consumers in the four states under study were available from 1969 to 1986 from CEA in unpublished form, we have tried to construct an index of the tariff charged to industrial consumers in the four states rather than taking the total revenue data from CEA.

The data on the tariff charged to different consumer groups in the four different states were taken from various issues of Average electric rates and duties in India, published by the CEA. The data were converted into an index taking 1961-62 as the reference year. The index of the tariff charged to industrial consumers (in each of the four states) was deflated by the index of prices of industrial production in India.

The data on the tariff charged to agricultural consumers in the four different states were taken from various issues of Average electric rates and duties in India, publication by CEA. The data were converted into an index taking 1961-62 as the reference year. The index of the tariff charged to agricultural consumers in each states was deflated by the index of prices of agricultural production in India.

The data on the price indices of industrial and agricultural production were taken from various issues of the Economic Survey.

Number of agricultural consumers:($IANC_t$).

Data on the number of agricultural consumers in each state were taken from CEA for the years 1961-1986.

Results.

Table 5.1

Results of the model without dummy for industrial consumers in Bihar and Kerala.
$\text{Log}(\text{IIsale}_{it}) = c_{01} + c_{11}\log(\text{ISDP}_{it}) + c_{21}\log(\text{RIITTR}_{it}) + e_{1t}$

State & period	c_0	c_1	c_2	$\bar{R}^2$	D-W stat.	RSS
Bihar						
1961-86	-18.1	2.4	-0.384	0.84	1.1	1.01
S.E	(2.7)	(0.28)	(0.22)			
T-statistic	-6.4	8.4	-1.7			
Kerala						
1961-86	-6.27	2.22	(0.13)*	0.94	0.79	0.34
S.E	(1.15)	(0.12)	(0.15)			
T-statistic	-5.4	17.9	0.85			

* Statistically insignificant coefficient.

Table 5.1a

Results of the model with dummy for industrial consumers in Bihar and Kerala.
$\text{Log}(\text{IIsale}_{it}) = c_{02} + c_{12}D + c_{22}\log(\text{ISDP}_{it}) + c_{32}D{*}\log(\text{ISDP}_{it}) + c_{42}\log(\text{RIITTR}_{it}) + c_{52}D{*}\log(\text{RIITTR}_{it}) + e_{2t}$

State & period	c_0	c_1	c_2	c_3	c_4	c_5	$\bar{R}^2$	D-W.	RSS
Bihar									
1961-86	-0.42	-1.3	0.92	0.77	0.23	-0.42	0.86	1.5	0.72
S.E	(4.1)	(5.3)	(0.64)	(1.2)	(0.72)	(0.86)			
T-statistic	-0.1	-0.2	1.43	0.62	0.32	-0.49			
Kerala									
1961-86	-9.3	7.8	2.5	-0.84	0.48	-0.78	0.96	1.6	0.51
S.E	(1.2)	(2.0)	(0.25)	(0.42)	(0.32)	(0.43)			
T-statistic	-7.5	3.9	9.9	-1.9	1.4	-1.7			

Table 5.2

Results of the model without dummy for industrial consumers in Maharashtra and Punjab.
$Log(IIsale_{jt}) = c_{03} + c_{13}log(ISIP_{jt}) + c_{23}log(RIITTR_{jt}) + e_{3t}$

State & period	c_0	c_1	c_2	$\bar{R}^2$	D-W stat.	RSS
Maharashtra						
1961-86	-0.40	1.48	-0.36	0.95	0.48	0.24
S.E	(0.43)	(0.06)	(0.1)			
T-statistic	-0.9	21.5	-3.3			
Punjab						
1966-86	0.573	0.18	0.69	0.80	2.6	0.26
S.E	(0.45)	(0.10)	(0.11)			
T-statistic	1.26	1.7	5.9			

Table 5.2a

Results of the model with dummy for industrial consumers in Maharashtra and Punjab.
$Log(IIsale_{jt}) = c_{04} + c_{14}D + c_{24}log(ISIP_{jt}) + c_{34}D*log(ISIP_{jt}) + c_{44}log(RIITTR_{jt}) + c_{54}D*log(RIITTR_{jt}) + e_{4t}$

State & period	c_0	c_1	c_2	c_3	c_4	c_5	$\bar{R}^2$	D-W.	RSS
Maharashtra									
1961-86	-6.57	7.74	2.2	-1.4	0.22	-0.12	0.99	1.15	0.04
S.E	(1.9)	(1.9)	(0.11)	(0.17)	(0.33)	(0.34)			
T-statistic	-3.3	3.8	18.4	-8.2	0.69	-0.36			
Punjab									
1966-86	-5.34	4.12	0.53	0.14	1.67	-1.27	0.82	2.9	0.2
S.E	(11.66)	(18.78)	(1.3)	(1.3)	(1.3)	(1.3)			
T-statistic	-0.45	0.21	0.4	0.1	1.25	-0.94			

Table 5.2b
Calculated coefficients for two period and their respective T-statistics for industrial consumers in the states of Kerala and Maharashtra.

	Income		Price	
	Period 1 (1953-72)	Period 2 (1973-86)	Period 1 (1953-72)	Period 2 (1973-86)
Kerala	2.5	1.6	(0.48)*	(-0.28)*
T-st.	9.9	4.78	1.48	-0.99
Maharashtra	2.2	0.78	(0.22)*	(0.10)*
T-st.	18.4	6.3	0.69	1.18

* Statistically insignificant coefficients.

Table 5.3

Results of the model without dummy for agricultural consumers in Bihar, Maharashtra and Punjab.
$Log(IAsale_{it}) = c_{05} + c_{15}log(ISDP_{it}) + c_{25}log(RIATTR_{it}) + c_{35}log(IANC_{it}) + e_{5t}$

State & period	c_0	c_1	c_2	c_3	$\bar{R}^2$	D-W stat.	RSS
Bihar							
1961-86	-10.5	3.6	-0.577	(0.15)*	0.90	1.44	3.51
S.E	(3.0)	(0.7)	(0.22)	(0.13)			
T-statistic	-3.4	5.0	-2.5	1.16			
Maharashtra							
1961-86	-2.9	1.1	-0.28	0.84	0.99	2.3	0.21
S.E	(1.06)	(0.17)	(0.10)	(0.03)			
T-statistic	-2.7	6.36	-2.6	26.9			
Punjab							
1966-86	-10.58	2.99	(0.26)*	-	0.90	1.0	1.38
S.E	(2.32)	(0.29)	(0.24)				
T-statistic	-4.5	10.29	1.09				

* Statistically insignificant coefficients.

Table 5.3a

Results of the model with dummy for agricultural consumers in Bihar, Maharashtra and Punjab.
$Log(IAsale_{it}) = c_{06} + c_{16}D + c_{26}log(ISDP_{it}) + c_{36}D*log(ISDP_{it}) + c_{46}log(RIATTR_{it}) + c_{56}D*log(RIATTR_{it}) + c_{66}log(IANC_{it}) + c_{76}D*log(IANC_{it}) + e_{6t}$

State & period	c_0	c_1	c_2	c_3	c_4	c_5	c_6	c_7	$\bar{R}^2$	D-W	RSS
Bihar											
1961-86	10.14	-23.5	0.53	-0.48	-1.85	1.65	0.1	2.5	0.93	1.7	2.14
S.E	(8.2)	(8.8)	(2.17)	(3.44)	(0.9)	(0.93)	(0.26)	(1.6)			
T-stat.	1.2	-2.6	0.24	-0.14	-2.06	1.75	0.4	1.6			
Maharashtra											
1961-86	-0.50	-6.62	0.23	-0.7	-0.05	0.28	0.96	1.08	0.99	2.5	0.13
S.E	(3.24)	(3.72)	(0.84)	(1.15)	(0.29)	(0.36)	(0.1)	(0.49)			
T-stat.	-0.15	-1.77	0.27	-0.61	-0.19	0.79	9.02	2.18			
Punjab											
1966-86	-52.4	47.4	7.86	-5.69	4.77	-4.78	-	-	0.93	1.5	0.76
S.E	(18.4)	(18.6)	(2.27)	(2.3)	(1.89)	(1.9)					
T-stat.	-2.8	2.5	3.46	-2.4	2.5	-2.5					

Table 5.4

Results of the model without dummy for agricultural consumers in Kerala.
$Log(IAsale_{kt}) = c_{07} + c_{17}log(IADP_{kt}) + c_{27}log(RIATTR_{kt}) + c_{37}log(IANC_{kt}) + e_{7t}$

State & period	c_0	c_1	c_2	c_3	$\bar{R}^2$	D-W stat.	RSS
Kerala							
1961-86	-7.5	2.75	-0.56	0.232	0.92	0.99	0.83
S.E	(4.4)	(0.77)	(0.37)	(0.08)			
T-statistic	-1.7	3.5	-1.5	2.8			

Table 5.4a

Results of the model with dummy for agricultural consumers in Kerala.
$Log(IAsale_{kt}) = c_{08} + c_{18}D + c_{28}log(ISAP_{kt}) + c_{38}D*log(ISAP_{kt}) + c_{48}log(RIATTR_{kt}) + c_{58}D*log(RIATTR_{kt}) + c_{68}log(IANC_{kt})$
$+ c_{78}D*log(IANC_{kt}) + e_{8t}$

State & period	c_0	c_1	c_2	c_3	c_4	c_5	c_6	c_7	$\bar{R}^2$	D-W Statistic	RSS
Kerala											
1961-86	-12.29	16.71	3.0	-2.15	0.37	-0.92	0.25	-0.27	0.95	1.8	0.38
S.E	(8.4)	(11.1)	(1.59)	(2.09)	(0.71)	(0.78)	(0.2)	(0.22)			
T-stat.	-1.4	1.4	1.88	-1.02	0.53	-1.18	1.23	-1.22			

Table 5.4b
Calculated coefficients for two period and their respective T-statistics for the agricultural consumers in the states of Kerala and Punjab.

	Income		Price	
	Period 1 (1953-72)	Period 2 (1973-86)	Period 1 (1953-72)	Period 2 (1973-86)
Kerala	3.0	(0.86)*	(0.38)*	-0.55
T-st.	1.88	0.633	0.53	-1.68
Punjab	(1966-72)	(1973-86)	(1966-72)	(1973-86)
	7.86	2.16	4.77	(-0.01)*
T-st.	3.46	5.39	2.52	-0.04

* Statistically insignificant coefficients.

Data.

Table 1.

Bihar State (1): Analysis of electricity sales to industries and agricultural consumers.

Year	$IIsale_1$	$IAsale_1$	SDP_1	$RIITTR_1$	$RIATTR_1$	$IANC_1$
1961	117.3	98.9	98.2	98.0	100.1	62.47
1962	100.0	100.0	100.0	100.0	100.0	100.0
1963	125.18	108.3	101.9	96.9	97.7	100.87
1964	152.12	105.4	102.4	124.9	92.2	110.95
1965	162.79	121.1	105.4	112.3	76.4	121.04
1966	186.7	158.8	91.0	105.0	70.6	198.93
1967	187.06	266.7	99.9	98.0	60.0	201.95
1968	121.38	330.7	102.9	99.9	61.4	203.41
1969	133.15	367.7	105.7	97.1	55.7	933.12
1970	141.61	386.7	117.1	114.1	61.6	1,067.5
1971	148.79	374.4	120.3	106.5	59.6	1,230.5
1972	258.62	303.3	123.7	99.3	60.1	1,381.3
1973	249.4	406.4	123.3	86.0	59.7	1,638.7
1974	250.23	399.8	121.1	76.9	47.3	1,822.3
1975	272.9	406.9	126.8	84.8	36.0	2,019.0
1976	324.04	2,460.0	135.7	109.8	31.3	2,215.7
1977	364.35	2,434.0	142.1	107.3	31.1	2,469.2
1978	386.04	1,621.1	149.3	104.9	28.2	2,612.1
1979	423.88	1,109.3	152.7	104.7	28.7	2,707.9
1980	350.96	2,405.3	144.4	135.3	13.8	2,899.4
1981	334.5	2,353.7	165.9	151.4	12.4	2,966.4
1982	411.57	2,674.3	168.9	179.6	40.2	3,233.8
1983	418.93	3,347.7	165.0	180.9	23.6	3,436.7
1984	444.94	3,500.6	179.7	204.7	46.5	3,565.8
1985	456.8	3,269.7	188.9	212.4	43.4	3,657.2
1986	491.7	4,330.6	197.0	204.1	42.5	3,837.4

$IIsale_1$: Index of electricity sale to industrial consumers in Bihar.
$IAsale_1$: Index of electricity sale to agricultural consumers in Bihar.
SDP_1: Index of State doestic product in Bihar.
$RIITTR_1$: Index of real tariff charged to industrial consumers in Bihar.
$RIATTR_1$: Index of real tariff charged to agricultural consumers in Bihar.
$IANC_1$: Index of number of agricultural consumers in Bihar.

Table 2.

Kerala State (2): Analysis of electricity sales to industries and agricultural consumers.

Year	$IIsale_2$	$IAsale_2$	$ISDP_2$	IAP_2	$RIITTR_2$	$RIATTR_2$	$IANC_2$
1961	78.1	100.5	98.6	103.7	98.1	100.1	88.2
1962	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1963	99.2	100.8	103.7	103.2	108.2	97.7	112.9
1964	104.9	81.8	105.8	104.2	105.5	92.2	156.88
1965	108.5	121.9	110.3	105.9	132.76	101.8	200.79
1966	118.9	132.1	111.4	104.9	124.13	94.1	229.6
1967	147.8	167.4	117.2	111.5	115.91	80.0	292.32
1968	198.3	169.1	125.0	117.3	135.01	70.8	379.87
1969	220.3	237.5	131.1	122.7	131.25	74.3	456.16
1970	234.4	217.9	136.8	128.6	133.88	77.0	581.06
1971	248.3	224.8	145.7	125.2	124.94	74.5	620.58
1972	247.8	367.8	153.6	130.5	116.53	75.15	757.9
1973	265.0	419.1	157.3	130.4	100.9	74.6	895.68
1974	276.5	504.0	156.6	128.3	88.21	59.1	1,016.9
1975	275.1	560.5	158.3	130.4	72.9	48.4	1,190.7
1976	295.3	662.0	165.3	135.6	71.88	52.3	1,364.6
1977	313.4	564.8	163.3	128.3	82.73	64.7	1,756.9
1978	346.4	431.8	165.5	126.9	80.89	58.7	1,947.1
1979	349.2	453.1	169.1	127.8	80.75	59.7	2,187.7
1980	328.9	442.8	176.5	128.5	85.28	63.0	2,570.7
1981	381.3	439.2	188.7	127.6	96.03	66.1	3,016.2
1982	381.1	577.3	185.7	126.8	91.3	58.8	3,445.7
1983	353.4	589.1	187.1	127.3	100.21	56.0	3,576.4
1984	292.8	514.2	188.3	118.4	96.23	49.2	3,811.9
1985	413.4	538.5	197.0	132.2	96.77	45.9	4,119.2
1986	447.3	555.1	207.2	134.6	90.24	44.9	5,021.9

$IIsale_2$: Index of electricity sale to industrial consumers in Kerala.
$IAsale_2$: Index of electricity sale to agricultural consumers in Kerala.
SDP_2: Index of State doestic product in Kerala.
IAP_2: Index of Agricultural production in Kerala.
$RIITTR_2$: Index of real tariff charged to industrial consumers in Kerala.
$RIATTR_2$: Index of real tariff charged to agricultural consumers in Kerala.
$IANC_2$: Index of number of agricultural consumers.

Table 3.

Maharashtra State (3): Analysis of electricity sales to industries and agricultural consumers.

Year	$IIsale_3$	$IAsale_3$	IIP_3	$ISDP_3$	$RIITTR_3$	$RIATTR_3$	$IANC_3$
1961	86.2	105.6	92.94	100.1	98.1	100.1	81.7
1962	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1963	111.5	127.4	103.02	102.9	105.4	107.5	103.2
1964	127.3	186.4	108.46	107.3	102.7	101.4	182.4
1965	138.9	336.3	114.79	110.7	99.5	84.0	261.6
1966	153.5	640.7	121.6	106.8	99.7	77.6	518.8
1967	167.8	812.6	124.35	112.4	93.1	66.0	728.2
1968	180.6	1,108.5	129.03	118.3	90.4	58.4	1,031.2
1969	208.9	1,689.9	136.73	125.7	101.5	61.3	1,397.1
1970	228.9	2,187.4	145.24	129.4	96.5	56.5	1,792.7
1971	247.2	2,550.7	152.28	133.4	90.0	54.6	2,342.4
1972	264.3	2,948.4	155.88	137.1	85.9	71.5	2,554.2
1973	278.5	3,268.1	161.16	130.0	74.5	70.9	3,067.1
1974	283.0	3,488.3	160.71	145.6	65.1	56.2	3,619.8
1975	292.0	4,778.3	169.58	159.3	100.7	61.4	3,958.6
1976	276.2	5,742.3	180.85	167.3	99.3	66.3	4,297.5
1977	312.3	6,571.7	198.62	176.3	97.1	65.8	4,892.8
1978	334.7	7,547.7	213.06	191.7	94.9	59.6	5,329.9
1979	362.7	9,879.7	237.93	203.7	94.7	60.7	5,867.3
1980	355.7	9,612.7	241.83	207.8	90.4	44.1	6,480.4
1981	378.5	12,332.2	243.75	206.8	114.5	39.6	7,249.7
1982	398.9	13,440.7	249.59	216.6	138.6	35.2	7,832.0
1983	382.9	16,777.0	261.63	223.8	153.0	40.3	8,634.6
1984	432.2	18,178.6	268.26	234.6	152.2	35.4	9,325.1
1985	466.1	24,133.6	270.27	235.9	131.0	32.9	10,171.5
1986	518.5	26,231.7	302.13	248.8	187.9	21.5	11,044.0

$IIsale_3$: Index of electricity sale to industrial consumers in Maharashtra.
$IAsale_3$: Index of electricity sale to agricultural consumers in Maharashtra.
IAP_3: Index of industrial production in Maharashtra.
SDP_3: Index of State doestic product in Maharashtra.
$RIITTR_3$: Index of real tariff charged to industrial consumers in Maharashtra.
$RIATTR_3$: Index of real tariff charged to agricultural consumers in Maharashtra.
$IANC_3$: Index of number of agricultural consumers in Maharashtra.

Table 4.
Punjab State (4): Analysis of electricity sales to industries and agricultural consumers.

Year	$IIsale_4$	$IAsale_4$	IIP_4	$ISDP_4$	$RIITTR_4$	$RIATTR_4$
1961	18.6	35.5	n.a	n.a	n.a	n.a
1962	57.5	47.3	n.a	n.a	98.71	125.4
1963	72.9	52.8	n.a	n.a	95.65	122.6
1964	102.1	53.7	n.a	n.a	93.21	115.7
1965	108.0	59.2	n.a	n.a	90.23	95.8
1966	100.0	100.0	100.0	100.0	100.0	100.0
1967	107.6	121.9	104.9	107.4	93.37	85.0
1968	94.7	68.1	107.6	120.7	90.62	69.5
1969	95.7	94.6	119.6	127.4	88.1	72.9
1970	97.2	174.1	126.1	135.7	83.75	67.2
1971	71.8	219.9	128.6	137.9	78.15	64.9
1972	76.4	263.9	131.8	142.6	72.89	65.6
1973	71.4	295.7	145.8	147.3	63.14	65.1
1974	86.7	336.6	144.3	151.5	55.18	51.6
1975	62.2	330.0	143.7	156.7	65.76	66.0
1976	106.9	425.5	168.1	170.2	93.9	97.2
1977	111.1	439.9	184.4	181.1	91.78	96.5
1978	92.9	516.8	205.6	196.3	89.73	87.5
1979	122.9	783.2	216.1	201.8	89.58	88.9
1980	121.4	899.4	215.7	210.9	109.36	48.6
1981	122.9	877.4	230.8	212.0	91.72	43.5
1982	123.0	882.2	239.7	236.1	136.57	38.8
1983	139.7	1,003.1	247.6	249.1	145.26	39.9
1984	156.5	1,035.7	254.1	253.5	146.64	35.0
1985	149.6	1,035.7	249.0	276.2	135.77	32.6
1986	189.5	1,313.1	255.9	294.6	187.54	31.9

$IIsale_4$: Index of electricity sale to industrial consumers in Punjab.
$IAsale_4$: Index of electricity sale to agricultural consumers in Punjab.
IAP_4: Index of industrial production in Punjab.
SDP_4: Index of State doestic product in Punjab.
$RIITTR_4$: Index of real tariff charged to industrial consumers in Punjab.
$RIATTR_4$: Index of real tariff charged to agricultural consumers in Punjab.

Table 5.
All India: Price Index

Year	Wholesale	Price Index of Indus. commodities	Price Index Of Agri. Commodities
1961	99.84	101.96	98.0
1962	100.0	100.0	100.0
1963	103.8	103.2	102.3
1964	110.2	105.9	108.4
1965	122.3	109.4	130.9
1966	131.6	117.0	141.7
1967	149.9	125.3	166.6
1968	167.3	129.1	188.2
1969	165.4	132.8	179.4
1970	171.6	139.7	194.8
1971	181.1	149.7	201.4
1972	191.24	160.5	199.6
1973	210.4	185.27	201.05
1974	252.99	212.02	253.7
1975	316.74	256.55	309.69
1976	313.3	260.2	286.7
1977	319.82	266.28	288.9
1978	336.48	272.36	318.6
1979	336.48	272.8	313.34
1980	394.07	327.99	343.96
1981	465.97	391.06	383.7
1982	509.43	411.28	431.09
1983	522.83	413.56	452.6
1984	572.27	449.58	515.49
1985	612.84	485.6	552.68
1986	647.97	520.71	564.34

Source: Constructed from the data given in Economic Survey, Government of India, New Delhi, for the years 1971-72, 1981-82 and 1988-89.

CHAPTER VI

ELECTRICITY DEMAND ANALYSIS: CASE STUDY III. Time Varying Responses in Gujarat.

Introduction.

For the detailed hourly analysis of demand, we need to know electricity demand for a particular region over the 24 hour period, i.e., the load curve. We also need to observe if this "load curve" has a particular shape that remains the same over the years, over different months (or weeks) of the years and different days of the week. An attempt is made to study the pattern of demand in the first three sections below and the final section studies the factors that may have had an effect on the load curve.

VI.1 The scope of demand management.

In the absence of seasonal variations, if the load curve has any of the following characteristics: (1) a deep trough at night, (2) a sharp climb from low to high demand in the morning, (3) fairly pronounced peaks and (4) sharp falls and rises occurring together between the two peak levels, there would be a major and unavoidable impact on the total costs of meeting demand. If the consumers could be influenced towards removing these features and taking their electricity more evenly throughout the 24 hours of the day; (i.e., if load factor could be raised) then significant savings would be made.

Influencing a utility's customers in this way is essential for successful demand management. The cost saving associated with this reshaping of demand occurs mainly in three areas: (i) reduced depreciation and interest on the lower capacity required to meet the necessary generation, (ii) reduced manpower and other works costs due to carrying less capacity, (iii) reduced fuel costs due to higher technical efficiency, less off-load heat and lower consumption of the scarce and most expensive fuels.

Policies can be pursued by utilities which are designed to optimise the use of expensive capital, plant, fuel and labour in support of more efficient and economic supply operations.

The variations in consumer demand for electricity display markedly regular patterns over daily and seasonal cycles. The following three aspects are particularly important: i) the absolute values of the peak demand, since these affect the capacity of the plant which must be installed; ii) the duration of the peaks, as this affects the plant utilisation; and, iii) the maximum peak rates of change of demand, as these influence the plant operating characteristics that are required.

The first of these, the absolute value of peak demand is the main determinant of installed capacity. Any additional capacity above forecast peak demand provides a margin for breakdowns or other unforeseeable conditions.

The scope for demand management varies with the level, character and location of the demand over successive periods. It is important to know the number of each type of consumers, and their average consumption, and even more important to know the predominant categories of consumers affecting the load in each area. These constituent demands constitute total demand and in practice the scope for successful demand management is circumscribed by the utility's ability to influence these constituent demands. Similarly, the shape of the system's load curve is determined by the shape of its constituent consumer groups' load curves.

In order to observe electricity demand in a particular region (i.e. Gujarat), one has to study the patterns of demand over 24 hours and whether they remain the same in different seasons or not. In order to examine ways to influence the consumers' demand for power at different time of the day, one has to study the factors that affect the consumers' decision to demand different levels of electricity at different times of the day.

The present supply system does not keep and maintain records of the hourly electricity supply to different categories of consumers. The transmission and distribution system is such that it is impossible to separate the supply provided to different groups of consumers from the total electricity supply. Hence, this study is restricted to the analysis of demand at different time of the day by all consumers and not extended to the analysis of demand at different times of the day by different consumer groups.

VI.1.1 Concept of "unrestricted demand".

From the reports published by the Gujarat Electricity Board and Central Electricity Authority, we can get the information on "energy requirement".

The "energy requirement" is defined as the sum of total electric energy consumption by the consumers within the system and the line losses (also known as system losses) in supplying power to these consumers during a fiscal year. It is equal to the total energy generation within the state plus imports of energy from outside the system minus the energy requirements of power station auxiliaries and exports of energy outside the system during the year.

This data on energy requirement has two characteristics: 1) since it gives information regarding energy requirement in a particular year, it is an aggregation of energy required at each point of time in a year and therefore it conceals the fluctuations occurring in the power required at each hour of the day in the whole year. 2) "energy required" represents the demand from the electricity supply system's point of view. We notice that in the reports after the year 1971-72 the level of "energy required" is the same as "energy available". If we assume that the "energy requirement" does represent the true demand picture, this would indicate that in Gujarat state there was a surplus until the year 1970-71 and thereafter there has not been either any surplus or any deficit. On the other hand a number of electricity cuts were experienced after 1972-73 by different consumer groups, and hours of load shedding were also recorded.

The data regarding the "energy requirement" represent the demand excluding the restrictions. Therefore data on "energy requirement" are essentially the electricity supply by the electricity industry rather than the demand. Thus, it becomes important to know the demand without the restrictions. If the supply system had been able to supply electricity to all customers without any restrictions and the supply system had been capable of taking care of the fluctuations in the level of the demand at different times of the day, there would have been no reliability constraint. The absence of a reliability constraint might itself have effects on the demand. The "spontaneous demand" at the consumer end might be affected adversely or favourably by such a reliability constraint. The existence of the constraint might make the consumer feel insecure and uncertain about the supply. The consumers might over-estimate their demand to get the level they need after the 'cuts'. On the other hand the less reliable supply system might force the consumers to have either a standby or an additional source of energy which could be more expensive to society as a whole, compared to the cost of supply from the electricity utilities i.e., compared to what the consumers pay for the supply from the utilities. But for industries it may work out less expensive compared to the loss in the production due to frequent power 'cuts' in the electricity supply from the electric utility. Thus the consumers might be willing to accept the level they are offered without revealing true demand which could be higher or lower. In either case the load curve would shift downwards or upwards depending upon the strength of the effects of the above mentioned factors.

It would be very interesting to calculate and observe the level of "spontaneous demand" and pattern of the load curve if the data were available. But due to lack of data we will restrict the analysis to the study of "unrestricted demand" i.e., the calculated demand in the absence of restrictions.

The Gujarat Electricity Board (GEB) recognised the need to know the demand from the consumers' end in the absence of the forced planned (load shedding) and unplanned (sudden power cuts) restrictions. The Gujarat Electricity Board adopted a method to calculate the level of "unrestricted demand" (demand in absence of restrictions). According to the method, they calculate the level of "demand" at any hour (e.g. hour i) by simple addition of the power demand fulfilled at that hour (e.g. hour i) of the day and the restriction imposed at that hour (e.g. hour i) on the previous day. The result of this simple addition of the two is called (by GEB) "unrestricted demand". i.e. "unrestricted demand" at hour i = (The demand fulfilled (or supply) at hour i) + (The restrictions imposed on previous day at hour i). Using this method, G.E.B calculates the "unrestricted demand" at each hour (i.e. i=1..24).

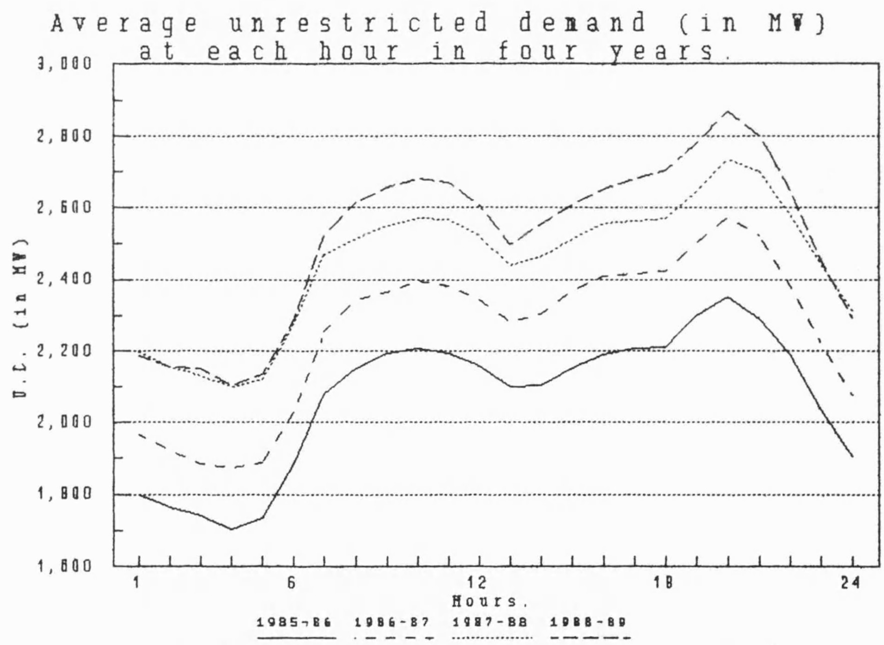
The calculation of the "unrestricted demand" by G.E.B does not take into account the second factor mentioned above (i.e., demand in the absence of reliability constraint). For the present analysis we assume that the "unrestricted demand" represents the true demand.

Using the data on "unrestricted demand" we studied the hourly pattern and seasonal pattern. The data on "unrestricted demand"(or demand) were collected personally from the unpublished records of GEB for the years 1985-86 to 1988-89.

VI.2 Hourly pattern of unrestricted demand.

Considering the time past midnight to midnight of the next day (i.e. 01.00hrs to 24.00hrs), a typical load curve had two peak and three trough periods in 24 hours. The first peak period before midday, is lower than the second peak, after midday. On the other hand, the first trough period before midday is deeper than the trough during noon and before midnight.

Graph VI.1



Graph VI.1 depicts the average load at each hour in 4 years, and consistency in the load pattern can be observed over all four years. From the analysis of variations in load around the arithmetic mean at each hour it can be observed that the standard deviation around the mean at each hour also had a similar pattern. This meant that the variations in load around the average load at trough periods is less than the variations around the average load at peak periods.

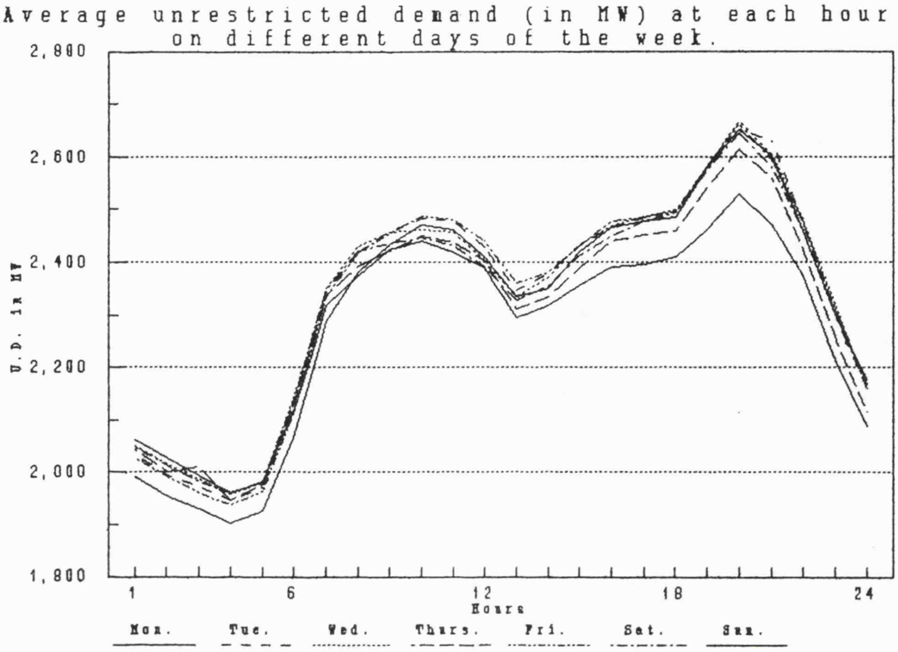
In order to differentiate between the peak hours and off-peak hours, one can calculate the range (above and below 1 standard deviation around the arithmetic mean) at one particular hour, for example at the hour that has the lowest average demand in 24 hours, and observe the average load at different hours in relation to this range of trough load (since the range is calculated around the minimum average load we can call it the range of trough load). If the average load at any other hour falls within this range, it would mean that the load at that hour is not particularly (statistically) different from the trough load. Hence, we can categorise the hours at which the average load falls within "the range of trough load", as trough hours; and the rest as peak hours.

The minimum average load was experienced at 04.00hrs. Using the average load at 04.00hrs and the standard deviation at 04.00hrs, the range of trough load can be calculated. It ranged between 1,585.09 and 2,303.55 KW. Comparing the average load at different hours in relation to this range we gather that the average load at the hours 01.00 to 06.00 (both inclusive), and hours 23.00 and 24.00 fell within this range. If we label these hours as trough hours then there were only two trough periods in the day, whereas from the graph we observed three trough periods.

In order to check whether this load pattern remains the same on different days of the week, we need to analyse the load pattern on different days of the week. The load pattern did not change over different days of the week. The average load at each hour on different days of the week were also not particularly different from each other (Graph VI.2).

Similarly in order to check whether the load pattern remained the same at different times of the year, we need to analyse the load pattern in different weeks of the year or different months of the year. Though the analysis of the load pattern over different weeks (i.e. 1 to 52 weeks of

Graph VI.2

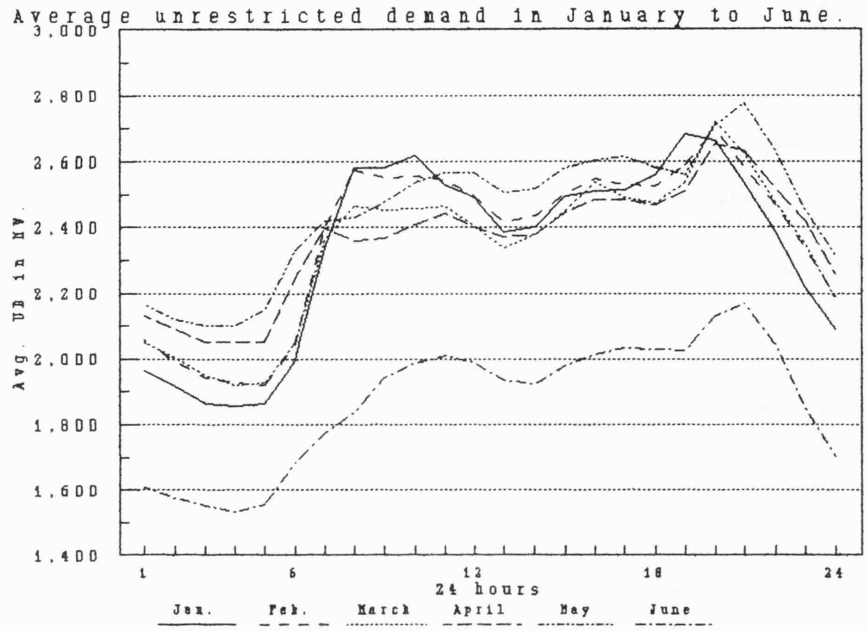


the year) may reveal a fuller picture, for convenience we analysed the load pattern over 12 months in 4 years. The minimum average load was experienced at 04.00hrs. and the range of trough hours covered the first 6 hours of the day and the last two hours of the day.

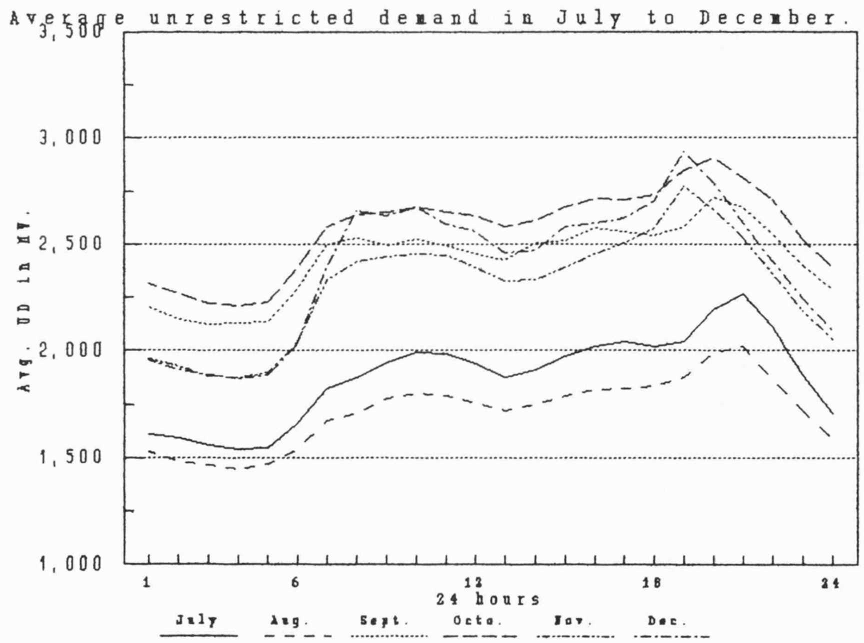
From Graph VI.3a and Graph VI.3b we can observe the average load over 24 hours in the first 6 months and the last 6 months of the calendar year respectively. Though the load pattern (in 24 hours) was not different, the level of average load at different hours in different months was different from each other (unlike the analysis of average load on different days of the week). This implies some seasonality.

We also observed (from Graph VI.1) that the demand (unrestricted demand) increased in the fourth year except during 23.00hrs to 06.00hrs. From the analysis on the average load on different days over four years, it was observed that during the hours 23.00 and 24.00, there was hardly any increase in the average load between 1987-88 and

Graph VI.3a



Graph VI.3b



1988-89 except on Fridays. On Fridays the average load at 23.00hrs and 24.00hrs in the year 1988-89 increased (compared to the year 1987-88). Over time, we would expect the average load at all hours of the day to increase but the average load at each hour on any particular day of the week did not increase during the first 6 hours of the day on any day. At night time, it did not increase on any day except Fridays. This could have happened if the consumers continued to spend time on recreation activities on Friday nights as they used to in the previous year). This could be the result of the failure on the part of the pricing policy to encourage demand at trough hours.

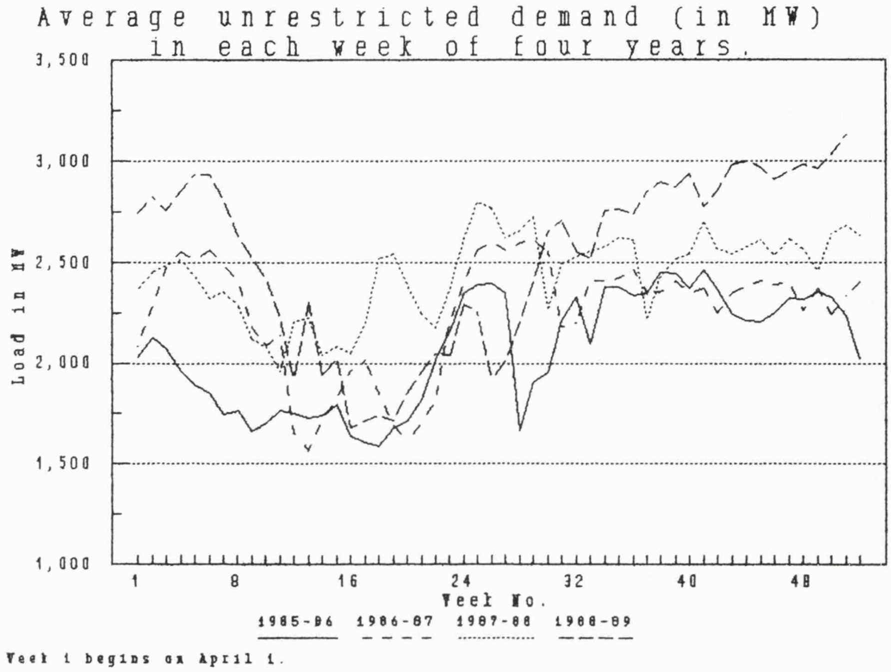
VI.3 Seasonal pattern of unrestricted demand.

So far we have assumed that there are no seasonal variations but we observed that the average load in different months is different from each other at any hour. Hence the above assumption need to be questioned.

In order to observe the seasonal pattern, one has to decide on what basis of time one would like to form "seasons". It could be weeks and/or months. On the basis of average load in a week (average of load over 24 hours, in 7 days), and/or average load in a month (average of load over 24 hours, in 28 or 30 or 31 days), one can differentiate the peak period in the year using the same method (calculating the confidence intervals using standard deviations around the arithmetic mean) as in the hourly analysis.

We can observe the average load in each week of four years from Graph VI.4. Keeping in mind that week 1 starts in April, we observe the average begin to fall after week 5 compared to average load in first four weeks. Again, from week 21, the average load appears to be higher than the

Graph VI.4



average load in weeks 5 to 20 (approximately).[106]

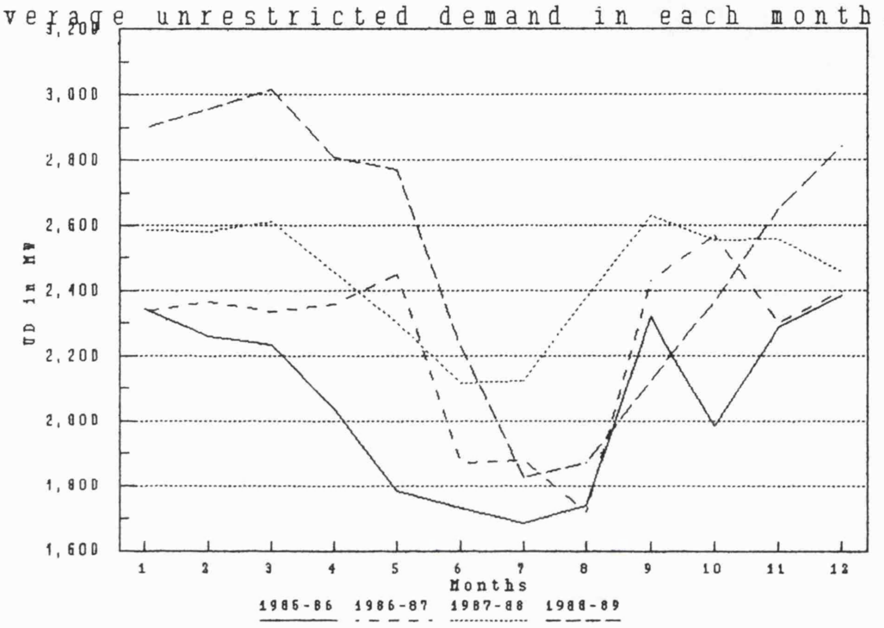
We take the month as a unit to differentiate seasons of the year as generally in India, farmers do use months as a unit of time to differentiate seasons of the year. In Gujarat, June, July and August are the months of monsoon, when the farmers may not require electrified pumps for irrigation. Thus, the demand in monsoon is expected to be less. But there was drought in Gujarat during the years 1985-86 to 1988-89 (four consequent years), and it is likely that the farmers did require to use the pumpsets for irrigation. Hence we can not assume that the demand would be less in these months. In the calculation of unrestricted demand as we have seen earlier, not only demand factors but supply factors are also equally important. If there is drought, the hydro-electric plants may find it more

[106] Note that there is exception of week 28 in 1985-86. In week 28 (i.e., last week of October 1985-86), the average load is very low.

difficult to operate depending upon the level of water as was the case in Gujarat in this period.

Graph VI.5

Average unrestricted demand in each month.



If we observe the average load in each month of the four years (from Graph VI.5), we observe that the months of June, July and August did have lower average unrestricted demand (MW) than the rest of the months, but as we are not aware of the relative importance of the demand and the supply factors, it is still very difficult to accurately differentiate the seasons.

VI.4 Demand analysis by Time-Of-Day.

Since demand characteristics vary by the type of consumer, geographic area and time period, a knowledge of loads at the disaggregate level is required. The properties of the aggregate demand at the system level may be quite different from the characteristics of the individual loads. Disaggregated loads are important in the system planning process. In generation planning, the system may be modeled as one source feeding a single lumped load. In the design of transmission networks, the characteristics of demand by region and by principal load centre, such as a city, become important. Ultimately, for planning distribution grids, a detailed knowledge of demand at each load centre is required. In the second section an attempt is made to study the non-structural KW demand models.

VI.4.1 Review of KW demand studies.

In the non-structural KW demand models, the cyclical pattern of consumption depends on climate, the price of electricity, the price and availability of substitute fuels, the income of consumers, the level and type of business activity, equipment stocks and other economic, demographic and geographic factors. Two issues concerning load curves are important. The first concerns the peaks and valleys of the curve (i.e., load factor) and the second concerns the peak or the highest point on the curve (i.e., the capacity requirement).

The literature on structural determinants of KW demand consists of few studies. The first attempt at structural analysis of KW demand was Cargill and Meyer's (CM) study of the deseasonalized monthly average hourly demands of two utilities from 1965 to 1968.[107] In that study, the forty-eight monthly averages of each hour's KW demand were explained by the ratio of the average price of electricity to the average price of gas, per capita income, employment levels in manufacturing, and time. Separate equations were estimated for each hour and for each utility. The short-run price elasticity was found to be negative but less than unity, and the elasticity during the off-peak hours was higher than during the peak hours. This peak/off-peak

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[107] T.P Cargill and R.A. Meyer, "Estimating the Demand for Electricity by Time-of-Day", Applied Economics, Vol.3, No.4 (December 1971), pp.233-246. The authors were not permitted to reveal the name of the two utilities.

elasticity differential is consistent with a priori expectations, since electricity consuming activities during peak periods are generally expected to be more inflexible than during off-peak periods.

Cargill and Meyer recognised that their preliminary estimates must be interpreted with care. For example, their income elasticities were negative and insignificant, implying that income did not have an important effect on electricity consumption, and what effect it did have was in the opposite direction to that expected. Since nearly all KWH demand studies have indicated that income is an important and positively correlated determinant of demand, CM's result on this matter is highly doubtful. Also the effect of electricity rates on demand in any one hour was assumed by them to be independent of its effects on demand during all other hours. Since equipment substitution would affect demand in all hours and peak/off-peak load shifting is likely, this condition, too, certainly does not hold. Finally, because declining block rate structures mean that average revenue declines as volume increases, CM's average price measure will result in a simultaneous estimation bias which will tend to increase the absolute value of the price coefficient and decrease the coefficients of other variables. In addition, the system-wide price measure may introduce further biases if the weights of the different customer classes change over time. For example, if industrial consumption grows faster than residential consumption, the systemwide average price would decrease even though the rates for each class remain constant. But CM's study indicates how altered rate levels may have an indirect impact on hourly demand by influencing the acquisition of electric equipment.

In the late 1970s there was much discussion in the United States about moving toward time-of-day pricing of electric power. Such a move had been advocated by peak load pricing theorists much earlier (in the 1950s) and implemented in Europe in the 1960s, but there was some reluctance to implement it in U.S. without some notion of what effects it might have. There had been virtually no experience with time-of-day tariffs and, hence, it was difficult to predict these effects. In developing countries like India too, there has been no experience with time of day tariffs and hence it is difficult to predict the effects of the time-of-day pricing of electricity. But so far, electricity demand at different times of the day has not been studied in any one region/state in India. The possible effects of existing pricing policy on demand at different times of day has not been studied either.

A promising approach to quantification of the effects of explanatory variables upon class load curves is contained in the Koenker and Hendricks study.[108] Koenker and Hendricks used hourly demand for forty load sites in the Commonwealth Edison service area (U.S.A) for the 120-hour weekday (working days of the week only) period during the peak week in 1972 and 1973. Each site contained from 10 to 350 residential customers without electric space heating. The climate influence was captured by current temperature and the temperature at that hour on the proceeding two days. The economic and geographic variables, taken from the 1970 census, included per capita income, appliance stocks, pressure of air conditioning, household size, and age and size of the dwellings. The price of electricity was not included because all customers paid the same marginal price for electricity.

They found that although the simple elasticity of demand with respect to income was positive and less than

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[108] R.Koenker and W. Hendricks, "Estimation of the residential Demand Cycle for Electricity", in J.W. Boyd, ed. Proceedings on Forecasting Methodology for Time-of-Day and Seasonal Utility Loads, Electric Power Research Institute, Special Report 31, (Palo Alto, March 1976).

one(indicating that electricity was a normal, but not a superior good), the partial elasticity (holding the stock of electrical appliances constant) was of ambiguous sign. Higher income families did not utilise their appliances more than low income families, or, if they did, they bought more efficient appliances in the first place. The pattern of electricity usage was very similar across six classes of residential users (as measured by their monthly consumption).

It is fairly difficult to evaluate the model and results obtained by Koenker and Hendricks. The data were transformed three times[109] to obtain a random error term in addition to the transformation required by the periodic spline approximation. It is quite possible that since each of these transformations only approximated the true correction, subtle biases were introduced each time. Also there was a high degree of multicollinearity among the 76 explanatory variables used in the equation. While many of the individual coefficients were insignificant, F-tests applied to groups of variables were significant. Finally, the economic and demographic data were based on estimates made two to three years previously, which Koenker and Hendricks believe may have affected the coefficients.

Panzar and Willig[110] made an attempt to develop a forecasting methodology which, in principle, allows one to predict the industrial demand for electricity under time-of-day pricing using data generated under uniform prices.

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[109] Heteroscedasticity was eliminated by multiplying each variable by the square root of the number of customers in the site. Autocorrelation was removed by second order differencing of each term. Contemporaneous correlation was controlled by generalised least squares methods.

[110] John C. Panzar and Robert D. Willig, "Theoretical determinants of the industrial demand for electricity by time of day", Journal of Econometrics, 9, (1979), pp.193-207.

But the methodology works the best when electricity is a relatively unimportant input and when its time-of-day price differential is small.

Patricia M. Davis[111] found that it was important to communicate the changes in cost to the utility's customers. Pricing electricity to reflect the utility's costs by time-of-use (TOU) should encourage customers to reduce their usage when it is most costly for the utilities to produce electricity.

According to Alexander[112] the technique of economic cost-benefit analysis provides an acceptable approach to evaluation of time-of-use rates. This type of analysis must be undertaken if welfare changes are to be measured. However, the approach is very difficult to implement with any acceptable degree of certainty. Expensive and time-consuming experiments are required to get adequate estimates of demand functions. The degree of interclass homogeneity must be considered to determine the need for studies of distribution of costs and benefits.

Albert Yin-Po Lee[113] argued that peak demand for electricity had been one of the major concerns of public utilities for at least two reasons. First, suppliers were legally obliged to meet this demand on any day and at any hour. Second, the cost of a kilowatt hour of electricity taken at the peak is usually much higher than that of the same amount of power consumed during the off-peak period.

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[111] Patricia M. Davis, "Time-of-use Electrical Demand Pricing", Public Utilities Fortnightly, (December 4, 1980), pp.23-25.

[112] Barbara J. Alexander, "The Welfare Analysis Approach to the Time-of-day Pricing Decision", Public Utilities Fortnightly, (December 4, 1980), pp.26-32.

[113] Albert Yin-Po Lee, "Voluntary Conservation and Electricity Peak Demand: A Case Study of the Modesto Irrigation District", Land Economics, Vol.57, No.3, (August 1981), pp.436-447.

In his paper he presented the empirical evidence of a two-year conservation experiment conducted by the Modesto Irrigation District. The Modesto and Turlock Irrigation Districts (MID and TID) are two adjacent, publicly owned utilities located in the Central Valley of California, supplying water and electrical power to consumers within their respective service territories. The purpose of the study was to provide a quantitative measure of the effectiveness of the conservation program by using an analysis-of-covariance technique. He calculated daily savings in the system peak usage for each period during which the voluntary conservation program was implemented. The results were quite impressive. However, the entire amount of savings could not be attributed to the voluntary conservation efforts, since the price of electricity and the level of household income did not stay constant during these years. He concluded that rather than relying slowly on voluntary conservation as the solution to the problem of peak demand, it should be reinforced or substituted by other measures such as changes in working hours etc.

Tishler[114] developed and estimated a model of demand for electricity by a firm subject to time-of-use (TOU) pricing of electric power. In the application he used a quadratic production function and directly incorporated into the production process the restrictions that some inputs cannot vary over the day. He showed that the TOU structure implies a unique set of parameter restrictions across the demand functions for inputs.

According to Schwarz[115] time-of-day demand and energy

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[114] Asher Tishler, "The industrial and commercial demand for electricity under time-of-use pricing", Journal of Econometrics, North-Holland, (1983), pp.369-384.

[115] Peter Schwarz, "The estimated effects on industry of time-of-use demand and energy electricity prices", The Journal of Industrial Economics, Vol.XXXII, (June 1984), pp.524-539.

charges could have differing effects. The peak energy charge encourages, within the peak hours, a reduction in the area beneath the load curve, that is, a reduction in peak energy (KWH) use. It does not explicitly encourage a rearrangement of the load pattern within this interval, and so may not reduce the maximum intrapeak demand. The peak demand charge encourages a reduction in the maximum demand; this could be accomplished directly by flattening the peak period use, or less directly by reducing the use at each instant within the peak. Hence, the peak demand charge has its primary effect on the pattern of use, while the energy charge primarily affects the level of use. In the study the effects on industrial customers of two types of peak load prices were presented. The peak energy charge was expected to reduce peak energy use, intrapeak maximum demand, and coincident demand. The peak demand charge was expected to reduce the intrapeak maximum demand, but the effect of the price on peak energy use or coincident demand could not be determined "a priori". The estimated effects of the charges showed the peak demand charge reduced peak energy use, intrapeak maximum demand, and coincident demand, while the peak energy charge caused a significant reduction in coincident demand only. The peak energy charge is likely to reduce utility system coincident demand and peak energy use, since its effects on each sector should be the same as for the industrial sector.

Bosworth and Pugh[116] observed that the literature on both peak load pricing of electricity and shift work have tended to assume a single rhythmically varying price. Empirical evidence suggested that this assumption was unrealistic, and will result in an inherent bias. Most, if not all firms, face both shift premiums of TOU electricity

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[116] Derek Bosworth and Clive Pugh, "Industrial and Commercial Demand for Electricity by Time of Day", The Energy Journal, Vol.6, No.3, (1985), pp.101-107.

pricing, and take their combined effects into account when planning the timing of their production operations. The author felt that important data deficiencies restricted the testing of the multiple rhythmically varying price model. However, casual empirical observations suggested that the concept might be important.

VI.4.2 Models for unrestricted demand in Gujarat.

Given the difficulties associated with previous attempts to estimate the demand for electricity, an attempt was made to estimate the demand for electricity following Cargill and Meyer.[117] A total of 24 demand equation estimates were used to estimate demand over the entire hourly load curve with primary emphasis placed on economic variables. The demand variables in the model refer to monthly time periods built up from hour to hour load for a four year sample period.

The hourly demand for electricity is composed of the demands of seven principal classes of customers: i) Domestic, ii) Commercial, iii) Industrial, iv) Agricultural consumers v) Public lighting and Public water works, vi) Railways, vii) Bulk supply to non-industrial consumers. The data represent total demand for electricity by hour (i.e., the integrated demand over a 60 minute interval of time) for groups i) to vii). It would be more desirable to have a separate model for the major components of demand by class of customer but detailed data are not fully available at the present time.

The costs of generating electricity were increasing due to various reasons like the scarcity and deteriorating quality of coal, increasing labour cost, increasing repairs and maintenance cost, increasing capital cost. It is well known that the cost of providing electricity at peak hours

[117] T.P. Cargill and R.A. Meyer, op.cit.

is much higher than the cost of providing electricity at trough hours. If the electricity authority failed to reflect the increasing cost feature in its pricing policy, and also failed to reflect the higher generating cost at peak hours, it might have given wrong signals to the consumers. If the electricity board were successful in designing a pricing policy that reflected these features of costs, it would give the right signals to the consumers and even under uniform pricing policy (i.e., in the absence of time-of-day tariffs), the price elasticities should be negative and significantly different from zero. Failing to provide electricity at the time when consumers want, the electricity board became more unreliable in supplying electricity. The failure to provide electricity may have arisen due to the failure to create additional capacity, which could again be the result of lack of funds to invest due to poor financial performance.

From the hourly analysis in Section VI.1.2 and VI.1.3, we gathered that during the first 6 hours and last 2 hours of the day, unrestricted demand is lower compared to the rest of the hours of the day in all seasons of the year. The possible reasons for this pattern could be variation in temperature in 24 hours of the day, the level of industrial and agricultural activities, working hours in the offices, sunset and sunrise timings, living style of the people, the price of electricity etc. If the temperatures are significantly lower after 22.00hrs till morning, the electricity use for airconditioning, coolers or fans would be less during the night hours compared to their use during the day.

If all industries were running for 24 hours a day, the electricity consumption by industries would be constant over 24 hours. It is unlikely that all industries, including continuous and non-continuous process industries, large or small industries and seasonal industries, would run for 24 hours a day. And it was so in Gujarat. Only the continuous processing industries were running for 24 hours a day in all seasons. There are industries like the ice-making industry, Khandsari, that run only for 7 to 8 months in a year. Also, there are small factories and manufacturing units that run for less than 24 hours depending upon the demand for their product in the market. So long as the manufacturing units in the non-continuous process industries are not fully utilised, the rise in demand for their product may lead the managers (to decide) to use the manufacturing units more extensively. And to use the units more extensively, they may employ more workers and use the same manufacturing units for more hours a day.

The agricultural consumers may decide to use electricity for pumping the water from underground, if the rainfall is not sufficient for the crop at that time of the year. Agricultural use of electricity can be flexible as far as the time of the day for using electrified pumpsets is concerned. But usually the farmer would like to use it during the day time due to convenience. Agricultural electricity use is more likely to get affected by the time of the year (i.e. the month) and the extent of rainfall and the crop pattern.

The working hours at offices also affect electricity use at different time of the day. In Gujarat most public offices, educational institutions and research organisations keep 10.00hrs to 17.00hrs as working hours. The sunset and sunrise timing affect the load through the electricity used by the public lighting. The difference in the sunset and sunrise timings in Gujarat over the year does not vary as much as it does in countries like U.K. Roughly the variation in sunrise and sunset timings[118] is 45 minutes above or below the average time of 06.00hrs for

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[118] As noted by GEB for the purpose of lighting the street lights in the state.

sunrise and 18.30hrs for sunset. Also, electricity consumption by residential consumers is affected by working hours, the sunset and sunrise timings and living style. If the sources of entertainments are electricity-intensive (for example, cinema, T.V., V.C.R., radio etc.) the frequency of their use and time of their use may affect the load pattern.

If we assume the average price of electricity to be the same at any hour of the day, it might still have different effects on consumers at different hours. Average price of electricity is the cost to the consumers for extra electricity consumption. The consumers derive some benefits (utility) from consuming the electricity. If the benefit of using electricity at any particular hour is more than the cost of using electricity at that hour, the consumers would continue using the electricity at that hour. Even if the cost (i.e. the price) of consuming the electricity at any particular hour changes, the consumers would continue consuming electricity at that hour at least while he derives positive benefit. Unless the changes in the cost (i.e. price) of consuming electricity at that hour lead to a situation where the benefit of using electricity at that hour becomes less than the cost, and the consumer decides to consume electricity at some other time (hour) of the day, he may not be affected by the changes in the costs (i.e. the price of electricity). In these circumstances, the price of electricity would affect electricity consumption at different times of the day.

Though all the above mentioned factors affect the load pattern in one or the other way, factors like agricultural use of electricity and seasonal industries affect the load in different seasons but the rest affect the load pattern i.e. the effect of these variables may be different at different times of any day.

Though all the factors were thought to be important in their effects on electricity demand, it was found to be difficult to include all of them while studying the effects of such variables on the load at different times of the day. In order to capture the effect of agricultural consumers' use in different seasons, a dummy variable was included. Since, on the one hand, the agricultural consumers' use of electricity depends upon the season and on the other hand electricity consumption by agricultural consumers affected electricity load in different seasons, we expected a significant effect of the dummy variable. But the effects of seasons were not expected to vary over different times of the day hence, the values of the coefficient of the dummy variable at different times of the day were not expected to vary.

To incorporate the effects of seasonal industries, and whether the non-continuous industries use their manufacturing units for 8 hours a day (one shift) or more than 8 hours a day in different months, employment in the manufacturing sectors was assumed to be a good proxy. Since industries were thought to be employing more people as they used their manufacturing units more extensively, depending upon the demand for their respective product in the market, we expected a positive effect of employment on load at all hours. The employment variable was expected to affect load at different hours of the day differently at that hour when the industries would start the third shift, because once the people were employed for one shift between 08.00hrs and 16.00hrs, employment would not affect the electricity load differently within this period. It was only between 1^{st} and 2^{nd}, and between 2^{nd} and 3^{rd} shift and between 3^{rd} and 1^{st} shift, that the effect of employment would change and not within the 1^{st} and/or 2^{nd} and/or 3^{rd} shift. As noted earlier the price of electricity was the same at different hours of the day, so we included average revenue as the proxy for average price. The average price was expected to affect the load differently at different hours of the day and negatively at all hours but I was not too sure about the effect of price at the peak hour. It is quite likely that the consumers continue using electricity even if the price increases over time since the increase in price over time may not have been sufficient to lead the consumers to perceive negative benefits at that hour.

Though it may be useful, it is difficult to study the effects of the above explained economic variables on the power demand at every hour on each day of four years. Also, the data on independent variables for every hour on each day of four years is almost impossible to get (unless we studied only a few industries). Thus, though there is a need to study the load at different times of the day (i.e. every hour of the day) it is not necessary to study every day. It is possible to take average load at each hour, on a number of days. The number of days depends upon whether we take a week as a unit or a month as a unit. We found it more convenient to take the average over a month. On this basis, we get 48 observations for the dependent variable i.e. "unrestricted demand". The data on the independent variables are not different for each hour (i.e. for each one of the 24 hourly equations). Therefore the estimates of "unrestricted demand" from the 24 equations would give us an idea about whether the effect of the independent variables on load at different hours were the same or different.

$$\log(UD_{in}) = \sigma_{1i}SD_n + \sigma_{2i}\log(PE_n) + \sigma_{3i}\log(M_n) + \sigma_{4i}t + \epsilon_{1i} \quad \ldots.(6.1)$$

i= 1...24; and, n= 1,2,..48.

where,

UD_{in} = unrestricted demand (load) at i hour in Kilowatts in n^{th} month,

SD_n = seasonal dummy in n^{th} month such that month 6, 7, 8 =1 and 0 otherwise,

PE_n = average price (in Paise) per kilowatt hour in n^{th} month,

M_n = employment of production workers in manufacturing sector in n^{th} month,

t = time i.e. months 1...48.

(Note: The data sources are given in the Appendix to Chapter VI. If average revenue data is derived from the total revenue data and total sales, then all revenue from "services" provided is lumped together so that fixed elements of two part tariffs and charges are included in the total revenue. Although it may then appear that one is regarding price as a term calculated by total revenue divided by quantity- this can be avoided if monthly data on total revenue and sales is used to compute average revenue, which can be treated as the constant price over time of the day.

We can employ the assumption that supply is perfectly elastic at the tariff price, as done by Baestra and Nerlove.[119] This assumption is based on the regulated nature of the industry, not from "a priori" supply-demand analysis. Each form must meet whatever demand arises from a specified tariff up to its capacity limitations. Such an assumption implies that we may interpret each estimated equation as the demand function.

Since the same exogenous variables enter each equation and no lagged endogenous variables appear, it can be shown that a consistent and efficient estimator for the equations considered simultaneously is equivalent to single equation, ordinary least squares, applied equation by equation.

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[119] P. Baestra and M. Nerlove, "Pooling Cross Section and Time series Data in the Estimation of a dynamic Model: The demand for Natural Gas", Econometrica, 34, (1970), pp.585-612.

VI.4.3 Results.

Special care should be taken in drawing conclusions from any estimates on at least two points. a) The price for a kilowatt hour of electricity is an average, due to aggregation over all classes of customers, which covers up demand mix changes. Such mix changes are not irrelevant when calculating average revenue. In addition, different mix patterns imply different degrees of system loss because delivery is made at different points in the distribution network. b) Demand at each hour may depend to some extent on prices prevailing at other hours. The present system of tariffs afforded a simplification in the estimation procedure since there is only one average revenue figure associated with all 24 hours of a given observation.

The results of 24 equations for the analysis of unrestricted demand are presented in Table 6.1 in the Appendix to Chapter VI. We expected a significant effect of seasonal dummies on the average unrestricted demand at all 24 hours. From the t-statistic of the dummy variable in the 24 equations (Table 6.1 in the Appendix to Chapter VI), we can observe that the effect of the seasonal dummy variable was significant at all hours. This implied that seasonal variations did affect the average unrestricted demand in any month at different hours but the effects were not different from each other i.e. the values of d_{1i} are not significantly different from each other at different hours. This confirms that the hourly pattern remained the same in the trough months and peak months but the average unrestricted demand at any hour in trough month was significantly different from the average unrestricted demand at the corresponding hour in the peak months.

We also observed the expected positive sign of the coefficients of employment. Due to the transformation of variables into logarithms we can consider the coefficients of employment as elasticities: employment elasticities at all 24 hours were significantly different from zero at the 1% significance level.

While comparing the values of employment elasticities at different times of the day (from Table VI.1), though they appear to be similar. But only the elasticities at hours 02.00 and 03.00, 13.00 and 14.00 are not statistically different from each other. Except these two times, the elasticities are different from each other. Generally, employment elasticities during 01.00hrs to 08.00hrs and 22.00hrs to 24.00hrs are lower from the values of employment elasticities between 09.00 and 22.00hrs. Since employment elasticities between 09.00 and 22.00hrs were higher than the rest of the hours we can say that employment during 09.00 to 22.00hrs affected electricity consumption to a greater extent than during 01.00 to 09.00 and 22.00 to 24.00 hours.

As shown also in Table VI.1, the price elasticities between the hours 01.00 to 04.00 and 21.00 to 24.00 were significantly different from zero (at 5% significance level); whereas during the rest of the period (i.e. between hours 05.00 and 20.00 both inclusive) the price elasticities were not significantly different from zero. This indicated that the consumers may not respond to the changes in the prices at least within the range charged during the period.

We expected the price of electricity to affect the unrestricted demand negatively i.e. negative sign of the price coefficient. As can be observed from the values of d_{2i}, except at hour 19.00, the signs of d_{2i} are negative. As indicated earlier it is quite likely that so long as the consumers derive positive net benefit, they would continue to consume electricity despite the increase in the prices. At hour 19.00, due to other factors i.e., lock-in effect for example after the sunset at about 18.30hrs, the lighting requirement in all households is unavoidable. The use of other electrical equipment, either for cooking purpose or for entertainment, and the electricity required to switch on the public lighting (though the share of public lighting was very small) led to a sharp rise in demand which may not respond to the increase in electricity pricing.

Table VI.1
Employment and price elasticities at different hours.

Hours (i)	Elasticities. Employment	Price
1	1.096	-0.2774
2	1.0874	-0.3051
3	1.0826	-0.3125
4	1.0786	-0.3195
5	1.0896	-0.2478@
6	1.1073	-0.246@
7	1.1277	-0.1893@
8	1.1357	-0.1709*
9	1.1636	-0.0844*
10	1.1509	-0.1313*
11	1.148	-0.146*
12	1.1424	-0.1786*
13	1.1393	-0.1916*
14	1.1407	-0.171*
15	1.1456	-0.1662*
16	1.1511	-0.1495*
17	1.1535	-0.1383*
18	1.1515	-0.1385*
19	1.1864	0.1274*
20	1.1541	-0.1808@
21	1.1499	-0.225
22	1.1408	-0.2317
23	1.1189	-0.29
24	1.1	-0.3334

Note: @ indicates that elasticities are significantly different from zero at 10% significance level.
And * indicates that elasticities are not significantly different from zero.
Source: From Table 6.1 in Appendix to Chapter VI.

We do not expect households and the public lighting to switch back to oil/kerosene lamps. Such a lock in effect may be reflected in the positive price coefficient at 19.00hrs.

The second important feature is the absolute values of the coefficients of the price variable in the 24 equations. We can observe (from Table VI.1) that between hours 01.00 to 06.00 and 21.00 to 24.00, the values of the price coefficients ranged between 0.22 and 0.333. Between hours 07.00 and 20.00, the price coefficients ranged between 0.08 and 0.192. In comparison to the absolute values of price coefficients in the hours 01.00 to 06.00, 21.00 to 24.00, the absolute values of the hours 07.00 to 20.00 are smaller. The higher night time values of the price coefficients imply that consumers respond to the changes in prices to a higher extent compared to the response that the consumers would have at the hours when the absolute values of the price coefficients were less. It is quite convincing that during the trough hours electricity demand responds more easily than at peak hours. From the hourly analysis in Section VI.1.2, we observed that hours 01.00 to 06.00, 23.00 and 24.00 were the trough hours. And at least during these hours we would have expected the consumers to respond to changes in the prices. What is worth noting is that during the hours 21.00 and 22.00 also, the consumers were responding to the changes in the prices more than between the hours 07.00 to 20.00.

As noted earlier, the estimated values of price coefficients can be interpreted as price elasticities since the equations were estimated after transforming the data into logarithms.

If a time-of-day pricing policy were adopted and if the consumers were charged more between hours 01.00 to 04.00 and 21.00 to 24.00, the consumers would respond and consume less electricity. The decrease in cost of consuming electricity would lead them to derive a net benefit from consuming electricity at that time of the day. On the other hand the price elasticities between the hours 05.00 and 20.00 were not statistically different from zero. This implies that the consumers may not respond to changes in the prices (under time-of-day tariffs). The consumers' net benefit from consuming at the peak hour may not only be positive but also very large and hence their response to increases in prices would be slow and/or negligible. In order to discourage the consumers from consuming electricity at peaks, the increase in price may have to be sufficiently large that the consumers have negative benefit from continuing to consume at peaks. At hour 19.00, though price elasticity was positive, it is not significantly different from zero, and hence the consumers' response to an increase in the price of electricity at that hour may continue to be insignificant but at least they would not consume more electricity simply because the electricity prices at that hour went up. It is quite likely that a high price of electricity at that hour would not affect the significance level of the elasticity.

The relative range of prices between which the consumers may respond may differ with the respective hours between the period 05.00 to 20.00 hours. For example, between 09.00 to 11.00 hours, the range of prices between which the consumers may respond may be larger than the price range between 05.00 and 08.00hrs.

On the whole, from the price elasticities at different hours, we can observe two things. First, even if there is uniform price over different times of the day, the consumers' response to prices was found to be different in different periods of the day and different hours. Second, the response to the changes in the prices, though negative for 23 out of 24 hours, was significantly different from zero for only 8 out of 24 hours. This implied that for 16 hours out of 24 hours of the day, the price of electricity was not a significant factor that affected the decision to consume electricity.

VI.5 Conclusion.

If we accept that the price of electricity is one of the instruments to manage demand effectively, we can say from this analysis that pricing as an instrument was not properly used by Gujarat Electricity Board in the period 1985-86 to 1988-89. This might have affected the electricity board in two related ways. Firstly, its financial performance, and secondly its reliability. If GEB wants to use pricing as an effective tool to manage demand in such a manner that the existing plants would be utilised in a better way and thereby reduce the extent of power cuts and fulfil the existing demand for electricity, then the existing pricing policy may not help. Thus, it is important to observe GEB's pricing policy and the financial performance over the years.

Appendix to Chapter VI.

Explanation of the data used.

Unrestricted demand: (UD_n).

As explained in Section VI.1.1, the data on unrestricted demand include the calculation of demand in the absence of restrictions imposed by Gujarat Electricity Board. It is measured in MW. The data were collected from the unpublished sources of Generation department and Load Despatch Centre of Gujarat Electricity Board, for the years 1985-86 to 1988-89.

Employment in the manufacturing sector in Gujarat: (M_n).

The data on employment in the manufacturing sector in Gujarat includes employment only by companies registered in Gujarat. Only quarterly data were available. The data were collected from unpublished sources of the Planning Commission of India,(New Delhi) for the period 1985-86 to 1988-89.

Average price of electricity in Gujarat: (PE_n).

The data on the average price of electricity in Gujarat were derived by the simple division of revenue earned (in million Rupees) in each one of the 48 months in the period 1985-86 to 1988-89 by the sale of electricity (in million KWH) in the corresponding month. The data on sales and revenue were collected from unpublished sources of the Planning and Commercial department of the Gujarat Electricity Board for the period 1985-86 to 1988-89.

Results.

Table 6.1

Model: $Log(UD_{in}) = d_{1i}SD_n + d_{2i}log(PE_n) + d_{3i}log(M_n) + d_{4i}t + e_{i1}$

Hour:i	d_{1i}	d_{2i}	d_{3i}	d_{4i}	$\bar{R}^2$	D-W
1	0.155	-0.2774	1.096	0.0094	0.584	1.35
S.E	0.033	0.1559	0.0242	0.0025		
T-st	4.69	-1.778	45.3	3.73		
2	0.157	-0.3051	1.087	0.0101	0.582	1.34
S.E	0.0343	0.1618	0.0251	0.00262		
T-st	4.595	-1.8856	43.318	3.84		
3	0.1526	-0.3125	1.0826	0.0105	0.5546	1.354
S.E	0.0366	0.1729	0.0268	0.0028		
T-st	4.164	-1.8073	40.35	3.74		
4	0.158	-0.3195	1.07	0.0106	0.569	1.39
S.E	0.036	0.1709	0.0265	0.00277		
T-st	4.379	-1.87	40.68	3.828		
5	0.154	-0.2478	1.0896	0.0097	0.5767	1.4505
S.E	0.0355	0.1676	0.026	0.0027		
T-st	4.35	-1.478	41.9	3.57		
6	0.1466	-0.246	1.1073	0.00901	0.5415	1.35
S.E	0.0351	0.1659	0.0257	0.00269		
T-st	4.173	-1.483	43.01	3.35		
7	0.182	-0.1893	1.1277	0.008806	0.6723	1.36
S.E	0.0296	0.14	0.0217	0.00226		
T-st	6.139	-1.3527	51.92	3.5524		
8	0.189	-0.1709	1.1357	0.00763	0.6883	1.2798
S.E	0.0292	0.1377	0.0214	0.00223		
T-st	6.48	-1.2407	53.15	3.41		
9	0.1715	-0.0844	1.1636	0.00519	0.6352	1.066
S.E	0.0286	0.1348	0.0209	0.002186		
T-st	6.00	-0.6259	55.62	2.37		
10	0.1463	-0.1313	1.1509	0.00695	0.6393	1.1367
S.E	0.0282	0.1331	0.0206	0.002158		
T-st	5.18	-0.9865	55.74	3.22		
11	0.1368	-0.1461	1.1488	0.007217	0.6281	1.0973
S.E	0.0281	0.1327	0.0206	0.0021		
T-st	4.869	-1.1013	55.81	3.35		
12	0.1447	-0.1786	1.1424	0.00743	0.6137	1.1481
S.E	0.029	0.137	0.0213	0.0022		
T-st	4.987	-1.3037	53.74	3.344		

Hour:i	d_{1i}	d_{2i}	d_{3i}	d_{4i}	$\bar{R}^2$	D-W
13	0.1536	-0.1916	1.1393	0.007112	0.5823	1.35
S.E	0.0306	0.1446	0.0224	0.00234		
T-st	5.015	-1.3251	50.78	3.033		
14	0.1417	-0.171	1.1407	0.007279	0.607	1.2
S.E	0.029	0.1367	0.0212	0.0022164		
T-st	4.8935	-1.2514	53.79	3.28		
15	0.1453	-0.1662	1.1456	0.007076	0.6108	1.2215
S.E	0.0287	0.1356	0.021	0.002198		
T-st	5.06	-1.2255	54.456	3.21		
16	0.1407	-0.1495	1.1511	0.00684	0.609	1.14
S.E	0.0284	0.134	0.0208	0.00217		
T-st	4.9564	-1.1156	55.35	3.14		
17	0.1355	-0.1383	1.1535	0.006774	0.6062	1.112
S.E	0.0283	0.1337	0.0207	0.002167		
T-st	4.7855	-1.0347	55.62	3.12		
18	0.1378	-0.1385	1.1515	0.00713	0.6356	1.16
S.E	0.0278	0.1315	0.0204	0.002132		
T-st	4.948	-1.0536	56.45	3.34		
19	0.1956	0.1274	1.18	0.00265	0.7053	1.14
S.E	0.0274	0.1293	0.0201	0.00209		
T-st	7.14	0.9851	59.13	1.26		
20	0.15	-0.1808	1.154	0.00765	0.7128	1.27
S.E	0.0243	0.1146	0.0178	0.001858		
T-st	6.179	-1.578	64.92	4.11		
21	0.0926	-0.225	1.1499	0.00838	0.6302	1.268
S.E	0.0247	0.1166	0.0181	0.00189		
T-st	3.749	-1.9293	63.55	4.4337		
22	0.118	-0.2317	1.14	0.008239	0.5906	1.219
S.E	0.0276	0.1304	0.0202	0.0021145		
T-st	4.0485	-1.777	56.38	3.89		
23	0.1342	-0.29	1.1189	0.009107	0.5627	1.1513
S.E	0.0313	0.1476	0.0229	0.00239		
T-st	4.2929	-1.965	48.85	3.8		
24	0.152	-0.3334	1.1	0.009718	0.5591	1.14
S.E	0.0334	0.1576	0.0245	0.00255		
T-st	4.553	-2.1151	44.99	3.8		

SECTION III: ELECTRICITY PRICING IN GUJARAT.

Introduction.

The financial performance of one Electricity Board i.e. Gujarat Electricity Board (GEB) is evaluated. Pricing policy could have been one of the reasons for the present poor financial status of GEB, and features of the tariff structure in Gujarat were examined with the help of the tariff schedules for different consumer groups.

The present pricing policy was considered inadequate and, the need to re-design a pricing policy emerged. Hence, the literature suggesting different approaches to electricity pricing was reviewed and the principle for pricing leading to maximum welfare was derived.

Based on this principle, optimal electricity prices were calculated and compared with the actual prices.

CHAPTER VII

FINANCIAL PERFORMANCE AND ELECTRICITY PRICING IN GUJARAT ELECTRICITY BOARD.

VII.1 Financial performance of Gujarat Electricity Board.

VII.1.1 Government directives.

For proper evaluation of the performance of public utilities, it is essential to compare their performance in pricing with the desired pricing. According to the Power Finance Corporation,[120] the performance of any public enterprise, and more so of power utilities, should be evaluated in terms of the success achieved by the management in the following objectives and in the order of importance indicated below:

(i) Furthering of non-commercial objectives of the utility as specified by the Government. These were fairly well defined in the Electricity Supply Act, which enjoins upon the Boards to arrange for the supply, transmission and distribution of electricity in the most efficient and economical manner, with particular reference to those areas which, for the time being, do not have access to electricity supplies or have inadequate and unreliable electricity supplies.

(ii) Furthering of commercial objectives of the utility and maximisation of profit subject to fulfilment of non-commercial objectives and within the constraints of Government directives.

(iii) Improving the quality of services; and

(iv) Effecting economy and efficiency in the use of resources.

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[120] Seminar on Financial Performance of State Electricity Boards, organised by Power Finance Corporation Ltd. and Tata Energy Research Institute, 20-21 February, 1989, (New Delhi, 1989), p.20.

Often there are conflicts within these stated objectives. The SEBs are not only expected to perform a developmental role and fulfil service obligations, but also at the same time to function as commercial enterprises. They are expected to provide a substantial volume of services which are not commercially justified or remunerative.

Also, unlike many Western utilities, the above mentioned general objectives were not translated into specific performance targets, except that a standard was set up for an annual rate of return on invested capital or assets.

The criterion of adequate return to generate the required amount of internal resources for partial self-financing of investment is beset with uncertainty and fluctuation from year to year. An investment programme on this basis is necessarily resource-constrained rather than need-based. Resource generation also depends upon the capital structure, financing terms and rate of increase of capital assets. (Such a set of criteria would be difficult to set up and monitor.)

Prior to the recent amendment of the Act in June 1978, the Electricity (Supply) Act, 1948 had laid down in Section 59 that the Electricity Boards shall not, as far as practicable, carry on its operations at a loss and shall adjust its charges (tariffs) accordingly from time to time. The Electricity (Supply) Act, 1948 was amended in June 1978 to make the State Electricity Boards commercially viable and to earn a net return on their investments.

In the Statement of Accounts of GEB of each year during the period 1979-86 it was mentioned that,

> "Section 59 of the Electricity (Supply) Act, 1948, as amended by the Electricity (Supply) Amendment Act, 1978, provides that the Board shall, after taking credit for any subvention from the State Government under Section 63 ibid, carry on its operations under this Act and adjust

> its tariff so as to ensure that the total revenues in any year of account shall after meeting all expenses properly chargeable to revenues including operating, maintenance and management expenses, taxes (if any) on income and profit, depreciation and interest payable on all debentures, bonds and loans, leave surplus, as the State Government may from time to time specify. The State Government has not specified the amount of such surplus for the year ...."[121]

Thus, the Act gave some directions to GEB (and all other SEBs), but left it to GEB to evaluate its own financial performance and adjust tariffs such that it earns a positive rate of return. No rate of return was mentioned and it was left to the State Government to decide. According to the directives GEB was and still is mandated to charge rates so as to cover the full cost of operation, including depreciation as well as a stipulated rate of return by the Government of Gujarat. During the period 1961-86, the Government of Gujarat did not specify the amount or percentage rate of return.[122] But from time to time the Government of India set up Committees to comment on energy issues in India. These Committees also reviewed the electricity prices charged by different State Electricity Boards (SEBs).

A Working Group set up by the Planning Commission in 1963[123] on the Price Policy of the State Electricity Undertakings had recommended that the State Electricity Boards should earn a return of 12% (including electricity duty) on capital investments, after providing for operating expenses and depreciation. The Energy Survey of India

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[121] The Annual Statement of Accounts, Gujarat Electricity Board, (Baroda, 1986).

[122] Ibid, For the years 1961-86.

[123] As referred in Report of the Energy Survey of India Committee, Planning Commission, Government of India, (New Delhi, 1964), p.157, also known as Venkataraman Committee report.

Committee[124] in 1964 had recommended that the State Electricity Boards should earn a return of 11% on the capital employed, if not immediately, at least within a period of 10 years. This return was to be computed after providing for operating cost and depreciation but included receipts from electricity duty which were estimated to be about 1.5% of the capital. The required net return was about 3% after providing for interest charges (6%), transfer to general reserve fund (0.5%), and after excluding receipts from electricity duty (1.5%), representing the revenues to the State Government.

The Report of the Fuel Policy Committee[125] in 1974, examined the rate of return proposed by the Energy Survey of India Committee and again emphasised the 11% gross rate of return or 3% net rate of return on average "capital base", i.e., 3% net return, after the payment of depreciation, finance and interest charges, and excluding the electricity duty. The average "capital base" was defined as the average of depreciated capital at the beginning of the year and at the end of the year. Thus, as the assets are depreciated, the required return also goes down.

The Committee on Power, in 1980, recommended a 15% gross rate of return on the average capital base i.e. after providing for operating expenses and depreciation.[126] On this basis the net returns of the Electricity Boards as a whole would be roughly 6% of the average capital base after meeting interest on the loan capital both in respect of the completed works and works-in-progress. The gross return of

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[124] Ibid, p.160.

[125] Report of the Fuel Policy Committee, op.cit, (New Delhi, 1974), also known as the Chakravarty Committee Report.

[126] Report of the Committee on Power, op.cit, (1980), p.79.

15% was recommended on the assumption that the average composite lending rate (i.e. weighted average of the interest rates being charged by the Government and other lending institutions) to all State Electricity Boards was 7%. If the interest rate rose or was higher in the case of a particular State Electricity Board, then the Committee recommended that the required return of 15% should be increased correspondingly.

The Committee gave directions on how to calculate the rate of return. According to the Committee,

> "... the return should be calculated by taking the gross revenue receipts of the Board consisting of revenue from tariffs, subsidy from the government and miscellaneous receipts like meter rents, licence fees etc. (excluding receipts from electricity duty) and subtracting from it-operating cost consisting of fuel cost, cost of power purchases, administration and establishment charges, operation and maintenance charges and provision for depreciation of fixed assets in use; and dividing this net revenue figure by the capital base.."[127]

According to the Committee, the capital base should be defined as the average at the beginning and the end of a financial year of the total of the gross value of the fixed assets in operation and working capital to the extent of 1/6th of the administrative and operating costs for the fiscal year reduced by the amount of accumulated depreciation, and consumers' contributions to fixed assets.

The rate of return on assets suffers from the problem of historical value and may not generate adequate resources for asset replacement. Under inflationary conditions, the historic value of assets falls way behind the replacement cost very soon, and thus the prices charged for electricity are not the appropriate economic prices and the return earned is not adequate to finance future investments. The rate of return on fixed assets gives a higher yield on debt

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[127] Ibid, p.78.

financed assets than on equity financed assets, as the surplus is the residual after charging all expenses including interest.

While keeping in mind the above mentioned limitations, it is interesting to observe the actual rate of return earned by Gujarat Electricity Board as a proportion of its average capital in the period 1961-86.

There are two main problems in calculating the return (particularly for Gujarat) as recommended by the Committee on Power. The first problem is related to the amount of interest charges. To avoid the confusion regarding different interest rates in Gujarat compared to 7% Committee target, it is better to include interest charges in the fixed cost of GEB and hence include it in the calculation of total cost which should be deducted from the total revenue to derive the net return on capital base.

The second problem is that information on the subsidy by the State Government is not available. If the Electricity Board is expected to run on commercial principles and earn a positive rate of return on capital investment, the rate of return on investment calculated on the basis of the revenue, including the subsidies from the State, may not give the correct picture. In my opinion, it would be appropriate to exclude the subsidies from the State from the total revenue. Thus total revenue would include the revenue from electricity sales and other miscellaneous receipts only. Deducting the total cost (including variable cost i.e, power generation and purchase, administration, repairs and maintenance, and fixed cost i.e. the depreciation charges, total wage bill and the interest charges), from the total revenue would give us the net difference or the net return in absolute terms. Dividing this net revenue by the capital base should give us the ratio of return to capital base. Though the 'expected rate of return' remained the same throughout the period, the 'expected return' (in absolute terms) changed every year depending upon the value of the capital in each year. The actual return can be compared with the 'expected return' in each year.

VII.1.2 Cost analysis.

In this section GEB's total, average and marginal cost functions are estimated. It is known that these functions are related in such a way that, given the total cost function, one should be able to derive the average and marginal cost functions. (Both the total and marginal cost functions are also deducible from the average cost function. But, given the marginal cost function, one cannot infer the particular average and total cost functions, unless a point on either curve is known or one knew the constant of integration in advance. Nevertheless, the general form of the functions can still be determined.) This section is based on this premise. In estimating the functions, a distinction is made between fixed (capacity) cost and variable (operating) cost. (The operating cost included the administration cost, cost of repairs and maintenance, cost of generating power and purchasing power from the plants owned by the central government or from the neighbouring States.) The main reason for this is that, in public enterprise pricing, particularly when variable loads are involved, a knowledge of capacity cost to be allocated between peak and off-peak load is necessary. The costs also differ in their nature: variable (operating) costs tending to vary with output (and possibly with some other variables as well) while fixed (capacity) costs do not. In estimating the costs, two approaches are used, one simple and the other involving econometric methods.

(i) The simple approach.

This approach assumes that, in each period (i.e. a year), both average and marginal costs are constant. Given this, average cost (AC) is the ratio of total cost and output while marginal cost (MC) can be computed according to the following formula:

$$MC_t = \frac{C_t - C_{t-1}}{X_t - X_{t-1}}$$

where C = total costs, X = output (electricity sales) and t = time period.
So, marginal variable (operating) cost (b) is given by,

$$b_t = \frac{OC_t - OC_{t-1}}{X_t - X_{t-1}}$$

And marginal fixed (capacity) cost (ß) is

$$\beta_t = \frac{CC_t - CC_{t-1}}{X_t - X_{t-1}}$$

where OC = total variable (operating) cost and CC = total fixed (capacity) cost. Note that, $MC_t = b_t + \beta_t$.

The results are presented in Table VII.1a and VII.1b. Before commenting on them, two points are noteworthy. One is that total fixed (capacity) cost is approximated by the sum of depreciation charges, wage bill and interest charges. The other is that output refers to sales. Ideally, electricity output should equal electricity sales since electricity is supplied on demand. However because of transmission and distribution losses, sales are often less than output. Electricity sales are preferable in determining cost since the losses are costs to GEB.

As can be seen from Table VII.1b, the average variable (operating) cost ranged between 8.0 paise in 1966 and 56.8 paise in 1986. Whereas the average fixed (capacity) cost ranged between 5.1 paise in 1963 and 26.7 paise in 1986.

Table VII.1a
Electricity sales and costs in Gujarat Electricity Board.

Year	GTS	DGTS	TVC	DTVC	TFC	DTFC
1961	441.1	-	38.4	-	23.4	-
1962	509.0	67.8	48.2	9.7	29.7	6.3
1963	576.6	67.6	58.7	10.5	29.2	-0.5
1964	656.8	80.2	72.1	13.4	43.6	14.3
1965	764.1	107.3	86.0	13.9	44.4	0.8
1966	945.3	181.2	75.9	-10.2	68.7	24.3
1967	1,174.7	229.4	111.2	35.3	107.0	38.3
1968	1,403.7	228.9	134.1	22.9	127.5	20.4
1969	1,752.1	348.4	154.0	19.9	143.5	16.0
1970	2,013.2	261.0	182.6	28.6	157.8	14.3
1971	2,346.4	333.3	258.3	75.6	180.8	23.0
1972	2,469.5	123.1	239.7	-18.5	198.4	17.5
1973	2,948.5	478.9	289.2	49.5	247.1	48.7
1974	3,144.1	195.6	347.8	58.6	255.3	8.2
1975	3,678.0	533.9	587.3	239.5	304.4	49.2
1976	3,974.7	296.6	691.1	103.8	343.9	39.4
1977	4,692.5	717.8	707.3	16.1	562.6	218.7
1978	5,155.1	462.6	718.9	11.7	668.8	106.2
1979	5,883.6	728.5	1,057.2	338.2	821.9	153.1
1980	6,243.8	360.2	1,337.0	279.8	954.0	132.1
1981	6,516.7	272.9	1,751.8	414.8	1,071.3	117.2
1982	7,047.2	530.5	1,996.1	244.3	1,288.7	217.5
1983	7,240.1	192.9	2,741.1	745.0	1,484.5	195.7
1984	8,080.4	840.3	3,323.9	582.8	1,655.0	170.5
1985	8,578.1	497.7	4,238.6	914.6	1,900.1	245.1
1986	9,015.2	437.1	5,122.7	884.1	2,404.1	504.0

GTS = Total electricity Sales in Gujarat in million KWH (or GWH).
DGTS = GTS-GTS(-1)
TVC = Total variable cost in million Rupees.
DTVC = TVC-TVC(-1)
TFC = Total fixed cost in million Rupees.
DTFC = TFC-TFC(-1).

Marginal fixed cost had the wrong sign once and the marginal variable cost had the wrong sign on two occasions. Marginal fixed cost and marginal variable cost fluctuated a great deal. For instance, the marginal variable cost ranged between -15.0 paise in 1972, and 386.2 paise in 1983. This result is not satisfactory. The Table (i.e VII.1b) also shows that total marginal cost (i.e. the sum of both: marginal fixed and variable, costs) fluctuated in the period from -0.8 paise in 1972 and 487.0 paise in 1983.

In contrast, the total average cost increased after 1972.

Table VII.1b
Estimated average and marginal costs (using simple approach) in Gujarat Electricity Board. (paise per KWH)

Year	MVCS	MFCS	MTCS	AVCS	AFCS	ATCS
1961	-	-	-	08.7	05.3	14.0
1962	14.3	09.2	23.6	09.5	05.8	15.3
1963	15.6	-00.7	14.9	10.2	05.1	15.2
1964	16.7	17.9	34.6	11.0	06.6	17.6
1965	13.0	00.7	13.7	11.2	05.8	17.1
1966	-05.6	13.4	07.8	08.0	07.3	15.3
1967	15.4	16.7	32.1	09.5	09.1	18.6
1968	10.0	08.9	18.9	09.6	09.1	18.6
1969	05.7	14.6	10.3	08.8	08.2	17.0
1970	10.9	05.5	16.4	09.1	07.8	16.9
1971	22.7	06.7	29.6	11.0	07.7	18.7
1972	-15.0	14.2	-00.8	09.7	08.0	17.7
1973	10.3	10.2	20.5	09.8	08.4	18.2
1974	29.9	04.2	34.1	11.1	08.1	19.2
1975	44.8	09.2	54.1	15.9	08.3	24.2
1976	35.0	13.3	48.3	17.4	08.6	26.0
1977	02.2	30.5	32.7	15.1	12.0	27.0
1978	02.5	22.9	25.5	13.9	13.0	26.9
1979	46.4	21.0	67.5	17.9	14.0	31.9
1980	77.7	36.7	114.4	21.4	15.3	36.7
1981	151.9	43.0	194.9	26.9	16.4	43.3
1982	46.0	41.0	87.0	28.3	18.3	46.6
1983	386.2	101.5	487.7	37.9	20.5	58.4
1984	69.4	20.3	89.7	41.1	20.5	61.6
1985	183.7	49.2	233.0	49.4	22.1	71.6
1986	202.3	115.3	317.6	56.8	26.7	83.5

MVCS= Marginal variable cost (in paise) using simple approach, i.e. (DTVC/DGTS)*100.
MFCS= Marginal fixed cost (in paise) using simple approach, i.e. (DTFC/DGTS)*100.
MTCS= Total marginal cost (in paise) i.e. MVCS+MFCS.
AVCS= Average variable cost (in paise)i.e. (TVC/GTS)*100.
AFCS= Average fixed cost using simple approach, i.e. (TFC/GTS)*100.
ATCS= Total average cost (in paise) i.e., AVCS+AFCS.

By and large, the main problem with the results is the fluctuating marginal costs. One simple solution is to approximate the marginal costs by their corresponding average costs. This follows from the fact that if, at any instant, average cost is constant, then it is equal to marginal cost. So, given our initial assumption of constant marginal and average costs over all years, marginal operating costs should equal average operating cost at least once and marginal capacity cost should equal average capacity cost in each year. But how reasonable is the assumption of constant costs? The assumption may be plausible for marginal capacity cost since capacity cost is generally independent of output. With regard to marginal operating cost, what the assumption boils down to is that there are constant returns to scale, a feature hard to come by in an electric utility. A single plant exhibits increasing returns to scale for a substantial range of output (or decreases slowly). So, if the utility has only one plant, marginal cost will decrease with output over that range. With more than one plant, and a rational utilisation policy, plants are used in decreasing order of their running efficiency or increasing order of cost implying that the system's marginal cost is most likely to be increasing. So, at least, the nature of GEB's operating cost needs investigating.

(ii) The Econometric approach.

With this approach, we attempt to estimate GEB's total operating cost function and from the function, to derive the average and marginal variable cost functions. The main issues are (1) The variables to include, (2) the form of the function, and (3) the estimation technique to use. On the first, economic theory suggests that total cost depends on output and input prices. So, ideally, one should estimate a cost function whose explanatory variables are output and input prices. The main problem is that, in reality, the inputs used are many and heterogeneous and aggregation is at best tedious and rough. The second problem is that the input prices utilised by GEB are not available for a sufficient number of periods. One way of resolving this problem is to assume that input prices increased with time and use a trend term to approximate them.

A plot of cost on output between 1961-1986 suggests that the variable (or operating) cost function is basically exponential.[128] So we fitted a function of the form:

$$TVC_t = e^{\alpha 01 + \alpha 11t + \alpha 21Xt + \epsilon t1} \quad ....(7.1)$$

where TVC is total (nominal) variable cost measured in million Rs. and X is output measured in million KWH. This function is equivalent to the function,

$$\text{Log } TVC_t = a_{01} + a_{11}t + a_{21}X_t + u_{t1} \quad ....(7.1a)$$

The OLS technique was applied to above function. The result is,

$$\text{Log } TVC_t = 3.3803 + 0.1410_t + 0.0001463X_t \quad ....(7.2)$$

T-statistic(45.01) (9.61) (3.64)

D-W statistic = 1.68

$\bar{R}^2 = 0.9945$

All the coefficients are statistically significant. Expressing (7.2) in form of (7.1a), we have,

$$TVC_t = e^{3.3803 + 0.1410t + 0.0001463Xt}$$

$$= e^{Bt + 0.0001463Xt} \quad ....(7.3)$$

where $B_t = 3.3803 + 0.141_t$ ....(7.4)

From (7.4), the average variable cost function is,

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[128] For data on cost and output between 1961-86 see Table VI.1a.

$$AVC_t = \frac{1}{X_t} e^{Bt + 0.0001463Xt} \quad ....(7.5)$$

The marginal variable cost function is

$$MVC_t = 0.0001463e^{Bt + 0.0001463Xt} \quad ....(7.6)$$

So, to obtain the total variable cost function and, therefore, the average and marginal variable cost functions for each year, all we need to do is specify the value of B_t for the year and substitute B_t and X_t into (7.5) and (7.6). B_t can be derived from (7.4). Note that t=1 in 1961 and t=26 in 1986.

The usefulness of this approach is illustrated by estimating the total, average and marginal operating costs between 1961 and 1986 at the actual output level. The estimates together with actual total operating costs are presented in Table VII.2. Firstly, average cost increased from 9.42 paise in 1961 to 10.02 paise in 1965, but then decreased to 8.87 paise in 1969. After 1969 it increased monotonically. In contrast, marginal cost increased monotonically throughout the period. Secondly, average cost was higher than marginal cost before 1982 but less thereafter. Thirdly, the actual and estimated total costs can be used to determine the actual and estimated regressions between 1961 and 1986. Both the functions indicate that a proportionate increase in output requires a more than proportionate increase in cost to supply that output.

Table VII.2
Estimated average and marginal costs (using the econometric approach) in Gujarat Electricity Board.

Year	TVC	B_t	Xt	AVCE	MVCE	TVCE
1961	28.4	3.66	0.064	09.42	0.61	41.54
1962	48.1	3.8	0.074	09.49	0.71	48.31
1963	58.7	3.94	0.084	09.74	0.82	56.18
1964	72.1	4.08	0.096	09.97	0.96	65.45
1965	86.0	4.22	0.111	10.02	01.12	76.55
1966	75.9	4.36	0.138	09.58	01.32	90.51
1967	111.2	4.5	0.172	09.18	01.58	107.78
1968	134.1	4.65	0.205	09.14	01.88	128.32
1969	154.0	4.8	0.256	08.87	02.27	155.47
1970	182.6	4.93	0.294	09.24	02.72	185.98
1971	258.3	5.07	0.343	09.58	03.29	224.84
1972	239.7	5.21	0.361	10.68	03.86	263.59
1973	289.2	5.35	0.431	11.04	04.76	325.52
1974	347.8	5.49	0.46	12.27	05.64	385.69
1975	587.3	5.63	0.538	13.06	07.03	480.16
1976	691.1	5.78	0.581	14.53	08.45	577.38
1977	707.3	5.92	0.686	15.74	10.81	738.4
1978	718.9	6.06	0.754	17.65	13.31	909.71
1979	1,057.2	6.2	0.861	19.81	17.05	1,165.2
1980	1,337.0	6.34	0.913	22.66	20.7	1,414.2
1981	1,751.8	6.48	0.953	26.02	24.8	1,694.7
1982	1,996.1	6.62	1.031	29.94	30.87	2,108.7
1983	2,741.1	6.76	1.059	34.51	36.56	2,497.5
1984	3,323.9	6.9	1.182	40.26	47.6	3,251.7
1985	4,238.6	7.05	1.255	46.97	58.94	4,026.7
1986	5,122.7	7.19	1.318	54.86	72.35	4,942.5

TVC= Total variable cost in million rupees.
Bt= 3.3803 +(0.141*t).
Xt= 0.0001463*GTS.
AVCE= Average variable cost estimated using econometric approach, i.e., 1/GTS $*e^{Bt+0.0001463Xt}$.
MVCE= Marginal variable cost estimated using econometric approach, i.e., $0.0001463*e^{Bt+0.0001463*Xt}$
TVCE= Total variable cost estimated using econometric approach.

VII.1.3 Comparison of the actual rate of return with the expected rate of return.

Table VII.3 shows the revenue earned from sale of electricity and return earned from other sources.[129]

[129] These sources include interest on staff loans and advances, investments, loans and advances to licensees, on advances to suppliers/contractors, from trading, delayed payment charges from consumers and other charges paid by the consumers for repairs etc.

Table VII.3
Total costs and total revenue of Gujarat Electricity Board, actual and expected net return of Gujarat Electricity Board. (Rupees in million).

Year	ER	OR	Total Rev.	Total Cost	Capital base	Expected return (3%)	Expected return (6%)	Actual return (TR-TC)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1961	55.5	4.5	60.0	61.9	231.8	6.9	13.9	-1.9
1962	65.7	5.8	71.5	77.8	265.4	7.9	15.9	-6.4
1963	75.0	11.8	81.0	87.9	346.7	10.4	20.8	-6.9
1964	91.7	6.8	98.5	115.6	511.2	15.3	30.7	-17.1
1965	110.5	7.7	118.2	130.4	669.0	20.1	40.1	-12.1
1966	114.6	12.2	126.7	144.5	738.8	22.2	44.3	-17.8
1967	142.4	21.5	161.3	218.2	795.9	23.9	47.7	-56.9
1968	169.1	20.9	185.4	261.6	880.9	26.4	52.8	-76.2
1969	217.5	26.5	237.5	297.5	964.7	28.9	57.9	-60.0
1970	252.6	28.4	274.8	340.5	1,068.2	32.0	64.1	-65.7
1971	328.6	113.0	354.7	439.1	1,203.3	36.1	72.2	-84.4
1972	363.1	24.2	378.8	438.1	1,351.4	40.5	81.1	-59.3
1973	445.2	25.5	461.3	536.3	1,634.0	49.0	98.0	-75.0
1974	501.9	27.4	522.3	603.1	1,898.0	56.9	113.9	-80.7
1975	745.1	34.2	776.0	891.8	2,042.7	61.3	122.6	-115.8
1976	857.8	44.9	898.1	1,035.0	2,174.9	65.2	130.5	-136.9
1977	1,158.3	42.1	1,206.7	1,269.9	2,758.3	82.7	165.5	-63.2
1978	1,311.3	63.7	1,374.7	1,387.8	3,494.7	104.8	209.7	-13.0
1979	1,592.8	157.4	1,749.9	1,879.1	4,164.9	124.9	249.9	-129.2
1980	2,046.9	67.1	2,113.8	2,291.0	4,897.4	146.9	293.8	-177.2
1981	2,363.3	489.8	2,453.2	2,823.1	5,462.1	163.9	327.7	-369.8
1982	3,163.2	153.3	3,262.8	3,284.8	6,220.7	186.6	373.2	-22.1
1983	3,959.2	268.7	4,082.3	4,225.6	7,561.2	226.8	453.7	-143.3
1984	4,875.8	183.2	5,040.5	4,979.0	9,000.7	270.0	540.0	61.5
1985	5,592.2	649.5	5,773.4	6,138.7	10,190.6	305.7	611.4	-365.3
1986	6,314.4	1,150.0	6,387.8	7,526.8	11,240.7	337.2	674.4	-1139.0

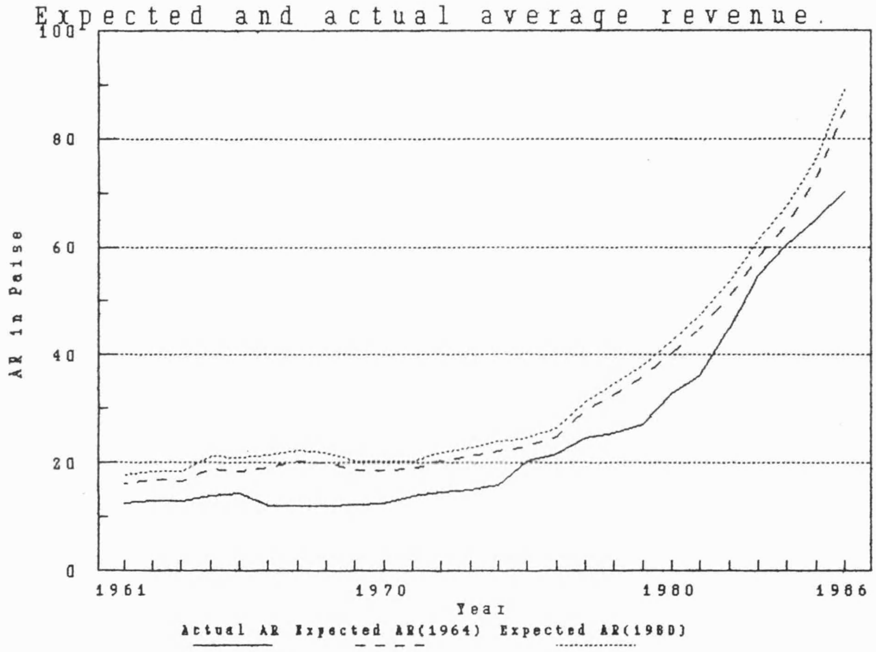
Note: ER = Revenue earned from sale of electricity.
OR = Revenue from other sources.

The total revenue earned by GEB which is an addition of the revenue from electricity and other sources in the period 1961-86 is also given in the Table. The Table also shows the total cost that GEB incurred to provide electricity in Gujarat. This includes the variable (i.e repairs and maintenance, administrative, power generation and power purchase) and fixed (i.e. depreciation, interest charges and the wages) costs. The difference between revenue and costs is the net return earned by Gujarat Electricity Board. The "expected return" in Table VII.3 is calculated on the basis of the recommendations of the two Committees: a 3% net rate of return on capital base as recommended by the Energy Survey of India Committee, and a 6% net rate of return as recommended by the Committee on Power. It can be clearly observed that the actual profit/loss (a negative sign shows losses) is way below the target minimum return of both Committees. This definitely should not only worry GEB but also the Government of Gujarat.

VII.1.4 Comparison of actual and expected average revenue.

In the method suggested by the Pricing Policy for Electricity Undertakings (1963), the expected average revenue is decided first and then the average revenue of each consumer group is fixed in such a manner that the arithmetic mean of the average revenues to different consumer groups yield the expected average revenue, i.e., in short, cost plus pricing such that the electricity board can earn the expected rate of return on its investment. We can use this method to calculate the expected average revenue from electricity sales to different consumers. Using the data on the average fixed cost (using the simple approach as explained in Section VII.1.2), from Table VII.1b and average variable cost (using the econometric approach as explained in Section VII.1.2), from Table VII.2, we can derive the total expected average cost. From the expected total net return as per the recommendations of the Energy Survey of India Committee Report (calculated as 3% rate of return on capital base), and the Committee on Power (calculated as net rate of return of 6% on capital base), one can calculate expected return per unit of electricity sold i.e. by dividing the total return on capital by the electricity sales. Using the data on expected return given in Table VII.3, and on electricity sales in Table VII.1a, one can derive the expected return per unit. Addition of the total average cost and expected return per unit would give us the expected average revenue.

Graph VII.1



Comparing the expected average revenue with the actual average revenue earned by GEB from Graph VII.1, we gather that the actual average revenue has always been lower than the average revenue target implied by the recommendations of the Energy Policy of India Committee (in 1964) that the Electricity Boards should earn a minimum of 3% rate of return on their capital base. The actual revenue is, of course, also lower than the return recommended by the Committee on Power in 1980, i.e. rate of return of 6% on capital base.

Thus, we can observe that GEB needed to revise its electricity prices in order to avoid deficits.

Consequences of low/negative rate of return.

1) The recurring losses incurred by GEB, even two

decades after its formation, has placed a heavy burden on Government of Gujarat. Demand on the other hand has increased and this calls for substantial investments. The failure of GEB to raise adequate resources has generally resulted in a slowing down of the pace of investment in the power sector. Power being an essential input for economic development in the state, this affects the development of the state in longer run. Lack of resources and pressure to invest in creating more capacity together discourage expenditure on maintenance of the existing system. This in turn affects the reliability of supply. Reduced reliability of supply leads to inconvenience to consumers, loss in production, interruptions in services and/or encouragement for the private generation sets that consume expensive oil by generating electricity on a very small scale.

Poor financial performance led to limited resources also for the labour force. Keeping down wages meant that only people with low skills would seek employment in Electricity Boards.

The inability of the Boards to earn adequate surpluses to meet their commitments has resulted in the requirements of the power sector being largely met from public taxation. This has led to a transfer of resources from the tax payers (who are not necessarily all consumers of electricity) to those who consume electricity, without the objective or principle underlying such transfers having been established.

The low internal resource generation of the power sector could pose problems of finding sufficient resources for the sector from external sources. The funds that can be attracted from financial institutions within and outside the country will obviously depend upon the ability of the power supply undertakings to generate adequate returns on their investments. If the level of returns that are generated by undertakings continues to be as low as it is now, it will become increasingly difficult for the undertaking to attract investment from financing agencies.

Possible causes of poor rate of return.

There have been sharp increases in the costs of all inputs going into the power industry-plant, wages, coal, fuel, oil, cement, steel, aluminium and transportation. Partly due to resistance from the State Government or partly just lack of awareness of even relatively simple economic realities, the case for evolving a rational tariff structure has neither been studied nor does it seem to be a cause of concern, either to the State and to GEB. The realisation that, as things stand, the Centre has no option but to bail out improvident Boards has been a contributing factor to their financial indiscipline.

There were cases of thefts of electrical equipment like transformers and switch-gear belonging to the State Boards, so the high and fluctuating losses were not just due to technical inefficiencies. The substantial delays that take place in executing projects and commissioning has added substantially to the interest paid on works-in-progress and led to significant increases in costs on account of inflation.

The absence of uniformity in the preparation of annual accounts, the obvious errors in computing profit and loss accounts, delays of more than a year in preparing balance sheets and the near absence of a management information system which can focus the attention of management at various levels on the critical problems facing GEB, lead to gross inefficiency in operation. There are no statistical or economic cells which can advise on matters such as pattern of load growth or, tariff fixing, or carry out inter-division comparisons. The result is a failure to control costs and operate as an efficient industry.

According to the Committee on Power (1980), there are today no principles guiding the power tariff structure and decisions are made largely on grounds of political expediency coupled with some uninformed thinking on the link between cheap power and the economic development of the State. In particular, there is considerable evidence to suggest that in rural areas the beneficiaries of the power subsidies are the larger and more affluent farmers who could well afford to pay the real cost of their power supply. The case for indiscriminate subsidies of rural consumers as a class has no rationale in a situation where the number of people below the poverty line is large and growing year after year and they are getting little or no benefit from such subsidies.

In one respect pricing policy did not provide appropriate signals to consumers, since it was too low. When on historical costs it is making a loss, it would have made a huge loss on replacement cost. Therefore tariffs were a lot less than average up to date accounting costs and there is a strong presumption that tariffs were less than marginal economic costs. In a simplistic way, having shown tariffs are low in general, let us now look at particular features of tariff structure.

VII.2 Aspects of pricing.

The pricing of commodities supplied by public enterprises in general, and of electricity in Gujarat in particular, involves three broad and sequential procedures. The first is the identification of the criteria (or requirements) of tariff policy. As the policy need not be "good" or optimal (especially in practice), the criteria can range from the "no criteria" situation in a fully arbitrary pricing system to a set of criteria in an optimal system. The second procedure involves the approach or methodology adopted in utilising the criteria to determine the optimal pricing rules. A large choice is also available here, ranging from the arbitrary to the analytical approach adopted by economists. The last is the determination of the prices which emerge from the criteria and approach. A detailed treatment and understanding of the pricing policy of an electric utility must examine these three aspects of pricing.

It is clear that, given the approach to pricing policy as well as prices, it is possible to deduce the criteria on which a pricing policy is based. In the same way, it should be possible to infer at least some of the criteria used by GEB from its pricing methodology and tariff structures. Since the criteria of Gujarat Electricity Board (GEB)'s pricing policy were not explicitly mentioned, we will try to infer criteria from its pricing methodology and tariff structures. But first we should discuss the directions to GEB (or any other State Electricity Board) by the government.

VII.2.1 Government directives.

The Electricity (Supply) Act 1948 directives on electricity tariffs divide into two major categories, namely those relating to the magnitude of the tariff and those dealing with the institutional procedure for establishing or changing it. As discussed in Chapter II, the State Electricity Boards were established under the Electricity (Supply) Act 1948, and were given full responsibility for taking all the decisions necessary to run the electricity utilities in the respective States. As far as the magnitude of the tariffs is concerned, the Act did not indicate any specific range within which the tariffs for different consumer groups had to be charged. And this may be due to differences in the plant mix, utilisation of plants and cost of generation in different States, where a uniform range for different consumers in different regions would not have helped.

In 1964, The Energy Survey of India Committee[130] held the view that

> ".... for a relatively risk-free public utility in India the rate of return should not be less than 10% and are glad to know that SEBs are being encouraged to aim at that rate of return on their investments when fixing their rates...."[131]

The report[132] on Pricing Policy for Electricity undertakings estimated that, if the average price of electricity was to equal the average cost including the necessary interest charges during the construction period, an average price of 11.56 paise per KWH was necessary. They recommended that this should be distributed between various users by taking into account the specific costs of providing service to these users. The average prices that they recommended were as given in the Table VII.4.

Table VII.4
Average prices for providing electricity to various consumer groups recommended in "Price Policy for Electricity Undertakings".

Consumer group	Paise/KWH
Industrial Power	07.5
Small Industrial Power	11.2
Domestic Light and Power	32.1
Commercial, Irrigation and Public Lighting	20.1
Average for all groups	11.56

Source: Ibid, Table 169, page 158.

The Energy Survey of India Committee in 1964 mentioned the recommendations of the "Price Policy for Electricity

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[130] Report of the Energy Survey of India Committee, (1964), op.cit.

[131] Ibid, p.157.

[132] As referred in the report by The Energy Survey of India Committee, (1964), op.cit.

Undertakings" but did not fully agree with it. The Committee envisaged considerable cost reductions as the result of higher thermal efficiencies, larger plants and fuller use of transmission and distribution systems. Their calculation suggested that, consistently with earning a 10% return, SEBs should be able to provide electricity at an average cost of 10.8 paise per KWH. Also the Committee recognised the importance of tariffs as incentives to use energy economically and suggested that serious consideration should be given to tariffs that reflected both the fixed costs involved in the service and the marginal costs in providing marginal consumption.

The implication throughout was that electricity consumers as a group should not be subsidised by the general taxpayers. However uniform rates need not prevail across consumer classes.

As reported in the Fuel Policy Committee Report,[133] the committees which have examined the pricing of power in India have all recommended that the revenues collected by the electricity boards by sale of power should allow a fair return on the investments made on power generation, transmission and distribution. Also the Report of the Committee on Power recommended that "no single class of consumers should be sold power at less than "cost" of providing them this power, i.e. at most the 15% rate of return could be waived."[134] Thus, it was generally believed that electricity prices should be set up in such a manner that they should at least cover cost.

It is the responsibility of the Commercial Department of GEB to design new tariffs or changes in the existing tariff. The Commercial department of GEB along with the

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[133] Report by the Fuel Policy Committee, (1974) op.cit, pp.64.

[134] Report of the Committee on Power, (1980), op.cit. p.81.

accounts department reviews the anticipated financial performance for the current and the next year at prevailing tariffs. Whether modifications and adjustments in tariffs are required for meeting the statutory ratio (i.e. return on capital as recommended by the Committees) is decided by the commercial department. (The commercial department has to interact with other departments to decide the modifications and adjustments in tariff.) Formal proposals are discussed by the Board and decisions are made on tariff changes needed. (The State government has a representative on the Board.) Proposals then are sent to the State Government (i.e., Minister/Secretary of Ministry of Energy) for concurrence or modification, though this is not required legally. Discussions are held with various consumer interest groups, for example, Chambers of Commerce, or agricultural organisations. The proposal is revised after the discussions with consumer interest groups and after receiving comments from the State Government, and the revised proposal is again sent to the State Government for approval. The Board approves the final proposal. Also, notices are given in the newspapers detailing revisions of tariffs. Thus, a new tariff or change in the existing tariff is implemented after the approval of the Board and the Government of Gujarat. It should be noted that GEB represents one side of the bargain, while the Government of Gujarat represents the other side.[135]

I was also informed that the general approach is to modify existing tariffs for various categories like industrial and commercial so as to earn the required net return in the following financial year. For this, anticipated KWH sales and KW demands for each category are assessed. Effect on sales of likely revisions are also

[135] The information here is presented on the basis of interviews with several GEB officials particularly in the Commercial Department of GEB.

allowed for on a judgemental basis. Effort is also made to incorporate some desirable features, e.g., for demand management, though it is much too limited.

Much attention is paid to the likely reactions from politically strong groups e.g., the agricultural lobby, small industries etc.. This often disturbs tariff studies and usually inhibits the earning of the required return. Tariff revisions also required attention to expected costs of operations and aspects like transmission and distribution losses, fuel efficiency, wages, interest charges etc. For this, the revised estimates of tariffs are extrapolated and little or no credit is taken for likely improvement.

The institutional procedure for establishing a new tariff design is such that much time is likely to be consumed and time is very important in tariff adjustment. The period of adjustment should not be too long to make the underlying conditions for changing the tariff redundant or subject to further change.[136]

VII.2.2 Basic methodology.

From the previous Section it will be evident that GEB's pricing methodology, the second of the three broad aspects of pricing, in theory consists of a financial constraint to determine the average revenue for the electricity industry and the arbitrary structuring of prices across consumer classes in such a way as to yield the average revenue for the electricity industry. But whether this financial constraint approach was ever implemented is a question to be investigated.

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[136] In one of the interviews with GEB official I was told that "rule of thumb" is the method used to reach decisions regarding changes in the existing tariff as well as the extent of change.

VII.2.3 Particular features of tariff structure in Gujarat.

From the analysis of the tariff structure in the period 1961 to 1986, four main characteristics can be noticed. They are: classification of consumers, block tariff, multi-part tariff and differential pricing. The important question is what is the rationale for these characteristics and what can be said about the characteristics as implemented by GEB?

Classification of consumers.

The consumers were classified on the basis of voltage difference, for example, low and medium voltage and high voltage. Within these groups the consumers were further classified into sub-groups on the basis of their behavioural pattern; for example, low and medium voltage consumers were classified mainly into 7 groups: 1) service for lights and fans, 2) service for refrigerators, small cookers, heaters, 'X' ray machines 3) service for cinemas, theatres, 4) motive power service including water works, 5) service for educational institutions, research and development laboratories, 6) motive power services contracting for a load of 50 KW and above but not more than 100 KW at low voltage and 7) service used for agricultural purposes. This classification remained more or less the same throughout the period 1961-86. These 7 sub-groups under the low voltage consumers had meters and they paid an energy charge i.e. rate per KWH. Three out of seven sub-groups, [i.e., category 4), 6) and 7)] paid a demand (KW) charge too. The consumers who had to pay a demand charge had decreasing block energy (KWH) charge.

Amongst the sub-groups in the low voltage consumers, major changes in the tariff structure for different sub-groups were experienced at different times. For example, agricultural consumers experienced a big change in 1967, but thereafter the tariff structure was not changed, though there has been an increase in the schedule from time to time. In 1967 agricultural consumers were offered two options to choose from. Though the amount of demand (KW capacity) charge to be paid was the same in both the options, in the first option the consumers had to pay a uniform energy (KWH) charge for all units consumed, whereas in the second option the consumers were charged on the basis of a decreasing block i.e., electricity consumption after the first 75 units had a lower rate than the first block.

Domestic and Commercial consumers were charged a uniform energy (KWH) charge till 1976; and, after 1976, they were charged on the basis of an increasing block tariff, i.e., for the first block of energy consumption the consumers had to pay less compared to the subsequent blocks. A demand (KW) charge was introduced, in 1980, to the domestic and commercial consumer group using heaters, refrigerators, x-ray machines etc.. Consumers were offered a prompt payment discount at 3 paise per rupee, if the payment of the bill was made in full within 15 days from the date of billing.[137] There was a further change in the structure in 1981. Till 1981, electricity consumption by domestic and commercial consumers for heaters, refrigerators, x-ray machines etc. and for lights and fans was considered separately. After 1981, GEB stopped considering electricity consumption by domestic and commercial consumers for different purposes separately. Hence from 1981, there were only 6 categories of sub-groups under this category.

Between 1961 and 1967, industrial consumers (low and medium voltage) were charged on the basis of decreasing blocks. The blocks for industrial consumers were changed in 1971 but the principle of a decreasing block charge was

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[137] This discount did not apply to meter rent, any other charges including excise duty and electricity duty etc.

maintained. A demand charge was introduced for the low voltage industrial consumer group in 1980.

For all industrial consumers (including low, medium and high voltage), two different tariff schedules were introduced in 1984 for two periods in a year. The demand and the energy charges during the period May to October were less than the demand and energy charges during the period November to April. Also, some seasonal consumers (i.e. who used power supply for ice factory, ice candy machines, ginning and pressing factory, oil mill, rice mill, salt factory, sugar factory, Khandsari, cold storage plants (including such plants in the fisheries industries), tapioca industries manufacturing starch or for such other industries as may be approved by the Board from time to time) were given concessions on a yearly basis. Seasonal consumers in low and medium voltage industrial consumers and all high voltage consumers had to pay delayed payment charges if the bill was paid after 15 days from the date of billing.[138]

Those industries (irrespective of voltage level) that started on or after 1st November 1978 in the developing areas only (the list of areas was given in the <u>Tariffs for Supply of Electricity</u>, published by GEB) and took power supply (from a separate point if a sister concern having separate legal entity) only from the GEB, were eligible for a concession. After 1980, a concession was given to all industrial and agricultural consumers for the use of electricity exclusively during night hours. The consumer had to request the Board for application of the concession and it was "subject to verification of his claim by the Board for use of electricity exclusively during night hours from the metering arrangement made by the Board at his

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[138] The delayed payment charge was calculated at the rate of 30% per annum from the date of billing till the date of payment.

premises, the consumer shall be eligible for concession at the rate of 5.0 paise per unit on the consumption."[139]

High voltage industrial consumers had to pay additional charges of 6 paise per unit of energy consumed during the two peak periods, i.e. 7.00 hrs to 11.00 hrs. and 17.00 hrs. to 21.00 hrs. But nowhere was it mentioned how GEB could measure the consumption during the peak periods and off-peak periods in the absence of time of day meters.

Block tariff.

GEB adopts a decreasing block tariff for industrial consumers: the greater the consumption, the lower the per unit (KWH) charge. Several reasons have been advanced in defence of such a tariff. Firstly, there is the argument that if returns to scale are increasing, and if the exact nature of the marginal cost curve is unknown, then the decreasing block tariff could be seen as a method of approximating marginal cost. But, the decreasing block tariff is not always appropriate. This is because in an electric utility having several plants and with an optimal utilisation policy such that plants are used in increasing order of their running cost, the system's marginal cost is most likely to be increasing even though the marginal cost for each plant may be decreasing.[140] (And this fact is borne out by GEB's marginal cost function estimated in the cost analysis.) Secondly, there is the argument that a public utility should encourage consumption in order to realise economies of scale in production. Yet persistent and significant (planned and unplanned) power shortages have plagued the industry, especially since 1973. A policy of

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[139] Tariffs For Supply of Electricity, Gujarat Electricity Board, (Baroda, 1981), p.12.

[140] See Ralph Turvey, (1968), op.cit, p.102.

sales promotion is rational only if there is excess supply. Electricity sales should be promoted if at all, only at particular times i.e., at off-peak hours. The existing tariff does not do so: it encourages electricity sales at any hour of the day. Thirdly, it is argued that a public utility can recover most of its fixed cost when consumption is low by pricing the initial slabs more highly. The counter-argument here is that fixed costs can be more effectively covered through other means rather than through a block tariff. For instance, consumer costs can be recovered through a variety of single or recurrent fixed charges. By and large a decreasing block tariff is difficult to justify.

Multi-part tariff.

The third feature of GEB's tariff structure is that it is multi-part. GEB's multi-part tariff is complex. Firstly, charges are divided into two, namely demand (power) charge (or KW capacity charge) and energy charge (or operating KWH charge). Secondly, for most of GEB's tariffs, both the energy and demand (power) charges are further broken down into a fixed charge (the minimum charge) and a set of variable charges. Thirdly, the fixed and the variable charges vary across consumer groups. Thus, GEB's multi-part tariff is a complex form of the two-part tariff. For example, from Table VII.5 we can observe the changes in tariffs for one consumer group over the period 1961-1986.

High tension industrial consumers were further distinguished in 1980, on the basis of the voltage of supply. Consumers supplied at more than 33 KV were charged more than the consumers consuming electricity at 33 KV or lower. Also, the number of blocks within the energy and demand charge were modified. The energy charge was made uniform, though it remained different for different consumers depending on their voltage level.

Table VII.5
Tariffs for high tension industrial consumers in the period 1961-86.

Consumer category	Demand Charge		Energy Charge	
HTP-1 (High tension industrial consumers)	Block	Rate	Block	Rate
In 1961 to 1967,				
	0-200KVA	10.0	0-100**	0.07
	201-500	09.0	101-400	0.06
	501-2000	08.0	401-900	0.05
	2001-5000	06.0	901-above	0.0475
In 1986,				
A) May to October				
I) Supply ≤ 33KV				
i) up to contract demand,				
	Per KVA	39.0	0-10000 @	0.30
			next 330@	0.34
			next 250	0.30
			all extra	0.27
ii) above contract demand,				
	Per KVA	72.0	Same as above	
II) Supply > 33 KV				
i) up to contract demand,				
	Per KVA	38.0	0-10000 @	0.30
			next 330@	0.335
			next 250	0.295
			all extra	0.265
ii) above contract demand,				
	Per KVA	72.0	Same as above	
B) November to April.				
I) Supply ≤ 33KV				
i) up to contract demand,				
	Per KVA	43.0	0-10000 @	0.32
			next 330@	0.37
			next 250	0.32
			next 150	0.30
			All extra	0.29
ii) above contract demand,				
	Per KVA	112.0	Same as above	
II) Supply > 33 KV				
i) up to contract demand,				
	Per KVA	42.0	0-10000 @	0.32
			next 330@	0.365
			next 250	0.315
			next 150	0.295
			All extra	0.285
ii) above contract demand,				
	Per KVA	112.0	Same as above	

@ The energy charge is for the units consumed in the particular block, per connected BHP per month.
** The units are measured in thousands.
Source: Tariff books, Department of Commerce, Gujarat Electricity Board, Baroda, for the respective years.

But the demand charge was changed, and it was on the basis of the maximum demand (which could be either under/equal to contracted demand, or in excess of contracted demand). Generally, the consumers having maximum demand in excess of the contracted demand were charged at a higher rate than the consumers consuming at/below contracted demand. This was mainly to encourage the consumers to estimate their own power demand much more efficiently and reveal it to GEB. With more awareness of the power and energy requirements from the consumers' end, GEB can plan more efficiently compared to the planning without precise knowledge about consumers' requirements. In 1981, the blocks for the demand and energy charge were again modified. The energy charge was changed such that consumers found it more expensive to consume electricity in the second block compared to the first. But the movement from the second block to the third was cheaper for the consumers. Since the movement from a lower to a higher block of electricity consumption provided assured utilisation of plants the decreasing block tariff can be justified but in a situation of power shortages especially at peak hour, there is no question of higher utilisation at that time and hence the decreasing block tariff is difficult to justify.

Differential pricing.

In principle, there are three main reasons for differential pricing across consumer groups. The first is differences in the cost of supply. Cost varies across consumer groups because consumers are supplied at different voltages. Since supply cost varies with supply voltage, it must be true that GEB incurs the highest cost on the agricultural consumers and the lowest cost on industrial consumers. GEB takes account of differences in cost but in an inappropriate way. One consumer pays a lower price than another if it has a low load factor, contrary to what should happen. The second factor is electricity demand. Ceteris paribus,[141] an examination of the structure of

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[141] This includes GEB's marginal cost function which may be an increasing function.

electricity demand according to consumer classes between 1961 and 1986 shows that, for most of the years, commercial consumers had the lowest demand while industrial consumers had the highest demand. But a more important thing is to know the cost of electricity supply to any particular consumer at the level of the consumer's demand. Even if the consumer's demand is low, if it happens to be at peak (of the system) hours, it is more expensive to the system to provide electricity supply. So, it is impossible to determine the appropriate ranking of the prices which should have been paid by the consumer groups unless the relevant cost and demand functions are known. Since we do not have the information on the costs, it is impossible to determine the appropriate ranking of the prices. The third factor is differences in government subsidy to the consumer groups, on the basis of their relative roles in economic growth and development or other factors.

The major difference across the sub-groups of low-medium voltage consumers was between domestic and commercial consumers and industrial consumers. Industrial consumers were charged on the basis of decreasing block whereas domestic and commercial consumers were charged on the basis of increasing block. Agricultural consumers were subsidised despite the recommendation of the Committee on Power not to subsidise any consumers. Though the Committee realised there was no need to subsidise electricity to power-intensive industries and that they should be charged at least the full cost of power plus the prescribed return, industrial consumers in Gujarat were charged on the basis of decreasing block, though the cost of providing electricity was rising. However, the Committee suggested that commercial and domestic consumers should be charged inverted block tariffs (i.e. rates should increase as the quantum of power taken increases), and this was adopted by GEB.

VII.2.4 Criteria for electricity pricing in Gujarat.

It can be seen that, though the tariff structure for different consumer groups of GEB has changed since it was established in 1961, the main three criteria that dominated GEB's pricing policy are as follows:

(i) The cost of operation. From the government directives stated earlier, it is obvious that the relevant cost concept was the total cost. This included depreciation, which could be regarded as a measure of the capital cost of capacity attributable to a particular year. Thus, total cost is the sum of the total variable (operating) cost and the total fixed (capital) cost incurred in a particular year. Other reasons for GEB's adherence to the policy of full cost recovery may be a) avoid the subsidising of electricity consumers by taxpayers, b) meet a revenue target so as to contribute towards the financing of system expansion, c) minimise waste of consumption of electricity.

If GEB adopts a policy of full cost recovery, why did GEB incur losses on historical cost? There has been a difference in what GEB intended to do and what it actually did. It seems that the pressure groups affected the proposed tariffs to a great extent.

If GEB adopts a policy of full cost recovery, why is it that electricity price increases have so much lagged behind the rate of inflation in the country, as depicted in Graph VII.2.[142] It is possible that the cost of procuring GEB's inputs increased at a much lower rate than the rate of inflation. This may be true for some of the inputs, especially fuel, whose price may have been, by government

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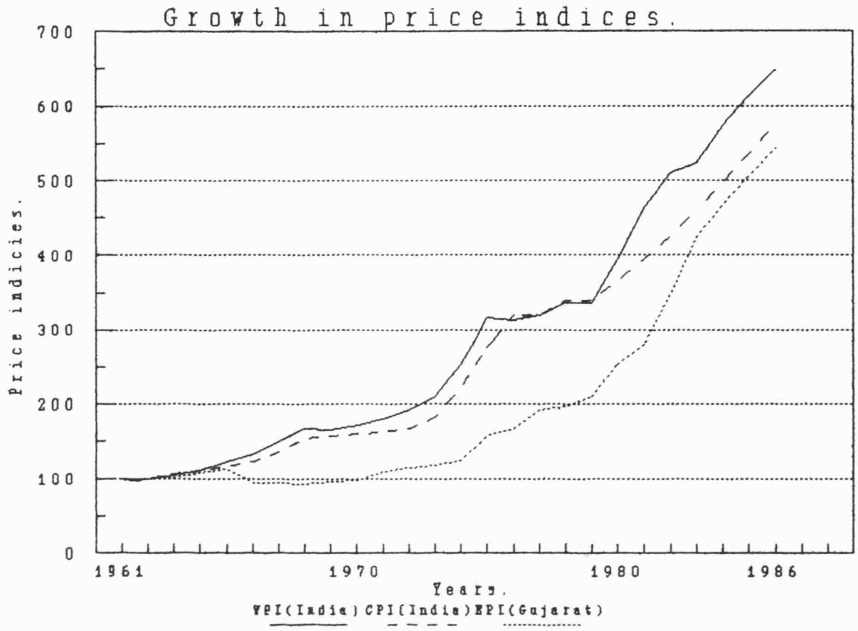
[142] Data on Wholesale Price Index and Coal Price Index were taken from various issues of Economic Surveys, Ministry of Finance, Government of India. Electricity Price Index was derived from the data on tariffs to all consumers given in various issues of Tariffs For Supply of Electricity, Gujarat Electricity Board, Baroda.

Graph VII.2



policy (since coal industry is also under public sector in India), kept lower than world prices. For some other inputs like labour, this is not true. Thus, even if the change in the cost of procuring GEB's inputs had lagged behind the rate of inflation, the difference could not be sufficient to explain the enormous disparity between the trends of the electricity price index and the wholesale price index for all India. According to a calculation by the Power Finance Corporation, the subsidy due from the Government of Gujarat was over 10% of revenue in the year 1985-86.[143] Sometimes, the amount being very large, non-payment of subsidy leads to a resource crunch not only for implementation of projects but even for day-to-day commercial operations. And still the benefits of subsidies on electricity prices may not reach consumers like the small and marginal farmers, landless labourers, artisans and urban slum dwellers.

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[143] Seminar on Financial Performance of SEBs, organised by the Power Finance Corporation and Tata Energy Research Institute, New Delhi, held on 20-21 February, 1989.

The question therefore is whether it is legitimate to subsidise electricity prices for any consumer group in a capital short country like India, where there are also high transmission and distribution losses, gross inefficiencies in operation, and wastage of electricity. In fact there is a need for a pricing policy that charges consumers the real cost of what they consume. Their awareness regarding the real cost may leads to less wastage. Such awareness lead to consistent signals to consumers and producers.

(ii) GEB implicitly takes into account the aggregate demand for electricity and the capacity constraint it faces. Electricity sales in any given year were forecast by using the trend model of electricity consumption in the previous years to forecast electricity sales in particular years. Forecasts have to be subject to the supply conditions of the industry, which in this case is the capacity constraint. One comment about the demand concept is noteworthy. The demand concept as used by GEB in any given year is one not related to price in that year, since the determination of output precedes the determination of price. In other words the demand is "restricted demand". The "unrestricted demand" would be very difficult to know.

We should also note that the relative impact of the 'demands' of the various classes of consumers on capacity is important for price structuring. **Ceteris paribus**, the consumer group that has the lowest plant utilisation factor pays the highest charge per unit. This partly explains the fact that the highest average revenue till 1980 was earned from the domestic and commercial consumers, since they utilised plant the least.

(iii) Other factors include the administrative capabilities of GEB, which obviously must have been compatible with its pricing policies. This does not imply administrative efficiency since minimum administrative cost is not implied. It includes the administrative ability to implement the tariff structure that reflects the real cost of electricity to its consumers and allows the consumers as well as the producers to make decisions consistently without facing excessive political pressures on their policy on electricity prices.

GEB's pricing policy is based on two other considerations. The first is the financial constraint and the second is GEB's administrative capabilities. On the first, *ceteris paribus*, there is nothing to choose between two pricing policies which incorporate the same financial constraint. But on the second, one tariff policy is preferred to another if it can be implemented at a lower cost. In evaluating GEB's tariff policy along this line, one must be sure that the proposed alternative tariff policy can be implemented in the first instance and, given this, that its administrative costs will at most be as high as GEB's.

The next question is to examine the approaches to electricity pricing in theory that may lead to maximum welfare of the society, keeping in mind the need to make the consumer aware of the cost of providing electricity and also earn minimum rate of return on capital investment to make future investment possible.

Appendix to Chapter VII.

Table 7.1
Tariff for all consumers (except street lighting) in the period 1961-1966. (in Rupees)

Consumer category	Demand Charge		Energy Charge	
	Block	Rate	Block	Rate
Rate LF.I	-	-		0.31
Rate DSII	-	-		0.15
Rate C	-	-		0.25
Rate LPT.1	Per BHP	5.0	0-75[@]	0.16
			76-above	0.12
Rate LPT.2	-	-		0.175
Rate LPT.3	Per KW	7.0	0-150[*]	0.13
			151-above	0.09
Rate Ag <100 KVA		60.0	0-75[@]	0.15
			76-above	0.12
Rate TH/HTP-1	0-200KVA	10.0	0-100[**]	0.07
	201-500	09.0	101-400	0.06
	501-2000	08.0	401-900	0.05
	2001-5000	06.0	901-above	0.0475
Rate TH/HTP-2	0-200KVA	10.0	0-100[*]	0.15
	201-500	09.0	101-400	0.12
	501-2000	08.0	401-above	0.10
	2001-5000	07.0		
	5001-above	06.0		
Rate TH/HTP-3	Per KVA of the contracted demand	10.0		0.12

[@] The energy charge is for the units consumed in the particular block, per connected BHP per month.
[*] First 150 units per KW of connected load per month and likewise for other blocks.
[**] The units are measured in thousands.
Source: Tariff books, Department of Commerce, Gujarat Electricity Board, Baroda, for the respective years.

Table 7.2
Tariff for all consumers (except street lighting) in the period 1984-86. (in Rupees)

Consumer category	Demand Charge		Energy Charge	
	Block	Rate	Block	Rate
Rate LFD				
(i) Residential premises	1 phase supply per installation	2.0	0-10	0.24
	3 phase supply per installation		11-100	0.44
		5.0	101-300	0.54
			301-above	0.74
Additional charge			0-10	-
			11-above	0.12
(ii)Commercial Premises	1 phase supply per installation	5.0	Same as above	
	3 phase supply per installation	15.0		
Rate C:				
	Per installation	30.0	1-350	0.47
			351-above	0.54
LPT-1:				
A) Installation up to 10 BHP				
i) Water Works per BHP		4.00	Per unit	0.31
ii)Others	Per BHP	6.0	Per unit	0.36
B) Contracting Load exceeding 10 BHP				
i) Water Works 1-10 BHP		4.00	Per unit	0.36
	11-50	5.50		
	51-above	11.0		
ii) Others 1-10 BHP		6.00	Per Unit	0.37
	11-50	7.50		
	51-above	11.0		
LPT-2:				
	-	-	Per unit	0.44
LPT-3:				
A) May to October				
i) up to contract demand				
	Per KW	41.0	0-200	0.30
			201-above	0.28
ii) in excess of contract demand				
	Per KW	76.0	0-200	0.30
			201-above	0.28
B) November to April				
*i) up to contract demand				
	Per KW	46.0	0-200	0.32
			201-above	0.30
i) in excess of contract demand				
	Per KW	126.0	0-200	0.32
			201-above	0.30
Rate Ag:				
Option I				
	0-5 BHP	1.55	Per unit	0.14
	6-15	1.80		
	16-25	2.05		
	26-above	2.30		

Option II	Same as above		0-50	0.19
			51-1050	0.15
			1051-above	0.09
<u>HTP-1</u>:				
A) May to October				
I) Supply ≤ 33KV				
i) up to contract demand,	Per KVA	39.0	0-10000	0.30
			next 330ℓ	0.34
			next 250	0.30
			all extra	0.27
ii)above contract demand,	Per KVA	72.0	Same as above	
II) Supply > 33 KV				
i) up to contract demand,	Per KVA	38.0	0-10000	0.30
			next 330ℓ	0.335
			next 250	0.295
			all extra	0.265
ii)above contract demand,	Per KVA	72.0	Same as above	
B) November to April.				
I) Supply ≤ 33KV				
i) up to contract demand,	Per KVA	43.0	0-10000	0.32
			next 330ℓ	0.37
			next 250	0.32
			next 150	0.30
			All extra	0.29
ii)above contract demand,	Per KVA	112.0	Same as above	
II) Supply > 33 KV				
i) up to contract demand,	Per KVA	42.0	0-10000	0.32
			next 330ℓ	0.365
			next 250	0.315
			next 150	0.295
			All extra	0.285
ii)above contract demand,	Per KVA	112.0	Same as above	
<u>HTP-2</u>:				
A) May to October				
i) up to contract demand,	0-500KVA	39.0	0-200	0.37
	500-10000 KVA	44.0	200-above	0.40
	All extra	48.0		
ii)above contract demand,	Per KVA	72.0	Same as above	
B) November to April				
i) up to contract demand,	0-500 KVA	43.0	0-200	0.39
	501-1000	48.0	201-above	0.42
	1001-10000	50.0		
	All extra	54.0		
ii)above contract demand,	Per KVA	72.0	Same as above	
<u>HTP-1b</u>:				
A) May to October				
I) Supply ≤ 33KV				
i) up to contract demand,	0-500KVA	39.0	0-10000	0.30
	501-10000	44.0	next 330ℓ	0.34

	All extra	48.0	next 250[θ]	0.30
			All extra	0.27
ii)above contract demand,				
	Per KVA	72.0	Same as above	
II) Supply > 33 KV				
i) up to contract demand,				
	0-500KVA	38.0	Same as above	
	501-10000	43.0		
	All extra	47.0		
ii)above contract demand,				
	Per KVA	72.0	Same as above	
B) November to April.				
I) Supply ≤ 33KV				
i) up to contract demand,				
	0-500KVA	43.0	Same as above	
	501-1000	48.0		
	1001-10000	50.0		
	All extra	54.0		
ii)above contract demand,				
	Per KVA	112.0	Same as above	
II) Supply > 33 KV				
i) up to contract demand,				
	0-500KVA	42.0	Same as above	
	501-9000	47.0		
	1000-above	53.0		
ii)above contract demand,				
	Per KVA	112.0	Same as above	
Additional Charge				
	Per KVA	0.10	Per Unit	0.04

Classification of consumers.

Ignoring street lighting, the consumers were categorised under three groups by 1985-86:

1) Supply of electricity at low and medium voltage,

2) Supply of electricity at high voltage (3.3 KV, 11 KV, 22 KV, 33 KV, 66 KV and above, 3 phase 50 cycles).

3) Supply of electricity at high voltage (3.3 KV, 11 KV, 22 KV, 33 KV, 66 KV and above, 2 phase 50 cycles).

Under the first two categories, there were sub-groups. The change in the tariff policy of the sub-groups under the main three consumer categories and in the tariff schedules charged to the sub-groups will be discussed under each main category of the consumers.

1) Supply of electricity at low and medium voltage.

The tariffs to consumers under this category were grouped under 7 sub-groups:[144]

i) Rate LF-1: The tariff was applicable to service for lights, fans, radios, etc. (residential as well as commercial).

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[144] Nowhere the meaning of short-forms was mentioned.

ii) Rate DS-11: The tariff was applicable to service for refrigerators, small cookers, heater, 'x' ray machines, battery charging equipment and small motors up to 5 HP attached to domestic appliances, when metered on a separate circuit (residential as well as commercial).

iii) Rate C: The tariff was applicable to combined lighting and power service for cinemas, theatres and such other institutions and organisations as may be approved by the board.

iv) Rate LPT-1: This tariff was applicable to motive power service (including water works)

v) Rate LPT-2: This tariff was applicable to educational institutions and research development laboratories for motive power service where machines and appliances are primarily used for demonstration/research purposes.

vi) Rate LPT-3: This tariff was applicable to consumers using electricity for motive power services and contracting for a load of 50 KW and above but not more than 100 KW at low voltage.

vii) Rate AG: This rate was applicable to motive power service used for agricultural purposes and other purposes permitted by the Board.

2) Supply of electricity at high voltage (3.3 KV, 11 KV, 22 KV, 33 KV, 66 KV and above, 3 phase 50 cycles).
There are two sub-groups under this category.

i) Rate HTP-1: The rate was applicable for supply of energy to electricity consumers using electricity at high tension (H.T. consumers), contracting for not less than 100 KVA and who required power for industrial purposes, water works, pumping, for irrigation. After 1984, this tariff was applicable to the supply of energy to H.T. consumers contracting for not less than 100 KVA but below 500 KVA and requiring power for industrial purposes.

ii) Rate HTP-2: This tariff was applicable for supply of energy to H.T. consumers, contracting for not less than 100 KVA and requiring power for railways (other than railway workshops), Hospitals, Hotels, Military Installations, Aerodromes, Cinemas, Auditoriums, Cantonments, Banks, Offices, Educational Institutions, Studios, Film production, Residential Colonies and townships requiring and given separate point of supply and such other establishments as may be approved by the Board from time to time. This tariff was also applicable to the H.T. consumers for temporary supply and construction purposes. It was not applicable for resale of power.

3) Supply of electricity at high voltage (3.3 KV, 11 KV, 22 KV, 33 KV, 66 KV and above, 2 phase 50 cycles).

(i) Rate HTP-1b:

This category of consumers was distinguished only after 1984. This tariff was applicable for supply of energy to H.T. consumers contracting for 500 KVA and above, who required power for industrial purposes, water works pumping, and irrigation.

We can observe from Table 7.1 and 7.2, that the tariff structure for all the consumer group became quite complicated in 1986 compared to what they were in 1967.

CHAPTER VIII

ELECTRICITY PRICING: THE LITERATURE AND DERIVATION OF MARGINAL COST BASED PRICING PRINCIPLE FOR GUJARAT.

> "Long before the decision to invest in electric power is made, broader issues must be faced. They involve the total future energy needs, availability of supply and the optimal mix of different sources to be developed. Ideally, the energy sector investment and pricing policies for the entire region should be analysed and determined within an explicit integrated framework".[145]

Three basic energy policy decisions are required. First the appropriate level of demand for energy that must be served to achieve social goals, such as development, growth and basic human needs, should be determined. Second, the optimal mix of energy sources must be established that will meet the desired demand, based on several national objectives, such as minimum cost, independence from foreign sources, conservation of resources, environmental considerations and price stability. Third, closely associated with and following the investment decision, is the pricing policy which will be based on criteria such as economic efficiency in resource allocation, sectoral financial requirements, social equity considerations and other political constraints.

VIII.1 Pricing in electric utilities.

The objectives considered by Mohan Munasinghe[146] in his

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[145] Mohan Munasinghe, "Integrated National Energy Planning (INEP) for the Developing Countries", National Resources Forum, Volume 4, (October 1980) pp.359-73. Also reprinted in Mohan Munasinghe, Electric Power Economics: Selected Works, (Aug,1990).

[146] Mohan Munasinghe and J. Warford, Electricity Pricing, Theory and Case studies, John Hopkins Press, (Baltimore, 1982).

analysis of designing optimal electricity prices are as follows.

(a) First, national economic resources must be allocated efficiently, not only among different sectors of the economy, but also within the electric power sector. This implies that prices that reflect costs must be used to indicate to the electricity consumers the true economic cost of supplying their specific needs, so that supply and demand can be matched efficiently. One also needs to state the efficiency concept that is being adopted, since by efficiency one could mean static or dynamic efficiency, allocative and/or nonallocative efficiency.

Second, as for equity, it is useful to state whether or not emphasis is being placed on interpersonal, intertemporal or interjurisdictional equity.

Thirdly, one should state the aspects of the stabilisation objective that are being considered. More specifically, one needs to know whether an electric utility is obliged to pursue the objectives of price stability, full employment and balance of payments equilibrium.

b) Certain principles relating to fairness must be satisfied, including allocating costs among consumers according to the burdens they impose on the system, and providing a minimum level of service to persons who may not be able to afford full cost. Also, the rates should discourage waste and promote all justified uses of utility services.

c) Power prices should raise sufficient revenues to meet the financial requirements of the sector.

d) The structure of electric power tariffs must be simple enough to facilitate the metering and billing of consumers.

e) Finally other economic and political requirements must also be considered. These might include, for example, subsidised electricity supply to certain sectors to enhance growth or to certain geographic areas for regional development.

VIII.1.1 The objectives of electricity pricing in Gujarat.

The objective in a developing country such as India, is obviously to utilise national resources as economically as possible to achieve the state economic goal of improving productivity and increasing national income, subject to considerations of equity. Apart from economic considerations, it is obviously not desirable for the electricity sector to continue to sustain financial losses as great as it has been doing so far. If the electric utility suffers financial losses, the losses have to be met from the state's budgetary resources, which would either come from additional taxation, or from other public expenditure, which is given up at the margin. The social and the economic consequences of such an income transfer from non-electricity users to electricity users, are difficult to quantify, but are nevertheless real.

Hence, two important objectives would be that the electric utilities should raise sufficient revenues to meet the financial requirements of the sector and to distribute costs fairly among consumers.

The concern for 'fairness' arises from the possibility of misuse of monopoly power by electricity undertakings. The criteria for fairness obviously depend on several considerations, including the magnitude and behaviour of national economic variables. Fairness in distribution of costs among different consumers results from the genuine concern that, as far as possible, the buyer should pay the cost of the services provided.

Now the question is to find the method by which one can derive electricity prices that fulfil these objectives.

VIII.2 Public utility pricing: the literature.

There are two noticeable features of the literature of public enterprise pricing, namely its vastness and its long history.

VIII.2.1 The emergence of marginal cost pricing in the context of welfare economics.

The essence of marginal cost pricing in the public sector is that producers should price their products at the marginal cost of production; without regard to whether or not total costs are covered by receipts from sales. The system thus necessarily involves subsidising all producers who operate under conditions of decreasing costs.

VIII.2.1.1 In the pre-War period.

Marshall[147] reasoned that maximum satisfaction could be achieved by taxing commodities which are produced under conditions of increasing costs and paying bounties on commodities which are produced under conditions of decreasing costs.

Pigou further developed this argument in his early book "Wealth and Welfare".[148] He argued that under a system of free exchange, however, the marginal "private" net product rather than the marginal social net product will determine the point where production will take place. According to him, decreasing cost industries would operate at a point below the social optimum, since in such industries the marginal social net product would be greater than the marginal private net product. For these industries

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[147] A. Marshall, Principles of Economics, 8th edition, Book III, (1936), p.468, in Nancy Ruggles, "The Welfare Basis of the Marginal Cost Pricing Principle", Review of Economic Studies, Volume XVII (1), (1949-50), pp.29-47.

[148] In Allyn Young's, "Pigou's Wealth and Welfare", Quarterly Journal of Economics, Vol. XXVII, (1913), pp.672-86.

a bounty was advocated; in order to increase production and thereby reduce marginal social net product to that of resources in general.

Allyn Young, in his review of "Wealth and Welfare"[149] did not let this analysis pass unchallenged. He pointed out that the basic causes of changes in costs were not symmetrical for increasing and decreasing cost industries.

Ten years later, this subject was reopened by J.H. Clapham.[150] But it was Robertson[151] who criticised the analysis with regard to decreasing cost industries. Robertson divided the causes of decreasing costs into two groups: i) internal economies in some industries appearing as external economies in other industries and ii) dynamic factors of improvement such as inventions and changes in technology. Robertson argued, on the basis of the assumption that Pigou intended his analysis to apply to the static case only, that all external economies could be reduced to internal economies elsewhere in the system. For this reason he not only favoured taxing increasing cost industries, but also opposed subsidies for decreasing cost industries.

At about the same time, F.H. Knight in a much more elaborate analysis[152] demonstrated that in the static case external decreasing costs are purely the result of internal decreasing costs in some other industry. He pointed out

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[149] Ibid.

[150] J.H. Clapham, "Of Empty Economic Boxes", Economic Journal, Vol. XXXII, (1922), pp.305-14.

[151] D.H. Robertson, "Those empty Boxes", Economic Journal, Vol. XXXIV, (1924), pp.16-31.

[152] H.F. Knight, "Fallacies in the Interpretation of social cost", Quarterly Journal of Economics, Vol. XXXVIII, (1923), pp.582-606.

here, and in a later article,[153] that decreasing costs mean monopoly, but it is highly significant that he took no part in the discussion of whether or not these decreasing cost industries should produce at marginal cost.

The major writers in the field gradually began to focus on internal rather than external decreasing costs.

Early evidence of this transition was an article by H.D. Dickinson,[154] on price formation in a socialist economy. His proposal was that all industries with increasing costs should have added to their costs a uniform unit tax and that all industries with decreasing costs should have a deduction from costs in the form of a subsidy. The amount collected from the tax or increasing cost industries would go into a "marginal cost equalisation fund" and from this fund subsidies would be paid to the decreasing cost industries. The balance would provide a surplus or deficit to be added to or made up from general taxation funds. This procedure would, according to Dickinson, provide the maximum amount of production for the economy.

The first attempt to examine the effects of the taxation which would be required to subsidise decreasing cost industries was made by L.M. Fraser.[155] His particular treatment was not very useful, however, for several reasons. One of the major difficulties is that Fraser believed it to be in the self-interest of entrepreneurs in decreasing cost industries to expand to the socially most

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[153] H.F. Knight, "On decreasing cost and Comparative Cost", Quarterly Journal of Economics, Vol. XXXIX, (1925), pp.331-33.

[154] H.D. Dickinson, "Price Formation in a Socialist Community", Economic Journal, Vol. XLIII, (1933), pp.237-50.

[155] L.M. Fraser, "Taxation and Returns", Review of Economic Studies, Vol. I, (1933-34), pp.45-59.

desirable point. Mrs. Robinson's reply[156] pointed out the obvious fact that a firm with decreasing costs will operate at the socially most desirable point only when it receives a subsidy equal to the difference between average and marginal cost, so that it can charge marginal cost to its customers and at the same time cover its total expenses.

Chamberlin, in the first edition of his book[157] pointed out that the monopolistic influence was generally toward prices higher than they would be under pure competition, and that the effect of monopoly on the individual's adjustment characteristically would lead to smaller scales of output. Chamberlin was always very careful not to draw any sweeping conclusions from these observations, but others were not. Lerner[158] seized upon the divergence between price and marginal cost as a measure of the social loss caused by a monopolist.

A synthesis of decreasing-cost industry arguments and the monopolistic competition arguments was provided by R.F.Kahn.[159] Kahn could state that decreasing cost industries, such as public utilities, should be subsidised in order to permit them to expand and operate at the point where price equals marginal cost. Kahn made one further advance over his predecessors; he drew attention to the fact that if all industries have similarly decreasing costs or similarly imperfect competition, the payment of

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[156] Mrs. J. Robinson, "Mr. Fraser on taxation and returns", Review of Economic Studies, Vol. I, (1933-34), pp.137-43.

[157] Edward Chamberlin, Theory of monopolistic competition, First ed., (Cambridge, 1933), pp.10-77.

[158] A.P. Lerner, "The concept of monopoly and measurement of Monopoly Power", Review of Economic Studies, Vol. I, (1933-34), pp.157-75.

[159] R.F. Kahn, "Some notes on Ideal output", Economic Journal, Vol. XLV, (1935), pp.1-35.

subsidies or bounties would not be useful or successful and there would be no case for interference.

About the same time, Meade also advocated the principle of marginal cost pricing.[160] Meade proposed both the control of monopoly so as to force production to take place at the point where marginal cost is equal to price, and also the extension of subsidies to all those cases where marginal cost pricing would not cover total costs. From Meade's point of view, the principle of marginal cost pricing was by this time no longer a controversial question, but rather something to be explained in a popular manner. Thus, by 1938, the marginal cost pricing principle had by stages evolved out of the original Marshallian premise with reference to increasing and decreasing cost industries.

VIII.2.1.2 The controversy.

Up to 1938, the development of the marginal cost pricing principle had for the most part been on a highly theoretical plane. During 1938, the emphasis of the discussion shifted to more concrete considerations of pricing systems. This shift was to a large extent due to Hotelling, since much of the later work in the field was stimulated by his article. Hotelling did not refer at all to the development of the marginal cost pricing principle in the period just prior to that in which he wrote. He chose to go back to the work of an engineer, Jules Dupuit,[161] who wrote on the subject of utility in about the year 1844, in connection with an analysis of such public

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[160] J.E Meade, An Introduction to Economic Analysis and policy, Second Edition, (1937).

[161] Collected and reprinted with comments by Mario di Bernardi and Luigi Einaudi "De l'utilite et de sa mesure", La Riforma Soziale, Turin, (1932), in H. Hotelling, "The relation of prices to marginal costs in an optimum system", Econometrica, Vol. 7, (1939).

works as roads and bridges. Dupuit's argument was based upon a concept of measurable utility and free interpersonal comparison. Hotelling maintained that by virtue of the analysis made possible by modern mathematical methods, the essence of Dupuit's propositions could be substantiated without any necessity for such dependence.

The controversy regarding the idea of pricing at the marginal cost is well discussed by Nancy Ruggles.[162] According to Nancy Ruggles, the advocates of marginal cost pricing maintained that in any situation in which all prices are not equal to marginal cost the general welfare can be increased by setting these prices equal to marginal cost. This argument had been put forth throughout the development of the marginal cost pricing principle. Marginal cost pricing would make necessary the payment of subsidies to producers with decreasing costs, since otherwise they could not cover their total costs. Many of the supporters of marginal cost pricing failed to consider this question. Lerner, Meade, Troxel, Reder and Vickery, all fell into this group.

It was argued by Frisch,[163] that if prices were proportional to rather than equal to marginal cost, the marginal conditions of exchange would be satisfied and also it would be possible to cover the total cost. Hotelling, in his reply to Frisch[164] agreed that proportionality is all that would be necessary. This was again proposed by Fleming

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[162] Nancy Ruggles, "Recent Developments in the Theory of Marginal Cost Pricing", Review of Economic Studies, Vol. 17, (1949-50), pp.107-26.

[163] Ragnar Frisch, "The Dupuit taxation theorem", Econometrica, Vol. 7, (1939), pp.145-50.

[164] H. Hotelling, "The relation of prices to marginal costs in an optimum system", Econometrica, Vol. 7, (1939), pp.151-155.

in answer to Meade, and Meade agreed. But Lerner[165] and Samuelson[166] pointed out that Frisch and Hotelling were both wrong on this point. Unless the prices paid to the factors of production, as well as the prices paid for consumers' goods, are included in the set which is raised proportionally to marginal cost, the marginal conditions with respect to the factors of production would be violated.

A practical question concerning the workability of marginal cost pricing was brought up by Wilson.[167] He raised the objection that in making investment decisions under the marginal cost pricing system there would be no test of the accuracy of the forecast. Because of the difficulty in raising the revenue required to finance the subsidies, pricing systems which would in themselves meet total costs have been proposed as alternatives to marginal cost pricing. Price discrimination was suggested by Clemens,[168] Lewis,[169] and Coase. All such proposals represented departures from marginal cost pricing.

VIII.2.1.3 Postwar period.

Ian Little[170] insisted that "nationalised industries

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[165] A.P. Lerner, The Economics of Control, (New York, 1914), pp.102-104.

[166] P.A. Samuelson, The Foundations of Economic Analysis, (Cambridge, 1947), p.240.

[167] T. Wilson, "Price and Output policy of state enterprise;A Comment", Economic Journal, Vol. 50, (1945), pp.454-461.

[168] E.W. Clemens, "Price discrimination in decreasing cost industries", American Economic Review, Vol. 31, (1941), pp.794-802.

[169] W.A. Lewis, "The two-part tariff", and "Two-part tariff:A reply", Economica, Vol. 8, (1941), pp.249-70 and 399-408.

[170] Ian Little, A Critique of Welfare Economics, Oxford University Press, (1957).

should at least aim to cover total costs" and it is this conclusion that typifies the standpoint of all those who oppose the view that marginal cost pricing principle leads to higher welfare.

Similarly Jan de Graff's devastating survey of the "new" welfare economics in 1957[171] returns again and again to the impossibility of separating efficiency from equity because of the impracticability of lump-sum redistribution of income or wealth. Like Ian Little, de Graff rejects marginal cost pricing on second best grounds,

> "...It seems fairly clear that the conditions which have to be met before it is correct (from the welfare viewpoint) to set prices equal to marginal costs in a particular industry are so restrictive that they are unlikely to be satisfied in practice. The survival of the marginal cost pricing principle is probably no more than an indication of the extent to which the majority of professional economists are ignorant of the assumptions required for its validity. How else can we account for the glib advocacy of the principle in a society where the marginal rate of income tax is certainly not zero, where optimum taxes are certainly not imposed on both imports and exports.........."[172]

Wiseman's argument[173] is based essentially on the fact that there exists no method of implementing the marginal cost pricing rule for decreasing cost industries - which for him comprise the typical case, - that does not entail a system of financing the resulting deficit, thus altering the distribution of income, which alteration however cannot be evaluated according to the "new" welfare economics. In

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[171] Jan de Graff, Theoretical Welfare Economics, Cambridge University Press, (1957).

[172] Ibid, p.154.

[173] Wiseman, "The theory of Public Utility Price: An Empty Box", Oxford Economic Papers, Vol. 9, 1973.

short, decreasing cost industries provide the outstanding example of how pricing rules based on principles of allocative efficiency necessarily imply a simultaneous decision about income distribution.

The early 1960s witnessed a new twist to the marginal cost pricing debate, which seemed to answer Wiseman's criticism that the marginal cost pricing principle requires a decision on the length of the run over which marginal costs are defined and yet provides no basis for such a decision. The answer takes its clue from the well-known theorem that short-run and long-run marginal costs coincide when capacity is optimally adjusted to demand from which it follows that any difference between the short-run and long-run implications of marginal cost pricing is a sure sign that capacity is not adjusted to its optimal level. If there is excess demand at a price determined by short-run marginal costs, marginal cost pricing tells us that prices must be raised until demand equals capacity. At the same time, however, capacity should be raised to meet the demand that would be forthcoming at the price that is optimal on the basis of long-run marginal costs. In other words, if there is an optimal investment policy, there is no contradiction between short-run and long-run marginal cost pricing, and if there is such a contradiction, it forms a criticism not of the marginal cost pricing principle but of the investment policy that is being pursued.

This argument is the gist of the contributions of a number of French economists, particularly Marcel, Boiteux and Pierre Masse, who were connected with Electricite de France in the late 1940s and 1950s. They noted that in electricity pricing at any rate, there was little alternative to pricing based on long-run marginal costs.[174]

The theoretical rationale for setting prices equal to

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[174] For details see R. Turvey, "Marginal Cost", Economic Journal, vol 79, 1969.

marginal cost in an electric utility has been well explained by many writers. Munasinghe & Warford[175] e x p l a i n e d the net benefit in mathematical terms as,

$$NB = \int_0^{\infty} p(q)dQ - MC(q)dq.$$

where p(Q) and MC(Q) are the equations representing the demand and supply curves respectively. Maximising NB:

$$d(NB)/d(Q) = p(Q) - MC(Q) = 0.$$

showing the point of interaction of the demand and marginal cost curves. (Prices p_o, quantity demanded & supplied Q_o.)

In actual practice, of course, adequate information regarding the demand curve may not be available, though the marginal cost curve may be estimated more accurately. Therefore, the establishment of the equilibrium point, or market clearing price, will be an interactive process. However, the conceptual basis for setting price equal to the marginal cost, and increasing the supply of electricity until the market clears, remains valid.

From the point of view of society in general, it can be stated that the purpose of pricing should be to allocate national resources efficiently by providing appropriate signals to consumers. Prices act as signals to consumers who see them as costs of using the commodity, which in this case is electricity. If the price of electricity is fixed below its marginal cost of production, consumers will think that the cost of an additional unit of electricity is less than the cost to society (and act accordingly). In this case, more resources would be devoted to electricity production than is socially efficient. (This argument

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[175] Mohan Munasinghe and J. Warford, (1982), op.cit, p.16.

presupposes the absence of "externalities" such as pollution costs etc. and also that all costs are measured in terms of social costs. Strictly speaking, marginal costs are marginal social costs.)

It may be objected that, while the above logic is valid for new consumers, there is no justification for charging marginal costs to existing consumers yet, all consumption is new in the economic sense. Just as B, a new group of consumers, may impose on the electric utility the need to add to system capacity because of their (new) additional requirements of electricity, so can an existing group A impose this need on the utility by continuing their consumption. Marginal cost pricing in electricity therefore involves a tariff structure so framed that the cost to any consumer of changes in the pattern/level of his consumption equals the cost to the electricity industry as a consequence of his action. Such pricing will cause individual consumption decisions to conform to the national interest if (a) consumers are well informed and rational, (b) the distribution of income is taken as given, (c) the cost to industry of responding to consumption changes coincides with social costs. i.e. the value to the economy of the resources involved. (This means absence of economies/diseconomies. Examples of externalities in the electricity industry are atmospheric pollution caused by thermal stations, and environmental problems of hydro electric projects), (d) prices of substitutes/complements for electricity, are equal to their marginal (social) costs; and a similar condition exists in the case of prices of goods using electricity in production.

The theory of optimal capacity of French engineers-cum-economists has been vigorously taken up by Ralph Turvey in his writings on the pricing problems of the British electricity industry. In his major study[176] Turvey defines long-run marginal costs in present value terms as "the greatest worth of all system costs as they will be with the investment in load which is to be costed, less what they would be without that increment" and shows that information about the structure of marginal costs is provided as a by product of the calculations required for national investment planning. Elsewhere too, Turvey has come down firmly on the side of marginal cost pricing as a second best pricing rule arguing that the prices of public enterprise products sold within the public sector should equal their long-run marginal costs, while those sold outside the public sector should be proportional to long-run marginal costs, the mark up over marginal costs being determined by the prices of their private sector substitutes.[177]

VIII.3 Approaches to electricity pricing.

For many years economists have discussed the merits of relating prices to the marginal or incremental costs of supply in electric utilities, but the concept has been slow to win acceptance except in France and Britain.[178]

The traditional approach (By Dupuit and his followers) begins with a comprehensive stocktaking & evaluation of all assets, old & new, from which by application of certain

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[176] R. Turvey, Optimal Pricing and Investment in the Electricity Industry, Allen and Unwin, (1969).

[177] R. Turvey, "The Second Best Case for Marginal Cost Pricing", in J Margolis and H.Guitton (eds), Public Economics: an analysis of public production and consumption and their relations to the private sectors, Proceedings of a Conference held by International Econoic Association, (1969).

[178] Ralph Turvey and Dennis Anderson "Electricity Economics-Essays and Case studies", A World Bank Research publication, (Washington D.C., 1981).

depreciation rules, the annual "capacity-related" or "kilowatt-related" costs are derived. There is an evaluation of various running fuel and other "energy-related" or "kilowatt-hour" related costs. Some costs, such as those for maintenance, have fixed and variable components and are allocated to capacity & energy-related costs respectively. Finally, there are some costs, such as those for metering and billing, that are "customer-related" and not correlated with either capacity or energy demands. (leading to "three-part cost tariffs").

The procedure then is to allocate these costs as "equitably" as possible among consumers through the tariff structure. With research into consumer demand patterns, the more advanced enterprises are able to find out how much each consumer class is contributing to the peak & thus to the capacity-related accounting costs. Then energy and consumer-related costs are added in and a 'cost-based' tariff is formulated for each consumer class.

The first limitation of this "accounting" approach is that, except by chance, prorated accounting costs are quite different from the costs relevant to resource allocation. Prices are amounts paid for extra consumption and need to be related to the incremental costs of meeting extra consumption. If new consumers are connected to the system, or if existing consumers increase their consumption, additions to generating and network capacity may be required. It is important therefore, that prices should signal to consumers the costs of such consumption changes. Prices should be related to the value of resources used or saved, and the valuation of these resources -the estimation of costs- requires a forward looking estimate. In addition if the past holds a number of poor projects, passing on the sunk costs to the consumer of extra consumption is not efficient.

Secondly, this approach generates tariffs which relate to average rather than to marginal costs. But for efficient resource allocation, prices should be related to the resource costs of changes in consumption. And therefore pricing should be based on marginal rather than average cost. The addition of a new consumer or an increase in the consumption of an existing consumer will impose additional costs on the enterprise, while a reduction in consumption will save costs. These alterations in costs are the ones that need to be reflected in tariffs.

This brings us to the third limitation of the accounting approach. Fairness or equity in the approach is couched in rather narrow terms: consumers should pay for their allocated share of accounting costs. These accounting costs may very well differ from the costs that consumers are causing the enterprise to incur.

The fourth limitation of the accounting approach stems from its neglect of the incentive effects of tariffs. In being inadequate as a signalling device, the accounting approach ignores the incentive effects of tariffs. Tariffs give incentives to consumers by telling them when electricity is cheap, e.g. during off-peak hours, and when it is expensive, e.g. during peak hours. Incentive effects are obviously relevant in regulating electricity demand in accordance with requirements of the undertaking, which incurs different costs during different periods of the daily cycle. The average accounting costs, being unrelated to the incremental cost of supply in different periods, are thus inadequate in this respect.

Economists are now generally agreed that the accounting approach is inadequate for efficient resource allocation.[179] The economic argument goes as follows. Accountants are concerned with the recovery of historical or sunk costs, whereas resource allocation emphasises the

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[179] Ibid, Chapter 2.

actual resources saved or used by every consumer decision.

Also, tariffs often have to be simpler than the cost structure they represent. And how do we simplify without nullifying the aims of tariffs? This depends upon the aims of the tariffs. Simplified tariffs designed with only accounting aims in mind may differ enormously from those suggested by economic analysis.

Stiglitz and Atkinson dealt with the issue of Public Sector pricing and production.[180] They addressed the issue of whether public sector prices should be equal to marginal cost and if not, how should they deviate? They did not discuss the definition of marginal costs and related questions such as peak load pricing; nor did they allow for uncertainty. They did consider the departures from marginal cost pricing that may be implied by the need to finance deficits, by the existence of monopoly elsewhere, and by redistributive goals.

They explained the simplest situation of a single public enterprise; producing one final product in quantity (Z), (in per capita terms) in an otherwise competitive economy (where the vector of per capita private outputs is denoted by X). Identical utility functions for all individuals U(X,Z,L) are assumed where L is the quantity of labour supplied per person. The production constraint was assumed to be of the form:

$$\Omega = F(X) + C(Z) - L = 0 \qquad \text{.......................(8.1)}$$

where,

F(X) = labour requirement in the private sector,

C(Z) = the labour requirement in the public sector,

L = quantity of labour supplied per person.

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[180] J. Stiglitz and A.B. Atkinson, Lectures on Public Economics, Mcgraw Hill Book Company (U.K.) Limited, (1980), pp.457-481.

It was assumed that the production set is convex. The condition for profit maximisation in the private sector implies that private sector profit,

$$\pi = q.x - F(X) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8.2)$$

(i.e., value of net output minus labour costs), is maximised. (Note: q.x = value of net output, F(X) = cost of output.)

A necessary condition for this is that $q_i = F_i$ where the latter denotes the derivation of F with respect to X_i. It is assumed at this stage that there are constant returns to scale in the private sector and so $\pi=0$.

The public enterprise is assumed to determine its price P, to maximise social welfare, as measured by the indirect utility function of the representative consumer, denoted by V(q,p) where, q denotes the vector of prices of private sector products and p indicates the prices of the public output.

The enterprise is constrained by the profit condition (per person):

$$pZ - C(Z) + T \geq \pi^{o} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8.3)$$

where T denotes the subsidy provided by the government and π^{o} the profit target. The subsidy is assumed to be financed by lump-sum taxation, so that T enters the indirect utility function. It is assumed that there were no other taxes at this stage. The solution to the pricing problem is seen by forming the Lagrangean;

$$\mathcal{L} = V(q,p,T) + \lambda[pZ - C(Z) + T - \pi^{o}] \ldots\ldots\ldots\ldots\ldots (8.4)$$

The first-order condition with respect to p may be written using the properties of the indirect utility function (the assumption of constant returns to scale in the private sector means that the only change in V is that arising from p):

$$-\alpha Z + \lambda[Z + (p+C')\delta Z/\delta p] = 0 \qquad \ldots\ldots\ldots\ldots\ldots(8.5)$$

where α is the private marginal utility of income.

Suppose first that T is freely variable, so that lump-sum taxation can be employed to finance any deficit. The first-order condition with respect to T (using the fact that $\delta V/\delta T = -\alpha$) is that;

$$-\alpha + \lambda = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8.6)$$

From (8.5) it follows that (provided $\delta Z/\delta p \neq 0$) a necessary condition for optimality is that;

$$p = C'(Z) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8.7)$$

i.e., price equals marginal cost. This is an illustration of the standard argument for marginal cost pricing.

Where there were constraints on the use of T, and the enterprise has an effective profit target, then the pricing rule must be modified. Suppose that $T \leq 0$, and that with marginal cost pricing this is not sufficient to allow the enterprise to satisfy (8.3).

In practice, public enterprises produce more than one product, and this introduces degrees of freedom into the choice of pricing policy. Suppose that there are two products Z_1, Z_2. There are typically many combinations of the prices p_1, p_2 that will satisfy the profit constraint. As seen earlier there are mainly two schools of thought explaining how the firm should depart from the marginal cost principle. One view is that the mark-up over cost should vary according to "what the market can bear", i.e., inversely with the elasticity of demand. Opposed is the position that prices should be proportional to marginal cost, advanced by, among others, Frisch and Allais. In order to consider the merits of these rival views, they modified the earlier analysis, so the maximisation problem is now represented by the Lagrangean;

$$\mathcal{L} = V(q,\ p_1, p_2,\ T) + \lambda[p_1 Z_1 + p_2 Z_2 - C(Z_1,\ Z_2) + T - \pi_0] \quad ..(8.8)$$

VIII.4 Derivation of marginal cost based pricing principle.

The requirements in an optimal electricity tariff, (keeping in mind the important two objectives, i.e., raising sufficient revenues and fair distribution of costs among consumers) are:[181]

(a) Marginal cost pricing and the revenue objective.

In most countries, developed as well as developing, the utilities are faced with a revenue objective as well, usually in the form of a required rate of return on capital investment. The revenue objective (i.e. a required rate of return on the capital base of the utility) is an accounting concept, and is thus based on the relationship between average accounting (usually historical) costs and price. It has been pointed out earlier that no a priori relationship exists between average accounting costs and marginal costs in a real life electric utility, with its mix of different types of plants.

Marginal cost pricing may, therefore, result in a deficit, or a surplus that is smaller or greater than a predetermined target, depending upon the actual situation in the electric utility concerned. The conflict may arises because average accounting costs are an average of

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[181] Criteria stated here can be found in Turvey(1968) op.cit, Turvey and Anderson (1977, chapter 9) op.cit, Munasinghe (1979) op.cit, Atkinson and Stiglitz (1980, Lecture 15) op.cit.

different types and ages of plant, and marginal cost is the incremental cost of new plant at current prices. The observed difference between average accounting costs and marginal costs, can therefore, very often be substantially accounted for by inflation and the firm's accounting practices. In the short run situation of excess capacity (i.e. where demand is below the available capacity when electricity is priced at marginal running cost), a financial deficit can arise with marginal cost pricing, as capacity costs are not covered by the short run rule. However there is no question of excess capacity in the long run.

The problem then becomes one of reconciling the objectives of resource allocation and the required rate of financial return, the latter being regarded as overriding. Originally, many utility managers and engineers saw in this conflict the necessity for some sort of average cost-plus pricing, which alone could ensure the achievement of the revenue objective.

From the accounting point of view, long-run marginal cost would include the opportunity cost of capital. What economists are advocating is that long-run marginal cost should be the starting point of any pricing policy, and the revenue surplus (i.e. over and above average accounting costs) objective, should be considered when making deviations from marginal cost based prices.

In this connection, reference must be made to the important contribution of Baumol and Bradford.[182] These authors demonstrated for the first time, in a systematic fashion, how, in theory, the demands of resource allocation can be reconciled with the requirements of the revenue objective. Where marginal cost pricing yields an overall

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[182] W. Baumol and D.F. Bradford, "Optimal Departures from Marginal Cost Pricing", American Economic Review' Vol.60, (June, 1970). pp.129-142.

deficit, the revenue constraint would require upward revisions in marginal cost-based prices. If we assume that the revenue constraint is overriding, then the problem becomes one of 'optimal' deviations from marginal costs, i.e. such deviations as would cause the least changes in consumption of different categories, from that dictated by marginal cost-based prices. This would imply pricing according to the 'inverse elasticity' rule, i.e. maximum deviations in prices of those consumer categories with the least elasticities of demand. In the case of revenue surplus arising from marginal cost pricing, the reverse procedure applies.

(b) The specification of the marginal cost of electricity output. The factors which affect the position of the cost curve should also be examined. A change in important factors like nonallocative efficiency, input prices and technology would lead to a change in marginal cost. Also, the plausibility of marginal cost disaggregation should be examined. For example, on technical grounds, it may be necessary to disaggregate marginal cost according to geographical area (or level of development, e.g., urban and rural), supply voltage (or consumer group, especially if different groups are supplied at different voltages), and season of the year, particularly in hydro systems. If marginal cost is defined as the cost of supplying an extra unit of electricity (e.g. KWH), as is usually the case, rather than the cost of supplying an extra unit to a new consumer then consumer costs such as the cost of metering and billing should be separately dealt with as fixed costs.

(c) The specification of the demand for electricity. This involves a determination of the aggregate demand function as well as its structure, where necessary. The disaggregation of demand is partly based on time and it involves answers to the following questions: (1) Are demand loads variable with time or not? (2) If demand loads are variable with time, are the different loads independent of one another? Are they also of equal duration?

On the basis of the analysis in Chapter IV and V, we can say that the demand aspect of electricity pricing is one of the most difficult to handle. The demand aspect is even more complicated if the marginal cost is disaggregated. In that case, it is necessary to disaggregate demand even further on the same bases as those upon which marginal cost is disaggregated.[183] Thus, demand can be disaggregated according to geographical area and supply voltage or consumer group.

The constraints that need to be dealt with when determining an optimal electricity tariff are;

(i) A financial constraint. A distinction should be made between constraints imposed on current and capital accounts. The constraints on capital account are mainly limits to borrowing, the rate of interest at which an electric utility can borrow and the sources of finance including the proportion of total finance to be accounted for by retained earnings. The constraint on current account is usually in the form of a rate of return on investment target or net revenue target. It turns out that most governments do impose the constraints as a method of financing anticipated deficits or as a way of imposing a limit on the surplus which can be earned.

(ii) The other constraints which the electric utility faces. One of the most significant of such constraints is the administrative framework of the electric utility including the ease with which information can be procured. In terms of administration, two basic questions should be

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[183] An exception occurs if both marginal cost and demand vary with the seasons of the year. In that case, demand would need to be disaggregated on that basis, independent of the disaggregation of cost.

answered: (1) Can the management cope with the requirements of an efficient organisation of production including the marketing of its inputs and outputs? In other words, can it meet an optimal quantity target at minimum administrative cost? (2) Can management estimate and administer at the minimum cost an optimum tariff policy arrived at after taking all the essential factors into consideration?

If the answers are affirmative, then administration need not be a constraint. Usually, there is administrative inefficiency and consequently, a first-best price-quantity combination can rarely be met. Sometimes the cause is external, especially when a utility has to conform with prescribed constitutional or bureaucratic procedures before policies can be approved. One should bear in mind the administrative framework when determining tariff policies for an electric utility. It is futile to derive and recommend a tariff policy which the administrative machinery is unable to implement.

Some of the above requirements and constraints are interrelated. For example, the net revenue target set by regulatory agencies may depend on the objectives of the marginal cost function and is partly dependent on administrative efficiency. So, each of the factors should not be seen in isolation too rigidly. Secondly, it is too difficult to take all the requirements into account in one formulation, and we have to be content with a few simplifications. The major simplifications centre around the demand and cost functions.

Following Atkinson and Stiglitz, we can design an optimal pricing rule for Gujarat Electricity Board. In determining the optimal pricing rule, we shall, for convenience, adopt a two-stage procedure. The first stage examines the optimal pricing rule in a world where the relevant objectives and constraints are taken into consideration but where some simplifying assumptions about the demand and cost functions are made. The second stage examines the plausibility of the assumptions as well as changes in the optimal pricing rule if some or all the assumptions are relaxed.

VIII.4.1 Assumptions.

For the purpose of the next section, we shall make the following assumptions;

(a) GEB's production technology is such that plant is perfectly divisible. This implies that capacity can be increased in infinitesimal amounts. However, the relevance of this assumption is contingent upon the nature of capacity. If there is no capacity limitation, there will be no need for increasing capacity so, if we assume that there is no capacity limitation, it becomes irrelevant whether or not plant is divisible. But, if capacity is constrained, the assumption of perfect divisibility becomes important. The capacity constraint makes SRMC vertical at capacity output.

The short-run marginal cost (SRMC) need not be uniform across consumer groups, particularly because GEB's generating plants include hydro-electric plants whose costs are affected by rainfall variations. But we shall assume that it is uniform. Thus, for instance, the SRMC is assumed to be uniform irrespective of whether supply is to residential, commercial or industrial consumers. Secondly, it is assumed that the technology involved in electricity generation is homogeneous. It is also assumed that the SRMC is invariant with the seasons of the year.

(b) Demand is of uniform load throughout a demand cycle. This means that the problems of peak-load pricing do not arise; or there are no problems of allocating joint costs among the demand loads belonging to a demand cycle. It also implies that the problems of inter-dependent demands is limited to those between commodities.

(c) The public enterprise operates in a world of certainty. The major implication of this assumption is that both the demand and cost functions are known for sure. Consequently, all the variables in the welfare function and the revenue constraint are also known. Moreover, GEB's investment and production plans are uninfluenced by uncertainty.

VIII.4.2 Analysis of the basic model.

The Basic Model:

Given the assumptions, the basic model consists of equations;

Max either $W_T = S_t(\underline{P}_t) + \underline{R}_t - C^m_t(\underline{X}_t)$.........(8.9a)

or $W_t = B_t(\underline{X}_t) - C^m_t(\underline{X}_t)$ ....(8.9b)

such that $R_t - C^m_t(\underline{X}_t) \geq \pi^o_t$ ....(8.10)

where W is welfare, S is consumers' surplus, $\underline{P}$ and $\underline{x}$ are the vectors of price and output respectively, R is revenue, C^m is the minimum cost incurred in earning the revenue, π^o is the net revenue target, B is benefit, i.e. the sum of the consumers' surplus and revenue, and t is the pricing period. Since the minimum cost concept is adopted, the model is compatible with the achievement of both allocative and non-allocative objectives as well as the revenue constraint faced by GEB. And if the shadow marginal cost concept is adopted in deriving the optimal pricing rules, it also takes into account the distortions resulting from market failures in the rest of the economy.

The model can be criticised. First, since the model is static, the "t"s can be deleted from it. Secondly, since the producer's surplus (i.e. the difference between revenue and cost) is constant, it suffices to maximise the consumers' surplus in so far as the budget constraint is binding. Nevertheless, the analysis below will be based on the maximisation of both the consumers' and producer's surpluses. The reasons are: (1) both approaches yield identical results if the budget constraint is binding, and (2) from the pricing rule obtained from the maximisation of both surpluses, it is easier to derive the optimal pricing rules if the budget constraint ceases to be binding. By and large, the approach opted for is more general than that in which only the consumers' surplus is maximised. Given this, the choice between the welfare functions in (8.9a) and (8.9b) can now be made. The latter is preferred for two reasons: (1) it requires no definition of consumers' surplus and, therefore, of the demand concept being adopted and (2) the optimal pricing rules are easier to derive from it.

A third comment is regarding the budget constraint related to definition of cost. Cost excludes consumer costs (e.g. cost of meters) most of which are traceable to particular consumers and should therefore be charged to them accordingly. So, the pricing rules derived (in this Chapter) are those over and above such charges.

Given the above comments, the basic model becomes,

$$\text{Max } W = B(x) - C(x) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(8.11)$$

$$\text{such that } \; R - C^m(x) \geq \pi^o \quad \ldots\ldots\ldots\ldots\ldots(8.12)$$

where B is total benefit with the property that $\delta Bx/\delta x = P$; and x is electricity sales.

VIII.4.3 Optimal Pricing Rule.

The Lagrangian expression for (8.11) and (8.12) is,

$$\mathcal{L} = B(x) - C^m(x) + \lambda[R - C^m(x) - \pi^o];\ \lambda \geq 0 \ldots\ldots(8.13)$$

where λ is the Lagrangian multiplier or the shadow price of the budget constraint. It should be noted that $dB/dx = P$;

where P is price. After differentiating (8.13) with respect to P and λ,[184] and then solving for P, we have

$$P = \frac{\{(1+\lambda)|\epsilon^d|\}}{\{[(1+\lambda)|\epsilon^d|] - \lambda\}} * C^{m\prime}; \quad |\epsilon^d| \neq 0 \qquad ....(8.14)$$

Letting $$\alpha = \frac{\{(1+\lambda)|\epsilon^d|\}}{\{[(1+\lambda)|\epsilon^d|]-\lambda\}}, \qquad ....(8.15)$$

$$\Rightarrow P = \alpha C^{m\prime} \qquad ....(8.16)$$

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[184] Differentiating (8.13) with respect to P and λ, we have the following first order conditions

$$\frac{\delta L}{\delta P} = P\frac{\delta x}{\delta P} - C^{m\prime}\frac{\delta x}{\delta P} + \lambda\{x + P\frac{\delta x}{\delta P} - C^{m\prime}\frac{\delta x}{\delta P}\} = 0 \quad (8.13a)$$

and $\delta L/\delta\lambda = R - C^m(x) - \pi^o = 0 \qquad ....(8.13b)$

where $C^{m\prime} = \delta C^m/\delta x$ is marginal cost.

From (8.13a), $(1+\lambda)(P-C^{m\prime})\delta x/\delta P = -\lambda x$.

Dividing both the sides by $(1+\lambda)x$, we have

$$(P-C^{m\prime})\frac{\delta x}{\delta P} * \frac{1}{x} = \frac{-\lambda}{1+\lambda} \qquad ....(8.13c)$$

Multiplying both the numerator and denominator of the L.H.S. of (8.13c) by P, we have

$$[(P-C^{m\prime})/P]*\epsilon^d = -\lambda/(1+\lambda)$$

where $\epsilon^d = P/x * \delta x/\delta P$ is the price elasticity of demand.

So, $(P-C^{m\prime})/P = -\lambda/[(1+\lambda)\epsilon^d]$

$$\Rightarrow [P-C^{m\prime}]/P = \lambda/[(1+\lambda)|\epsilon^d|] \qquad ....(8.13d)$$

Solving for P we get,

$$P = \{(1+\lambda)*|\epsilon^d|\}/\{[(1+\lambda)*|\epsilon^d|]-\lambda\} *C^{m\prime} \qquad ....(8.14)$$

which, more fully, is

$$P(x,\varphi) = \alpha C^{m\prime}(x,\Theta) \quad \ldots\ldots\ldots\ldots\ldots\ldots(8.17)$$

where φ and Θ represent demand and supply parameters respectively. Notice that both λ and P (or x) can be determined from (8.13b) and (8.17). Output (or price) is then determined by substituting price (or output) into the demand equation. Notice also that from (8.14), it is possible to deduce the first best result. Setting $\lambda=0$, i.e. assuming the budget constraint is not binding, (8.14) becomes

$$P = \frac{(1+0)|\epsilon^d|}{(1+0)|\epsilon^d|-0} C^{m\prime}$$

$$= C^{m\prime}.$$

So, if the budget constraint is not imposed, or it is not binding, the marginal cost pricing result is optimal.

Having derived the optimal pricing rule for the basic model, the immediate task is to interpret the rule and examine its implications. The interpretation is dealt with first. From (8.15), $\alpha \geq 1$[185] since, as indicated earlier $\lambda \geq 0$. Assuming that the budget constraint is binding (i.e. $\lambda > 0$), then $\alpha > 1$. It is then clear from (8.17) that price exceeds marginal cost. The rule is illustrated in Figure VIII.1.

In the figure, $C'(x,\Theta)$ is the marginal cost curve, AC is the average cost curve and $P(x,\varphi)$ is the demand curve. Consequently, A is the first-best optimum at which optimal price-quantity combination is (P_o, x_o). With this

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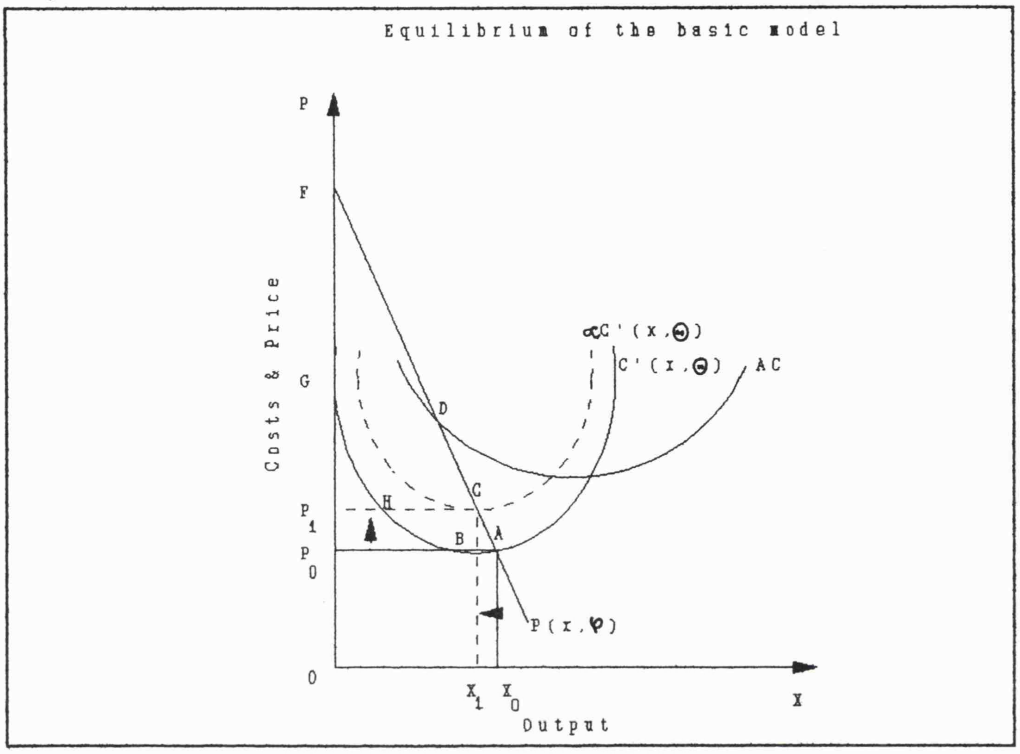
[185] For α to be less than unity, the profit target must be maximum. If it is, λ in (8.13a) is preceded by a negative sign and α in (8.15) becomes

$$\alpha = \frac{(1-\lambda)|\epsilon^d|}{(1-\lambda)|\epsilon^d| + \lambda}$$

So, $0 < \alpha < 1$ if $0 < \lambda < 1$.

Figure VIII.1



combination, the net benefit of commodity x is area AGF, i.e. the difference between total benefit ($OFAx_o$) and cost ($OGAx_o$) or between consumers' surplus (AP_oF) and the producer's deficit (AP_oG). Now suppose the regulatory authority feels the producer's deficit is too much and, consequently, it imposes a revenue target which reduces the deficit (but does not necessarily eliminate it). Then, there exists a curve such as $\alpha C'(x,\Theta)$ in the figure. The equilibrium point is then at C and the optimal price-quantity combination is (P_1 ,X_1). This implies that the target reduces output and raises the optimal price. But what is the effect of the budget constraint on welfare? At C, the producer's deficit is ($OGBx_1$ - OP_1Cx_1) = P_1GH - HCB, and the consumers' surplus is reduced to P_1FC. Therefore, the net benefit of x_1 is (P_1FC - P_1GH +HCB) = FCBHG. So, the welfare loss resulting from the budget constraint is area ABC.

Why should a government impose a regulation which reduces welfare? The answer involves a comparison between two economic states. The first state is a combination of first-best pricing and the need to finance any deficit or utilise the surplus through the central government. The second state is summarised by the basic model, implying that it combines efficient pricing with limits on the financial performance of the enterprise thereby resulting in a second-best optimum (C in the figure). On efficiency grounds, the government is rational in imposing a budget constraint if it turns out that the net benefit of commodity x in state 2 exceeds that in state 1 and vice-versa. There is indifference if the net benefits are equal.

State 1 will be preferable if there exists a system of lump-sum taxes which can be imposed to cover the deficit. In that case, the marginal conditions remain unchanged. So, welfare will still be correctly measured by the area AGF in Figure VIII.1, which exceeds the net benefit at second-best optimum. However the problem is that one rarely comes by such a system of taxes. Usually, a welfare loss is associated with the policies designed to solve the financial problem. So, with state 1, even though the net benefit of commodity x is initially as large as possible, some inefficiencies creep in when the financial problems are incorporated. The effective net benefit of commodity x is the sum of the consumers' and producer's surpluses when priced at marginal cost, less the welfare cost associated with the management of the financial state of the public enterprise. On efficiency grounds, it is irrational to impose the budget constraint if the welfare loss is less than area ABC in the Figure VIII.1.

One needs to know whether marginal cost refers to the SRMC and/or the LRMC. From the nature of the pricing decision, i.e. one of pricing in a pricing period or at a point in time, it is obvious that the SRMC is appropriate. None the less, the LRMC is also appropriate if plant capacity is optimal at the level of output determined by (8.17), in which case, the LRMC equals SRMC. It should be noted that, since a SRMC and a LRMC curve cannot intersect at more than one level of output,[186] and since the budget constraint leads to a second rather than first-best optimum, the level of capacity implicit in (8.17) must be different from that prevailing in a first-best world if the LRMC must equal the SRMC. By and large, even though the SRMC is the one directly relevant to the pricing problem, it is quite possible for the LRMC to do the same job even in the face of the budget constraint.

One implication of the pricing rule is that public enterprises are justified in adjusting their prices in line with the rate of inflation. This is because the cost concept in the pricing rule is the current marginal cost. Therefore, revenue adjustment to inflation should be fully automatic. However in practice, there are problems in adjusting prices to inflation. The first is attributable to the fact that the prices for the supplies of a public enterprise cannot be varied continuously in line with inflation. Price is normally allowed to remain steady over a period. Consequently, the problem is how to fix prices for the period so as to reflect the rate of inflation during the period. Various techniques are available for forecasting the rate of inflation. They range from guesses to sophisticated forecasting techniques. The problem is that most techniques are subject to error. So, the adjustment of prices to inflation would normally be imperfect.

The second problem involves the treatment of depreciation of fixed assets, inventories (of inputs only since electricity is supplied on demand) and capital gains (including those stemming from net monetary liabilities and

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[186] This is because both curves are at best convex from below, the SRMC cutting the LRMC from below.

assets) in an inflationary period. Notice that the problem of how best to treat these quantities exists even without inflation, in which case inflation merely accentuates the problem.[187] Given this observation and assuming for the moment that we are only concerned with inflation, a useful approach is to index the various quantities. For instance, depreciation allowances can be calculated on a replacement cost basis, different indices being applied to different classes of assets. However two main problems should be noted on this approach. The first is that other objectives may demand measures which exclude full indexation. For instance, the need to stimulate investment may require a policy of initial depreciation allowances rather than the replacement cost-based depreciation. The second problem is the choice of index. These and other problems often prevent a public enterprise from adopting measures which are ideal.

VIII.4.4 Multi-part tariffs.

According to the pricing rule derived above, unless the production technology exhibits constant returns to scale, the tariff is essentially a variable charge. Thus, consumption is open to all at a variable charge per unit consumed. The charge varies positively with demand.

For some enterprises, an alternative tariff policy is possible. It is a multi-part tariff, or two-part tariff. The main traditional case for this type of tariff was the possibility of covering cost without simultaneously distorting the efficiency of resource utilisation. In other words, it was thought to be a device for improving the efficiency of public enterprise pricing when the technology exhibits increasing returns to scale.

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[187] A.R. Prest and N.A. Barr, Public Finance in Theory and Practice, Chapter 16 (explanation regarding the treatment of depreciation of fixed assets, inventories and capital gains with and without persistent inflation). (1979).

A two-part tariff is designed in such a way that one part is a variable charge. This implies that this part is levied according to the use of the facilities. The other part of the tariff is a fixed charge and, as a result, is invariant with the volume of transactions. This part is contingent upon the need to meet a certain revenue requirement. (It is alternatively known as the licence fee or the admission charge for the right to purchase. In theory, the fixed charge would be the same for all consumers irrespective of the quantity supplied to each consumer.)

The exact magnitudes of the variable and fixed parts depend upon the assumptions made. If there is no change in the number of consumers as a result of changes in the fixed charge, given GEB's objective of efficiency, and revenue constraint in (8.10), the variable part of the tariff equals marginal cost and the fixed part can be determined as under: Let the level of output at which demand equals marginal cost be x_0. At x_1 the revenue constraint is

$$R - C^m(x_0) = \pi^o.$$

With a two-part tariff

$$R = C^{m\prime}\, x_0 + fN$$

where $c^{m\prime}$ is marginal cost, f is the fixed charge and N is the number of consumers. Substituting this into the budget constraint, we have

$$C^{m\prime}x_0 + fN - C^m(x_0) = \pi^o.$$

Hence,

$$f = \frac{\pi^o + C^m(x_0) - C^{m\prime}x_0}{N}$$

i.e.

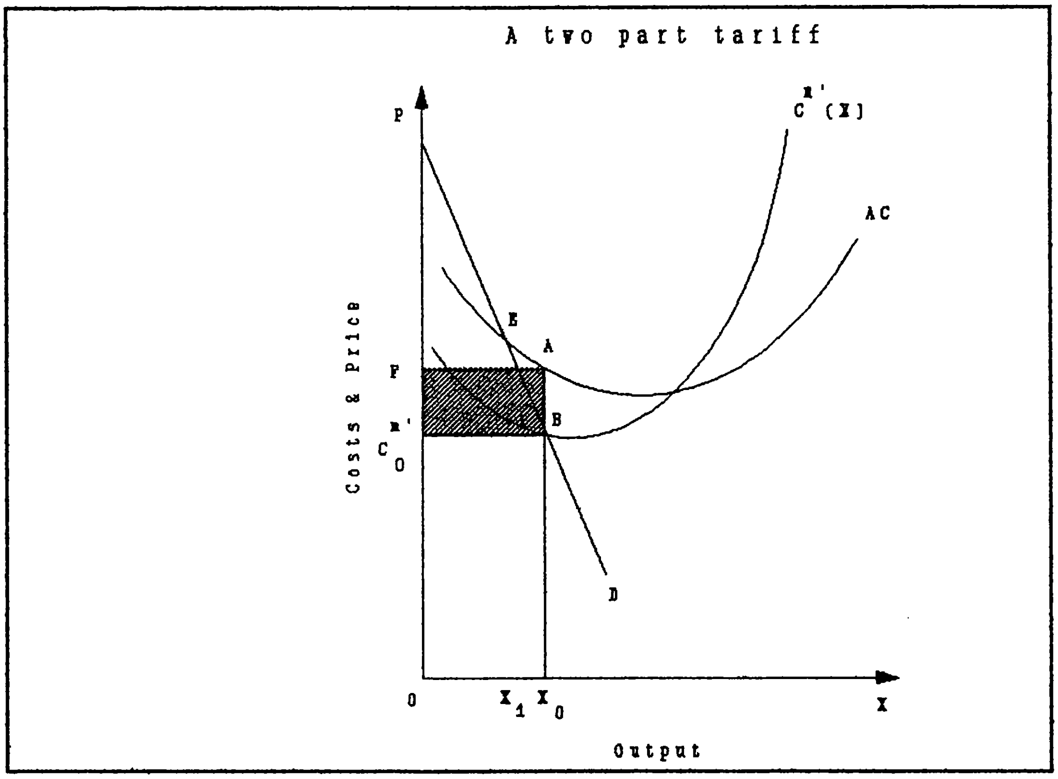
$$f = \frac{\pi^o}{N} + \frac{\{AC(x_o) - C^{m\prime}(x_o)\}x_o}{N} \quad \ldots\ldots\ldots(8.18)$$

Suppose GEB is directed to cover costs, then $\pi^o = 0$ and

$$f = \frac{(AC - C^{m\prime})x_o}{N} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(8.19)$$

This is illustrated in Figure VIII.2.

Figure VIII.2



In the figure, $C^{m\prime}(x)$ is the marginal cost curve, AC is the average cost curve and D is the demand curve. Without the budget constraint, equilibrium is at B. So, the variable part of the tariff is $C^{m\prime}_o$. At the equilibrium point, the enterprise incurs a deficit to the tune of the shaded area, i.e. $ABC^{m\prime}_oF$. Given that costs should be covered, the deficit is financed by levying a fixed charge on each consumer. The charge equals the quotient of the deficit and the total number of consumers. Notice that the levy is not the same as AB which is the quotient of the deficit and the optimal quantity. The fixed charge will equal AB only if the number of consumers equals the optimum quantity; that is, if each consumer purchases only a unit of commodity. If at least one consumer purchases more than one unit, then $x_0 > N$ implying that, given the size of the deficit, the fixed charge will exceed AB.

How suitable is the two-part tariff device as an alternative to the single-part tariff specified in (8.17)? Since the single-part tariff achieves a second-best optimum and a first-best optimum is impossible under a revenue constraint, the two-part tariff is at best as good as the single part tariff. Both types of tariff do adhere to the benefit principle and both involve distortions or departures from marginal cost pricing. The departure of the multi(two)-part tariff would yield an equilibrium at E (in Figure VIII.2) when a cost covering policy is pursued. For the two-part tariff, the ultimate equilibrium will not be at B. This is because the fixed charge is not truly lump-sum. We define a lump-sum charge as one in which the consumer cannot affect the size of the charge by modifying his behaviour.

The fixed charge can be affected by consumers. This is because a move from marginal cost pricing position to one in which price exceeds marginal cost is likely to crowd-out the marginal consumers. If one consumer backs out, that implies a change in the number of consumers and, therefore, a change in the fixed charge. The main point here is that the imposition of a fixed charge is likely to distort the choice whether or not to consume the service at all. For the second-best optimum, demand will decrease until, with the cost covering case, it intersects the marginal cost curve at a point that corresponds to x_1 in the figure. The variable charge is then equal to $C^{m\prime}(x_1)$ and the fixed charge may be determined according to (8.19) with x_1 replacing x_0.

The two-part tariff has several limitations compared to the uniform tariff. Firstly, a major characteristic of the fixed charge is that it is regressive (though we need not discuss this here since equity is not the concern at the moment). Secondly, a two-part tariff is only applicable where it is possible to determine the number of consumers. This requirement is easily satisfied by some enterprises such as electricity e.g. GEB. Thirdly, a two-part tariff is applicable mainly in decreasing cost industries. This is because (1) in practice, the fixed charge is usually positive and (2) operations need to be optimal. As noted earlier, the fixed charge is given by

$$f = \pi^o + \frac{(AC - C')x}{N}$$

Suppose $\pi^o = 0$, then

$$f > 0 \text{ if } AC > C',$$

i.e., if average cost is decreasing. In principle, there is no basis for restricting the sign of the fixed charge. It is therefore possible to apply the two-part tariff in increasing cost industries. In essence, it is possible to achieve a second-best optimum even with a negative fixed charge. However, in designing tariffs, principles have to be adopted to practical possibilities. In this regard, it seems the only stable practical possibility is for the fixed charge to be positive. To the extent that a negative fixed charge is inadmissible, the two-part tariff can only be applied to those enterprises whose technologies exhibit increasing returns to scale over some range of output.

VIII.4.5 Extension of the basic model.

The basic model needs to be extended to incorporate GEB's other features. First, the plausibility of the assumptions need to be examined. Second, the optimal pricing rules are determined if some rules are relaxed. Thus, in turn, we examine the following assumptions: capacity constraint and plant divisibilities, marginal cost structuring, peak-load pricing and uncertainty.

VIII.4.5.1 The capacity constraint and plant indivisibilities.

One of the assumptions underlying the analysis in the previous section is that GEB faces no capacity constraint. This implies that plant is of flexible capacity and any load demanded could be met without confronting the technical difficulty (or impossibility) imposed by maximum output. In fact, at any instant, most public enterprises, (including GEB) face a completely rigid capacity. Hence, it is necessary to modify the basic model for which (8.17) is the optimal result.

The problem is to maximise (8.11) subject to (8.12)

and $x < \overline{x}$ ....(8.20)

where $\overline{x}$ is capacity output. The Lagrangian expression is

$$\mathcal{L} = B(x) - C^{m}(x) + \lambda[R - C^{m}(x) - \pi_0] - \tau[x-\overline{x}];\ \tau\geq 0. \quad (8.21)$$

where τ is the Lagrangian multiplier associated with the capacity constraint, i.e. the rental charge arising from power outages. After differentiating (8.21)[188] and solving

[188] Differentiating (8.21), with respect to price, we have

(continued...)

for P we get,

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[188](...continued)

$$\frac{\delta L}{\delta P} = P\frac{\delta x}{\delta P} - C^{m'}\frac{\delta x}{\delta P} + \lambda[P\frac{\delta x}{\delta P} + x - C^{m'}\frac{\delta x}{\delta P}] - \tau\frac{\delta x}{\delta P} = 0$$

$$\text{»}\ (1-\lambda)\ (P-C^{m'})\frac{\delta x}{\delta P} = -\lambda x + \tau\frac{\delta x}{\delta P}.$$

Dividing through by x, we have

$$(1+\lambda)(P-C^{m'})\frac{\delta x}{\delta P} * \frac{1}{x} = -\lambda + \tau\frac{\delta x}{\delta p} * \frac{1}{x}$$

Multiplying both the numerator and denominator of the first and last expression by P, we have

$$(1+\lambda)\ \{\frac{P-C^{m'}}{P}\}\ \epsilon^{d} = -\lambda + \frac{\tau\epsilon^{d}}{P}$$

where ϵ^{d} is the price elasticity of demand. This implies

$$\frac{P-C^{m'}}{P} = \frac{1}{(1+\lambda)\epsilon^{d}}\{-\lambda + \frac{\tau\epsilon^{d}}{P}\}$$

$$P = C^{m'} + \frac{P}{(1+\lambda)\epsilon^{d}}\ [\ -\lambda + \frac{\tau\epsilon^{d}}{P}\ ]$$

$$= C^{m'} - \frac{\lambda}{(1+\lambda)\epsilon^{d}}P + \frac{\tau}{(1+\lambda)}$$

$$= \frac{(1+\lambda)|\epsilon^{d}|}{(1+\lambda)|\epsilon^{d}| - \lambda}C^{m'} + \frac{|\epsilon^{d}|}{(1+\lambda)|\epsilon^{d}| - \lambda}\tau \quad \text{...(8.21a)}$$

Letting $\alpha = \dfrac{(1+\lambda)|\epsilon^{d}|}{(1+\lambda)|\epsilon^{d}| - \lambda}$,

then, $P = \alpha C^{m'} + \dfrac{\alpha}{(1+\lambda)}\tau$ ....(8.22)

$$P = \alpha C^{m'} + \frac{\alpha}{(1+\lambda)}\tau \quad \ldots\ldots\ldots\ldots\ldots(8.22)$$

The first expression on the R.H.S of (8.22) is the same as that in (8.17) except that $C^{m'}$ should now be interpreted as the marginal operating or running cost. If the level operation is below capacity, $\tau = 0$, and the same result as in (8.17) is arrived at. But if the level of operation is at capacity output, $\tau>0$ and the optimal price exceeds $\alpha C^{m'}$. So, the influence of the capacity constraint is to potentially increase the optimal price by increasing the SRMC through the shadow price of the capacity constraint.

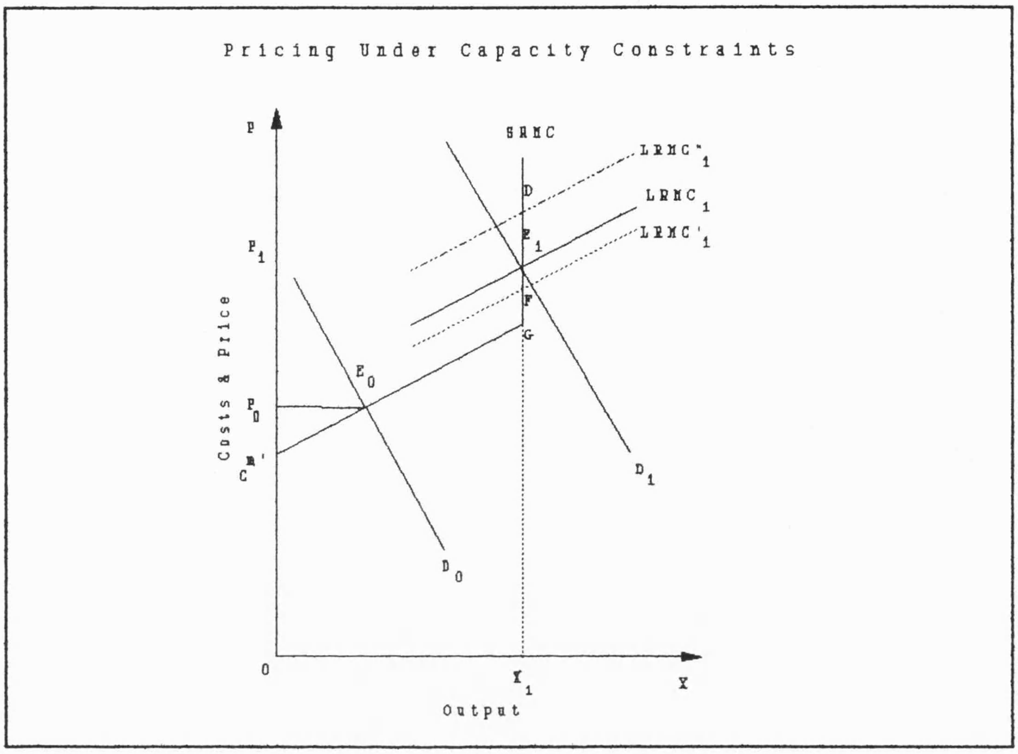
Since the effect of capacity is on cost, it is useful to examine the components of SRMC if the shadow price of the budget constraint (i.e. λ) is zero. In that case, $\alpha = 1$ and (8.22) becomes

$$P = C^{m'} + \tau. \quad \ldots\ldots\ldots\ldots\ldots\ldots(8.23)$$

So, price equals the SRMC, i.e. the sum of the running cost and the shadow price of the capacity constraint or the rental charge arising from excess demand. Since it is also known that the LRMC is the sum of the running cost and the marginal capacity cost (β), the relative magnitudes of the LRMC and the SRMC depend on the relative magnitudes of the shadow price of the capacity constraint and the marginal capacity cost. So, SRMC = LRMC if $\tau = \beta$, SRMC > LRMC if $\tau > \beta$ and vice-versa. The optimal result in (8.23) and the relationship between the SRMC and the LRMC are illustrated in Figure VIII.3.

In the figure, the initial level of demand is D_0, the equilibrium is at E_0 and the optimal price is at P_0. As output is less than capacity, τ is zero. So, the optimal price is equal to the running cost. Now suppose demand increases to D_1. Optimality now occurs at E_1 and the

Figure VIII.3



equilibrium price at P_1. Since capacity is fully utilised, τ assumes a positive value. In fact, with demand at D_1, its value is E_1G. So, optimal price, P_1, equals the sum of the running cost Gx_1 and the shadow price of the capacity constraint, $\tau = E_1G$. At the same level of output, β equals FG if the LRMC is LRMC$'_1$, E_1G if the LRMC is LRMC$_1$, and DG if the LRMC is LRMC$''_1$. Therefore, with LRMC$'_1$, $\beta < \tau$ and SRMC > LRMC; with LRMC$_1$, $\beta = \tau$ and SRMC =LRMC; and with LRMC$''_1$, $\beta > \tau$ and SRMC < LRMC.

A knowledge of the exact relationship between SRMC and the LRMC is useful for determining whether or not capacity should be expanded.[189] The rule is that $\tau > \beta$, there is overinvestment and capacity should be contracted.

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[189] O.E. Williamson, "Peak Load Pricing and Optimal Capacity Under Indivisibility Constraints", <u>American Economic Review</u>, Vol. 56, No. 4, pp.810-827, (1966), also reprinted in R. Turvey, ed. <u>Public Enterprise: Selected Readings</u>, Penguin Books, (1968).

Equilibrium occurs when $\tau=\beta$ or when SRMC=LRMC. In this sense, E_1 (in the figure) is indeed in both short- and long - run equilibrium. This result is based on the assumption that the budget constraint is not binding.

The assumption is in fact perfect plant divisibility. It implies that the SRMC is continuously smooth. But for most public enterprises, including GEB, plant indivisibility or lumpiness of investment is the rule. In fact, additions to capacity tend to be very large in electric utilities. So, the assumption of perfect plant divisibility will normally be violated in practice. However, plant indivisibility may or may not be important depending on the degree of interconnection of the system of electricity generation and the relative size of each plant to the total.[190] If the interconnections are extensive and each generating unit represents an insignificant fraction of total capacity, plant indivisibility would be insignificant.[191]

The indivisibility constraint has two major effects. (1) there is a need for more careful interpretation of marginal cost. The need for re-interpretation can be explained with the help of Figure VIII.4.

In the figure, P is the price, x is the output, $C^{m'}$ is the SRMC curve and D is demand. The initial level of demand is D_0. At this level of demand, the optimal price and output are P_0, x_0. Now suppose demand increases to D_1. With capacity constraint $\overline{x}_0$, the optimal price rises to P_1. Part of this price is the shadow price of capacity constraint which

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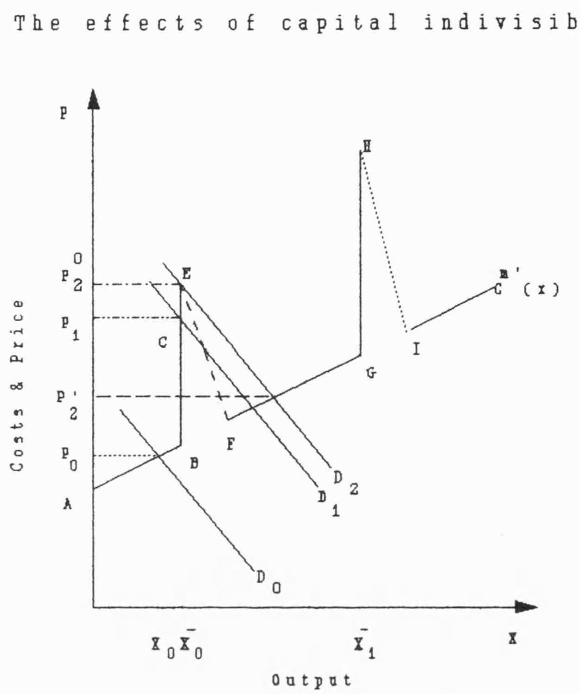
[190] H. S. Houthakker,"Electricity Tariffs in Theory and Practice", Economic Journal, Vol. 61, No. 241, 1-25. (1951).

[191] In case of GEB, plant indivisibility is important i.e. not insignificant. And this can be proved using the data on proportionate share of different plants in the total capacity and proportionate share of generation and installed capacity of GEB in the regional grid.

Figure VIII.4



equals BC in the figure. If BC exceeds the marginal capacity cost then the expansion of capacity is signalled. As investment is lumpy, there will be a sharp spike (BFF if investment is instantaneous) in the SRMC curve. Thus, with plant indivisibility, strict marginal cost pricing rule requires that development cost should be borne by existing consumers (e.g. price is P_2^o at E). As soon as investment is completed, the cost becomes a sunk cost and the marginal cost curve adapts to its old trend line. After this adjustment, the optimal price is $P'_2 < P_2^o$ when demand is D_2. The general effect of plant indivisibility is that it creates a practical problem - unacceptable price fluctuations - if marginal cost is not defined appropriately. This problem can be solved by adopting the

LRMC approach[192] thereby averaging capacity cost over the useful life of the plant.

The second effect of the plant indivisibility is that capacity output can only assume integer multiples of output units. Thus if there are n plants each capable of producing $\overline{x}_i$ units of output, then total capacity $\overline{x}$ can be expressed as:

$$\overline{x} = n\overline{x}_i.$$

So, the capacity constraint is:

$$x \leq \overline{x} = n\overline{x}_i.$$

However, this is of no major effect to the basic model. It only imposes a bound on the values which capacity output can assume.

What are the combined effects of plant indivisibilities and capacity limitations? The joint effects are illustrated in Figure VIII.5. Without both indivisibility and capacity limitation, the SRMC is ABCDEFG. With plant indivisibility, the SRMC is ABJCDKEFG. The need to keep price steady implies that plant costs should be averaged over the entire life of the plant. If this is done, the relevant cost is the LRMC. If instead of plant indivisibility, output were constrained to $\overline{x}$, then the relevant cost is SRMC, i.e. ABCDEFMN. This implies that the SRMC is kinked at capacity and is indeterminate unless demand is known. Combining both features, we have a dual

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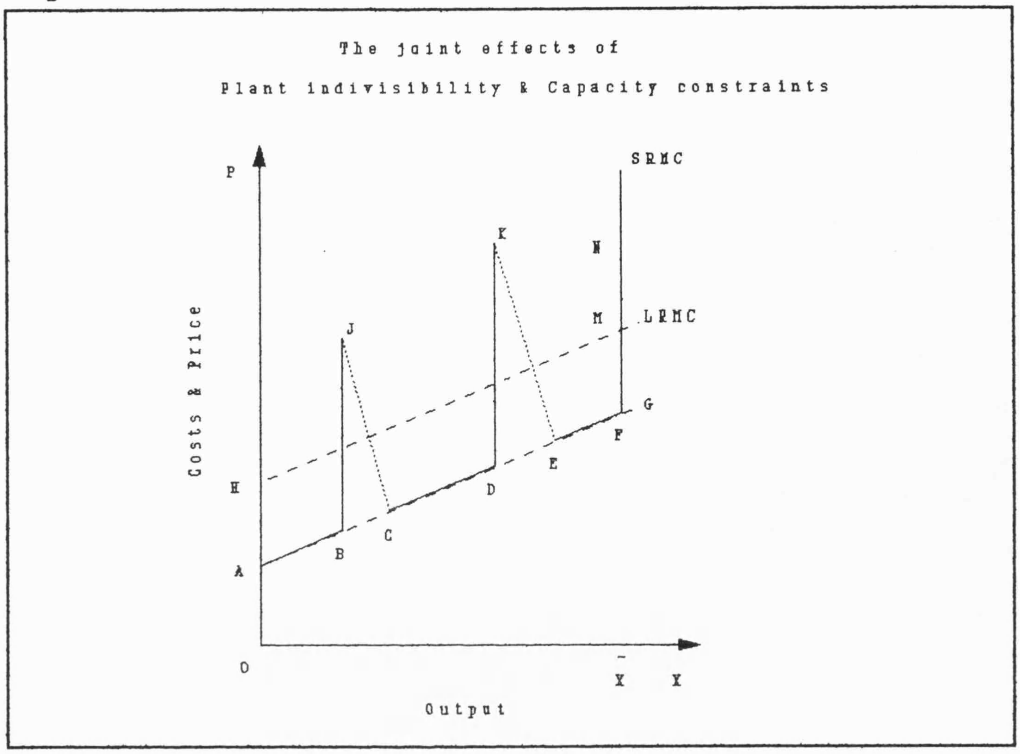
[192] This is typical World Bank approach. See, e.g. Mohan Munasinghe, Electric Power Pricing Policy, World Bank Staff Working Paper no. 340, (1979), (p.13), and R. Turvey and D. Anderson (1977), op.cit, p.358, H.Hotelling, "General Welfare in Relation to Problems of Taxation and Railway and Utility Rates", Econometrica, Vol.6, No.3, (1938), p.264 suggested similar solution.

Figure VIII.5



rule. At levels of operation below capacity, the relevant cost is the LRMC, i.e. HM. On the other hand, if the level of operation is at capacity output, the appropriate cost is MN, i.e. part of vertical portion of the SRMC curve. Therefore, marginal cost is the greater of the short- and long-run marginal costs, i.e. HMN.

VIII.4.5.2 Marginal cost structure.

The final assumption is that marginal cost (i.e. the LRMC and also SRMC) is uniform across consumer groups, generating plants and seasons of the year. This assumption is implausible. The LRMC is likely to vary across consumer groups mainly because they are supplied at different voltages. Given the nature of electricity transmission and distribution, the LRMC varies inversely with supply voltage. Thus, it must be true that GEB incurs the highest LRMC on agricultural consumers and the lowest LRMC on the industrial consumers. In any case, the important thing is not the ranking but the variations of LRMC across consumers when grouped according to supply voltage. Consumers can also be classified on other bases, especially according to geographical area - e.g. rural and urban. The LRMC is also likely to vary across GEB's generating plants. This is because plants differ in type and location as well as age. These differences imply that plants are most likely to differ in their running efficiency and therefore, in their costs. Given this, if GEB's management is rational the plants will be used in the order of their running efficiency, implying that the system's marginal cost may be upward sloping. So, the technical diversity affects the shape of the supply curve. This is in fact the only effect if one assumes that demand, if disaggregated, is such that the demand periods coincide with the optimal running times of the different types of the plants, an assumption that will be made here. So, the pricing rule is unaffected, though the optimal prices will be if demand is disaggregated.

The plausibility of a uniform demand LRMC across seasons is partly dependent on variation in demand loads. It should be noted that whenever the LRMC is disaggregated according to consumer groups, whether by supply voltage, geographical area or whatever, demand should also be disaggregated likewise for meaningful derivation of the optimal pricing rules. (The converse is not necessarily true. For instance, the optimal pricing rules can be derived from a combination of uniform LRMC and a demand disaggregated into peak and off-peak loads).

VIII.4.5.3 Peak load pricing.

The crucial demand assumption on which the basic model is based is that demand is of uniform load with respect to time, implying that there was no problem of peak-load pricing. But the assumption is clearly untenable. It should be noted that variable demand is not sufficient to cause a peak-load problem. Given variable demand, a peak load problem arises when the commodity supplied is non-storable or when the storage costs are prohibitive. In that case, the commodity is supplied on demand. The non-storability condition explains the prevalence of the peak load problem in such utilities as electricity. For those enterprises whose products are storable, the uniform load assumption does not alter the basic results and is therefore acceptable.

Whenever the peak-load problem exists, the general problem to be solved is how to apportion the joint capacity cost among different loads in a way consistent with efficiency or, more specifically, with the minimisation of excess capacity during the off-peak periods. The general strategy is to induce consumers to shift their demands from peak to off-peak periods by charging a lower price during the off-peak periods. Optimality is achieved when the price structure is such that the demand structure is compatible with minimum excess capacity in the off-peak periods.

Unfortunately, so far in India, demand is not metered according to the time of day. Also it is difficult to separate the costs: hence, it will be impossible to try and calculate the price for off-peak and peak periods.

VIII.4.5.4 Uncertainty.

There are three main areas through which uncertainty exerts significant influences on the activities of a public enterprise. On the demand side, the extent to which random changes in incomes, tastes and the prices of other commodities influence demand is usually unknown. Hence, demand is normally stochastic. The second area is plant capacity. In the short-run, the random variations in capacity can be due to equipment failures, strikes and the like. In the long-run, it may be due to such factors as errors in forecasts used as bases for capacity expansion, slippage in construction schedules and unplanned equipment outages. (Uncertainty will affect capacity, be it the existing (i.e. actual) one or the optimal one (i.e. the one that would prevail if GEB priced its supplies as if capacity were optimal). The third major area is the marginal operating cost. The random disturbances here are mainly due to changes in the prices of the inputs (e.g. fuel and labour) which GEB utilises.

Uncertainty is of significance to pricing precisely because, in practice, the pricing decision is taken prior to the beginning of a pricing period, i.e. before demand, operating and capacity costs are known for sure. Uncertainty in itself is not sufficient to present a problem for public enterprise pricing. It is the need to set prices over a specified immediate future that necessitates the use of anticipated demand and costs rather than the actual. In light of this what is the degree of implausibility of the uncertainty assumption? There are three main issues which should normally be considered. The first is the characteristics of uncertainty, e.g. its extent and variability, which in statistical terms are summarised by the mean and variance of the random disturbance. The second is the duration of the pricing period. There are two contradictory points. On the one hand, one can say that the longer the pricing period, the greater the influence of uncertainty since more unexpected events are likely in the long- than in short-run. But it can also be argued that a variable is likely to assume its permanent, long-run or trend value the longer the period involved, and, therefore, is likely to be more predictable. (This is the same as saying that the unexpected events are more likely to cancel out in the long- than in short-run). Which of the assertions is valid depends on whether or not things happen to cancel out. And whether they cancel out depends on the factors involved. The third factor is the quality of the forecasting techniques adopted by a public enterprise to determine demand and costs. The better the quality of forecasting techniques, the smaller the difference between anticipated and actual demand and costs. This factor is a very important one. The influence of uncertainty on errors in pricing decisions based on the pricing rules above can be reduced to an insignificant minimum. So, the assumption of certainty may not be implausible. With this background, the approach that will be adopted in this study is the use of appropriate forecasting techniques to determine expected demand and cost for a given period. Therefore, the influences of uncertainty which are not taken into account by this approach are assumed away. (Actually the lack of awareness regarding the expected demand without a supply constraint will not lead us to predict demand appropriately. Hence, by assuming the appropriateness of demand prediction, the study is of limited use).

VIII.5 Summary.

The procedure started with the basic model, i.e. the maximisation of the consumers' and producer's surpluses (based on uniform and smooth demand and cost) subject to the revenue constraint. The optimal price is one which equates demand price with the product of a scal~~e~~ar factor ($\alpha > 1$) and marginal cost. This type of tariff belongs to the class of single-part tariffs. However, for such a tariff, an equivalent two-part tariff can be derived. This consists of a variable charge which equals marginal cost, and a fixed charge which is the quotient of the deficit at the level of output where price equals marginal cost and the number of consumers. The fixed part is invariant with respect to the quantity consumed. Historically, such a tariff was thought to be capable of covering cost without simultaneously distorting the efficiency of resource utilisation. However, since the fixed charge is not truly lump-sum, it is highly unlikely that a two-part tariff will achieve a first-best optimum. The applicability of a two-part tariff is also largely limited to decreasing cost industries since the fixed charge is usually positive.

CHAPTER IX

ELECTRICITY PRICES IN GUJARAT AND MARGINAL COST PRICING.

Having derived the optimal pricing rules for GEB's electricity supply in the previous chapter, the next step is to estimate "optimal" electricity prices.

In determining electricity prices, a knowledge of electricity demand is indispensable.

Let the general form of the demand function[193] for the H^{th} consumer class be,

$$P_H = P_H(X_H) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9.1).$$

where,

P = price and,

X = quantity demanded.

The consumer class could be determined by a number of factors including the role of the consumer in the production process (e.g. residential, commercial, industrial etc.) demand period (i.e. peak and off-peak periods) and geographical area. So, a consumer class can be the residential consumers in rural areas during the off-peak period. If there are n consumer classes, n demand functions are required.

The second requirement for price determination is the budget constraint. With more than one consumer class, it is given by,

$$\sum_{H}^{n}[R_H - C_H(X_H)] = \pi^o \quad \ldots\ldots\ldots\ldots\ldots\ldots(9.2)$$

or

$$\sum_{H}^{n}[P_H X_H - C_H(X_H)] = \pi^o \quad \ldots\ldots\ldots\ldots\ldots\ldots(9.3).$$

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[193] As discussed in Chapter IV, demand for electricity is a derived demand, and how far the data is representative of true demand is a big question.

where,

R = revenue,

C = cost of earning the revenue and,

π^o = profit target.

Substituting the demand function (9.1) into (9.3) we have, either

$$\sum_{H}^{n}[P_H(X_H)X_H - C_H(X_H)] = \pi^o \quad \text{.................(9.4)}$$

or

$$\sum_{H}^{n} \{P_H X_H(P_H) - C_H[X_H(P_H)]\} = \pi^o \quad \text{............(9.5).}$$

The difference between (9.4) and (9.5) is that the former is expressed in terms of quantity while the latter is expressed in terms of price. However, both yield identical price-quantity combinations, since, for a given price, quantity can be uniquely determined and vice-versa.

The last requirement for price determination is the condition for the welfare optimum. If π^o is minimum, the welfare optimum condition for the H^{th} consumer class is given by,

$$\frac{P_H - C_H}{P_H} = \frac{\lambda}{(1+\lambda)|\epsilon_H^d|} \quad \text{........(9.6).}$$

If π^o is maximum, it is given by,

$$\frac{P_H - C'_H}{P_H} = \frac{\lambda}{(1-\lambda)|\epsilon_H^d} \quad \text{.............(9.7).}$$

where,

ϵ_d = own-price elasticity of demand,

C' = marginal cost and,

λ = shadow price of the budget constraint.

There should be n of either equation (9.6) or equation (9.7). These n equations together with (9.4) yield a system of (n+1) equations in (n+1) unknown (i.e. n prices and the shadow price of the budget constraint). So, the system is complete.

The solutions of the system of equations can be derived in two main ways. The first is the use of mathematical programming to solve the original problem from which the equations are derived. The second method, and one adopted in this study, is to solve the system of equations directly. This is by first using aggregate demand and cost functions to determine potentially "optimal" aggregate quantities which satisfy (9.4) equation. Notice that the number of potentially "optimal" outputs depends on the nature of the demand and cost functions.

IX.1 Derivation of electricity prices on the basis of LRMC in Gujarat:the requirements.

There are three main problems due to shortage of data. The first is the impossibility of determining the cost function relevant to each consumer class. The data are all aggregative. And we know that if cost is not disaggregated, demand disaggregation for pricing purposes is effectively limited to that between peak and off-peak loads. This brings us to the second problem, namely difficulties in estimating demand in peak and off-peak periods. Thirdly, there is the problem of estimating shadow costs or prices. This is mainly attributable to lack of public information on all of the GEB's inputs between 1961 and 1986.

The consequence of the first two difficulties is that one is compelled to limit the estimation of electricity prices to charges for all consumers taken as a group. Even with these charges much can be said about GEB's pricing policy. The consequence of the third difficulty is that, at best, one can only be sure that the estimated prices are "optimal" when there are no distortions in the economy.

The period of the analysis throughout is a financial year i.e. April 1 to March 31; i.e., 1979 would represent the period April 1978 to March 1979. So, the demand and cost functions as well as the profit targets and prices all refer to a twelve month period.

IX.1.1 Demand for electricity.

In this chapter the main purpose is to derive prices on the basis of the marginal cost principle, explained in Chapter VIII. The cost analysis is possible only at aggregate level. In this case, it is inappropriate to analyse electricity sales at disaggregate level. There are two points to be noted. One concerns the nature of Gujarat Electricity Board, in that not everyone willing to pay has access to electricity. This implies that there is a certain amount of suppressed demand and, consequently, it is impossible to provide a reasonable estimate of the demand function which incorporates potential and actual consumers. Given this, one must limit the demand function to existing electricity consumers. There is also a related problem of power shortages which makes the quantity demanded by connected consumers unobservable. What is in fact observed is actual electricity sales as constrained by outages. Therefore the observed data reflect sales and not demand. But for convenience we assume that electricity sales is electricity demand.

The second problem concerns the identification of the demand function. In a nutshell, this problem boils down to the question: how can one be sure that one is estimating the demand function and not the supply function? A less technical approach is to ask: are there any explanatory variables in the supply function (e.g. input prices) which are not included in the demand function. If the answer is yes, demand is identified.

As observed in Chapter III, economic literature showed a great variety of price variables that are included in the demand function for electricity.

(1) the marginal price,

(2) the average price, also called the ex-post average price,

(3) the intra-marginal price,

(4) a combination of two of those variables.

In Chapter IV, for the analysis of electricity sales at all India level, average price was used as a proxy for the price variable. In Chapter V, for the analysis of electricity sales at state level, marginal price was used as a proxy for the price variable. The choice of the marginal or average price variable in both the chapters depended upon data availability. In the case of Gujarat, it is possible to use both average price and marginal price. It is interesting to estimate the demand for electricity using a demand function which contains different sets of price variables and observe whether using one of the prices (average or marginal) in the absence of the other will lead in general to an upward bias in the estimate of the price elasticity, if average and marginal price are positively correlated, as is likely to be the case. In this section, we have tried to include an income variable, the electricity tariff charged to electricity consumers i.e. marginal price, and average revenue earned per unit of electricity in Gujarat in one equation. We can observe the effects using the following model.

$$\begin{aligned} \mathrm{Log}(\mathrm{GTsale}_t) = {} & \alpha_{11}\log(\mathrm{SDPg}_t) + \alpha_{21}\log(\mathrm{NCg}_t) + \alpha_{31}\log(\mathrm{MPg}_t) \\ & + \alpha_{41}\log(\mathrm{APg}_t) + \epsilon_{t1} \qquad \ldots\ldots(9.7) \end{aligned}$$

We can also observe the effect of average and marginal price on electricity demand individually in separate equations along with the income variable using the following models.

$$Log(GTsale_t) = \beta_{12}log(SDPg_t) + \beta_{22}log(NCg_t) + \beta_{32}log(MPg_t) + \epsilon_{t2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9.8)$$

$$Log(GTsale_t) = \beta_{13}log(SDPg_t) + \beta_{23}log(NCg_t) + \beta_{33}log(APg_t) + \epsilon_{t3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9.9)$$

where,

$GTsale_t$ = electricity sales in Gujarat in million KWH,

$SDPg_t$ = state domestic product at 1970-71 prices in Gujarat in million rupees,

NCg_t = number of consumers in millions,

MPg_t = marginal price of electricity in paise per KWH, deflated by the wholesale price index (India),

APg_t = average price of electricity in paise per KWH, deflated by the wholesale price index (India),

t = 1,2,...26 for the period 1961 to 1986.

Results.

The parameters of the income variable and number of consumers (See Table IX.1) have the right (i.e. positive) sign as expected in all the three equations. From the t-statistic it can be observed that the values of all the coefficients are significantly different from zero. The values of the parameters of income and number of consumers also are not significantly different in the three equations. In equation 1 the parameter of the marginal price has the wrong sign and that is due to the high correlation between the average price and marginal price. It can be deduced that the absolute value of the parameter of the average price variable decreases if the marginal price variable is eliminated from equation 1. Eliminating the average price from equation 1, i.e, model (9.8), leads to parameter estimates on marginal price which have the right sign and are also statistically significant. It is quite remarkable that the estimated value of the parameter on average price in equation 3,(b_{33}) is almost equal to the sum of the parameters on average price and marginal price from equation 1. In other words, $b_{33} \approx b_{31}+b_{41}$.

Table IX.1

Results of demand function in Gujarat for the period 1961-86.

Equation 1:

$Log(GTsale_t) = b_{11}log(SDPg_t) + b_{21}log(NCg_t) + b31log(APg_t) + b_{41}log(MPg_t) + e_{t1}$.

Equation 2:

$Log(GTsale_t) = b_{12}log(SDPg_t) + b_{22}log(NCg_t) + b_{42}log(MPg_t) + e_{t2}$.

Equation 3:

$Log(GTsale_t) = b_{13}log(SDPg_t) + b_{22}log(NCg_t) + b_{33}log(APg_t) + e_{t3}$.

Equation No. i	Income b_{1i}	Number of Consumers b_{2i}	Average Price b_{3i}	Marginal Price b_{4i}	$\bar{R}^2$	D-W Stat.
1	0.723	0.774	-0.6487	0.3771	0.99	2.1
SE	(0.01)	(0.01)	(0.13)	(0.13)		
T-st.	44.6	47.1	-4.3	2.1		
2	0.733	0.736	-	-0.225	0.99	1.4
SE	(0.02)	(0.02)		(0.08)		
T-st.	34.6	35.9		-2.59		
3	0.712	0.749	-0.32	-	0.99	1.7
SE	(0.01)	(0.01)	(0.06)			
T-st.	42.7	47.2	-4.7			

The parameters on average price have higher t-ratios. Equations 2 and 3 are restricted forms of equation 1. Therefore, we can compare equation 1 with equation 2, and 1 with 3 using an F-test. The results of the F-test show that Equation 1 explains variation in demand better than equation 2 at the 1% significance level, whereas equation 1 is better than 3 only at the 5% significance level. (And comparison of equation 2 and equation 3 is not possible.) Thus, the results which are obtained so far suggest statistical reasons for taking the average price variable over the marginal price variable. Including both the variables, i.e. average and marginal price, leads to biases in the parameter estimates and the parameter of the marginal price variable has the wrong sign. Hence, equation 3 is preferred.

For easy application of the demand function to price determination, the following transformation of equation 3 is useful. We can write the function as,

$$Log(GTsale_t) = 0.7103 log(SDPg_t) + 0.742 log(NCg_t) - 0.3315(NAPg_t/I_t).$$

where,
$NAPg_t$ = the nominal value of average price of electricity and, I_t is the wholesale price index in India.
This implies,

$$log(GTsale_t) = log\ \{(SDPg_t^{b13} * NCg_t^{b23} * I_t^{b33})/NAPg_t^{b33}\}.$$

If we rename, NAPg as P, GTsale as x, and SDPg as Y, we get,

$$x_t = (Y_t^{b13} * NCg_t^{b23} * I_t^{b33}/P_t^{b33})$$

If $Y_t^{b13} * NCg_t^{b23} * I_t^{b33} = A_t$,

we can say that, $P_t = [A_t/x_t]^{1/b33}$ ....(9.10)

A_t serves two purposes. First, it is the shift parameter in the demand function thereby determining the levels of demands in different periods. Secondly it indicates the quantity demanded when nominal price is unity, a fact that is deducible from (9.10).

IX.2 Estimated "optimal" prices.

In this section, we estimate "optimal" electricity prices in Gujarat between 1961 and 1986 given the circumstances under which GEB operated, except, in the main, those arising from distortions in the rest of the economy, that is those which make shadow pricing necessary.

One of the circumstances faced by GEB is the budget constraint recommended by the Government Committee. As discussed in Chapter VII, GEB never actually achieved the return on capital as recommended; in fact the net return was negative for most years. We seek to answer the question: how much should GEB have charged to achieve the targets and should electricity prices have been different even if earning actual profit?[194] The emphasis is on the single-part tariff.

IX.2.1 Single-part Tariff.

A modified form of budget constraint (9.3) is,

$$P(x)x - C(x) - F = \pi^{o} \quad \ldots\ldots\ldots\ldots\ldots\ldots(9.11)$$

where,

$P(x)$ = aggregate demand function,

$C(x)$ = aggregate cost function,

F = total fixed (capacity) cost and,

π^{o} = return on capital target.

In the case of GEB, total revenue consists of the revenue from electricity sales and from other sources as explained in Chapter VII, Section VII.1.3.

Hence the function (9.11) can be further modified as,

$$\{[P(x)x]+OR\} - \{C(x)\} - F = \pi^{o} \ldots\ldots\ldots\ldots\ldots\ldots(9.12)$$

where,

OR = revenue from other sources,

F = fixed costs,

π^{o} = targeted rate of return on capital,

[194] The second aspect of this question is posed in recognition of the fact that more than one price-quantity combination can yield the same profit but different consumer surpluses.

$C(x)$ = operating cost function,

$P(x)$ = price per unit or in other words, the demand function in terms of price. And when $P(x)$ is multiplied with x, it gives us the revenue earned from electricity sales.

The condition for a welfare optimum (from 7.13d), if π^o is a minimum, is

$$\frac{P-C'}{P} = \frac{\lambda}{(1+\lambda)|\epsilon^d|} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9.13)$$

and, if π^o is maximum, the condition is,

$$\frac{P-C'}{P} = \frac{\lambda}{(1-\lambda)|\epsilon^d|} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9.14).$$

where,

ϵ^d is the price elasticity of demand and,

λ is the shadow price of the budget constraint.

In estimating electricity prices, the first step is to substitute GEB's demand and variable cost functions into (9.12) and then solve it for potential outputs. If there is more than one potential output, (9.13) and (9.14) are used to estimate the value of λ for each level of output. λ is estimated by computing price, marginal cost and price elasticity of demand associated with each output and substituting them in either (9.13) or (9.14). The output with the lowest value of λ is that which maximises welfare. If there is one potentially "optimal" output, that output maximises welfare.

Thus, using (9.12), we can derive the level of output first and then, using that level of output, one can derive prices.

Using the transformed demand equation (9.10), and the cost function in (6.3) we can rearrange (9.12) as,

$$\{[(A_t/x)^{1/b33}]*x\} - \{e^{Bt+a2xt}\} = \{\pi^o + F - OR\}\ldots\ldots\ldots\ldots(9.15)$$

Dividing by e^{Bt} we get,

$$\frac{\{[(A_t/x)^{1/b33}]*x\}}{e^{Bt}} - e^{a2xt} = \frac{\{\pi_o + F - OR\}}{e^{Bt}}$$

If we name $\{\pi^o + F - OR\}/e^{Bt} = E$, and $[(A_t)^{1/b33}]/e^{Bt} = G$, we can rewrite as,

$$G*x^{1-1/b33} - e^{a2xt} = E \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(9.16)$$

After rearranging (9.16) and setting $z' = 1-1/b_{33}$,

$$G = Ex^{z'} + x^{z'}e^{a2xt} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9.17)$$

Notice that equation (9.17) is an exponential equation and has a unique solution for x.[195] In order to calculate the output and then prices, we need to first calculate G, and E. To calculate E and G, it is necessary to have knowledge of the parameters, F (fixed costs), OR (revenue from other sources), π^o (expected rate of return), P(x) (the demand function expressed as the price per unit) and C(x) (the variable cost function). The data on revenue from other sources were given in Table VII.3 under the heading (OR) and the data on expected profit are also given in Table VII.3 for expected returns of both 3% and 6% on the "capital base". In the case of a capital-short country like India, the 6% rate of return on capital base is perhaps more appropriate and hence that was used. The total variable cost was also estimated in Chapter VII, Section VII.1.2, and the result is given in equation (7.2). The demand function is estimated in Section IX.1.1, and the result of the third equation can be used to calculate the output and price at the expected rate of return. On the basis of the data on income (Y_t or $SDPg_t$), number of

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[195] It can be proved that the equation has a unique solution. For explanation please refer to the Appendix to Chapter IX.

consumers(NCg_t), and the wholesale price index (I_t) (as shown in Table 1 of Appendix to Chapter IX), and the value of their coefficients as given in Table IX.1 (for the equation 3), we can calculate the demand parameter A_t. Using the calculated value of A_t and e^{Bt}, we can calculate the parameter G. The value of z' can also be calculated using the value of b_{33} from the Table IX.1.

Substituting values of the parameters[196] in equation (9.17), for each year, we can solve for x.[197] Using the value of x for each year (i.e., new level of output, incorporating the target of return on "capital base"), and values of A for each year, and substituting in (9.10), one can derive the "price" that should have been charged in each year. Using the estimated level of output, one can calculate the marginal variable cost. If we add the marginal fixed cost of production (given in Table VII.1b), we have the total marginal costs at the level of output considering the expected return. With LRMC-based pricing, the industry may make losses or profits. The difference between the total marginal costs and the price at the estimated level of output gives us some idea about whether the government was implicitly subsidising or taxing the industry by allowing it to earn the expected return and continue pricing on the basis of long run marginal costs. If the ratio of price to total marginal cost is less than one, the government would have to subsidise the product in order to allow the industry to continue charging on the basis of LRMC, and still earn the expected return. The results for each year are presented in Table 9.1a in Appendix to Chapter IX.

Similarly, using the values of actual profit, one can

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[196] The results of the parameter A, G, and E are given in the Table 1 of the Appendix to Chapter IX.

[197] Though a mathematical solution is not possible, it is possible to solve the equation geometrically.

calculate the values of parameters A, G and E. Substituting the values of the parameters[198] using the actual profit in equation (9.17), one can estimate the level of output and the nominal price that should have been charged to sell that output. Also, the level of total marginal cost at the estimated level output corresponding to the actual return can also be calculated. The results are presented in Table 9.2a in Appendix to Chapter IX.

IX.3 Comparison of electricity prices in Gujarat.

We have not been able to determine optimal prices for the various consumer classes and hence it is not possible to compare these with prices actually charged. But it is true that the arbitrary policy of deciding charges for various consumer groups is unlikely to be optimal and should be dispensed with as much as possible. It results in unintended cross-subsidy as well as random discrimination among consumer groups. Though GEB should charge consumer groups differently, the prices should be determined in such a way that correctly reflects differences in the bases for the distinction. If the bases for distinction are cost, difference in price should reflect differences in cost.

We can compare electricity prices at aggregate level. The market prices, GEB's average prices and corresponding output and marginal (total i.e. variable and fixed) costs are presented in Table IX.2.

We can observe that the market prices are higher than the actual price for the period 1961-86. The estimated output is lower than actual output except for 4 years, i.e., 1965, 1974, 1982 and 1983. Also the marginal cost associated with estimated output is also less than the marginal cost of actual output.

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[198] For the values of the parameters, A, E and G, please refer to Table 2 in the Appendix to Chapter IX.

Table IX.2
Actual and estimated "optimal" prices, output and marginal costs using the target rate of return on capital base (i.e., 6%).

Years	Estimated			Actual		
	output	"optimal" price	marginal cost	Output	Price charged	Marginal Cost
	GWH	Paise per KWH		GWH	Paise per KWH	
	(1)	(2)	(3)	(4)	(5)	(6)
1961	341.461	19.90	5.81	441.14	12.58	5.92
1962	403.376	20.19	6.42	509.02	12.91	6.54
1963	491.978	18.69	5.75	576.63	13.01	5.89
1964	600.038	20.71	7.44	656.81	13.97	7.59
1965	810.176	17.69	6.78	764.14	14.00	6.93
1966	881.761	20.30	8.4	945.32	12.12	8.59
1967	1,034.17	22.00	10.46	1,174.7	12.13	10.69
1968	1,233.92	22.05	10.68	1,403.7	12.04	10.96
1969	1,196.99	25.59	10.05	1,752.1	12.41	10.47
1970	1,497.75	23.34	10.08	2,013.2	12.55	10.56
1971	2,043.67	20.25	10.5	2,346.4	14.01	11.0
1972	2,396.81	20.43	11.42	2,469.5	14.7	11.89
1973	2,201.2	26.45	12.22	2,948.5	15.1	13.14
1974	3,189.04	21.5	13.18	3,144.1	15.97	13.76
1975	3,200.83	24.51	14.17	3,678.0	20.26	15.3
1976	4,015.63	23.35	16.23	3,974.7	21.00	17.1
1977	4,258.73	30.07	21.06	4,692.5	24.68	22.8
1978	4,731.62	32.9	24.17	5,155.1	25.44	26.29
1979	5,342.69	34.61	28.03	5,883.6	27.07	31.02
1980	5,822.87	40.12	32.62	6,243.8	32.78	35.98
1981	6,462.1	42.85	37.85	6,516.7	36.27	41.24
1982	7,447.5	47.05	46.4	7,047.2	44.89	49.15
1983	7,304.9	54.82	52.6	7,240.1	54.68	57.06
1984	7,819.8	60.74	60.23	8,080.4	60.34	68.08
1985	8,443.5	68.22	72.04	8,578.1	65.19	81.1
1986	7,916.6	84.14	80.99	9,015.2	70.04	99.0

Source: Estimated "optimal" output and price are calculated using the method explained in this Chapter. The detailed data are presented in Table 9.1 and 9.1a in Appendix to Chapter IX.

The estimated "optimal" price (column (2)) approached marginal cost (column (3)) over time. The price marginal cost ratio decreased from 2.93 in 1961 to 1.00 in 1984. This implies that, by the marginal cost pricing principle, the distortions resulting from the budget constraint decreased with time. The estimated "optimal" price (column (2)) was greater than the associated marginal cost (column

(3)) except in 1985. The actual price charged (column (5)), exceeded marginal cost (column (6)) up to 1977 and thereafter fell, - implying that, from an initial position of marginal cost pricing, GEB "subsidised" electricity consumers between 1977 and 1986.

What factors prevented GEB from achieving its targets even though the targets were taken into account when determining prices?

One of them could be underestimation of cost. If cost were underestimated and output is not greater than forecast output then a chosen target will not be achieved. The method of trend extrapolation used in making the forecasts may be one of the reasons for costs to be underestimated. A lot of unforeseen events, which do not necessarily cancel out, may affect cost. As shown in Chapter VII, the total operating cost is an exponential function.

The GEB fails to take consideration of demand and cost functions while determining the grand average revenue, and this leads to incorrect estimation of average revenue itself. Also, by predetermining output before price determination, GEB limits the price-output options to one, an option that may never yield the desired target. And even if we assume that the cost and demand functions are rightly considered by GEB in determining the grand total average revenue, mispricing of a given output could be the third alternative reason for GEB not being able to meet the targets.

We fail to isolate the relative importance of the above mentioned factors. But since they all led to underpricing, it can be said that GEB's pricing policy was partly responsible for the consequent net welfare loss. Of course the high system losses also led to financial losses.

Comparison of output and prices using the actual profit earned by GEB.

The estimated "optimal" prices and GEB's charges as well as their associated costs and outputs are presented in Table IX.3. From the table, we can observe that the estimated "optimal" price was consistently greater than the actual price. The optimum output was less than the actual output except in the years 1965, 1972, 1974, 1976, 1982 and 1983.

The estimated "optimal" price approached marginal cost over time. Though the price-marginal cost ratio fluctuated in the period 1961 to 1986, it reached 1 in 1974.

Also, the estimated "optimal" prices were consistently greater than the associated marginal cost till 1984, whereas (as we observed before) the actual price exceeded marginal cost only up to 1977 and fell thereafter.

Thus, we can say that there were a number of faults with GEB's pricing policy. They include the factors on which electricity prices were based, the approach adopted and some of the features of the tariff policy, for example, differential pricing. Also, the prices resulting from GEB's pricing policy were in most cases different from what they were intended to be, judging from the disparity between the targets and the actual return the GEB earned. Though we could not figure out the amount of welfare loss to society, there is no doubt regarding the existence of welfare loss as a result of failure to meet the targets.

The major factors responsible for the present financial status of GEB were: incorrect output estimation, underestimation of costs and failure to reduce system losses.

In Chapter VII, GEB's pricing policy between 1961 and 1986 was examined in terms of the bases of tariff policy, the approach adopted and the tariff that prevailed. On the bases of tariff policy, it was indicated that four main factors dominated GEB's pricing policy in the period.

Table IX.3
Actual and estimated "optimal" prices, output and marginal costs using the actual return on capital base.

Years	Estimated			Actual		
	Output	"Optimal" Price	Marginal Cost	Output	Price	Marginal Cost
	GWH	Paise per KWH		GWH	Paise per KWH	
	(1)	(2)	(3)	(4)	(5)	(6)
1961	385.09	13.61	5.9	441.14	12.58	5.92
1962	466.41	12.76	6.52	509.02	12.91	6.54
1963	578.26	11.22	5.87	576.63	13.01	5.89
1964	745.97	10.4	7.58	656.81	13.97	7.59
1965	990.64	09.37	6.94	764.14	14.00	6.93
1966	1,065.25	11.17	8.58	945.32	12.12	8.59
1967	1,353.54	09.40	10.69	1,174.7	12.13	10.69
1968	1,627.87	09.19	10.97	1,403.7	12.04	10.96
1969	1,480.05	13.09	10.32	1,752.1	12.41	10.47
1970	1,828.41	12.43	10.42	2,013.2	12.55	10.56
1971	2,491.0	10.83	10.97	2,346.4	14.01	11.0
1972	2,757.9	13.11	11.93	2,469.5	14.7	11.89
1973	2,553.33	16.55	12.74	2,948.5	15.1	13.14
1974	3,643.58	14.11	13.98	3,144.1	15.97	13.76
1975	3,695.11	15.57	15.08	3,678.0	20.26	15.3
1976	4,561.12	15.61	17.51	3,974.7	21.00	17.1
1977	4,602.38	23.53	22.25	4,692.5	24.68	22.8
1978	5,025.67	27.19	25.52	5,155.1	25.44	26.29
1979	5,819.32	26.41	30.15	5,883.6	27.07	31.02
1980	6,326.05	30.87	35.31	6,243.8	32.78	35.98
1981	7,149.5	31.13	42.39	6,516.7	36.27	41.24
1982	7,765.76	41.22	50.92	7,047.2	44.89	49.15
1983	7,727.01	45.9	57.84	7,240.1	54.68	57.06
1984	8,110.77	54.11	65.89	8,080.4	60.34	68.08
1985	8,968.08	56.39	81.26	8,578.1	65.19	81.1
1986	8,773.14	60.82	92.81	9,015.2	70.04	99.0

Source: Estimated output and price are calculated using the method explained in this Chapter. The detailed data are presented in Table 9.1 and 9.1a in Appendix to Chapter IX.

The first is the total cost of operation but the actual cost did not lead to full cost recovery. The second is the capacity constraint and the "demand" for electricity. The interesting point here is that GEB's demand concept was strictly speaking not demand at all since it was based on trend extrapolation and these were independent of price. Putting it differently, electricity demand was assumed to be perfectly inelastic with respect to price. Also, the lack of awareness of demand in the absence of a supply constraint leads to underestimation/ overestimation of demand. The other factors were the financial target as recommended by the Energy Survey of India Committee (1964), the Committee on Power (1980) and the prevailing administrative framework.

GEB's approach to pricing could have been based on a two-stage procedure. The first stage involved the use of the budget constraint to determine the desired average revenue for the industry and for each year in a chosen planning period. In doing so, the cost of operation and electricity sales were both predetermined by GEB. The second stage involved the structuring of electricity prices among the various consumer classes such that the average of the prices equalled the desired grand average revenue. It is useful to determine the general conditions under which a financial constraint approach would lead to an "optimal" policy. Since the disaggregation is immaterial here, the model can be given by,

$$\text{Max} \quad W = S(P) + R - C^{m}(X) \quad \ldots\ldots\ldots\ldots\ldots\ldots(9.18)$$

$$\text{s.t. } (1) \; X \leq X \quad \ldots\ldots\ldots\ldots\ldots\ldots(9.19)$$

$$(2) \; R - C^{m}(X) = PX - C^{m}(X) = \pi^{o} \quad \ldots\ldots(9.20)$$

where P, X and X are price, output supplied and capacity output respectively, R is revenue, C^{m} is the minimum cost incurred in earning the revenue, π^{o} is the profit target, W is welfare and S is the consumers' surplus. GEB's pricing methodology is appropriate if the following conditions hold. The first is that the consumers' surplus [S] must be constant, for example, equal to zero. In that case, the producer's surplus (R - C) is constant and captured by the financial constraint. On a more general note, the condition is that GEB's objectives are irrelevant, or more specifically, that there is no welfare motivation. The second condition derives from the fact that in (9.20), there are two unknowns (P,X) but one equation. Thus, to determine price from (9.20), we require output to be fixed and or predetermined. The capacity constraint in (9.19) can be incorporated by using it partly to predetermine output.

So one could say that GEB's approach assumes that (1) there are no objectives and (2) output is fixed or predetermined and, therefore, independent of price. Even if we continue to assume that the output is given, the prices on the basis of given output could be derived as,

$$R - C^m(X) = PX - C^m(X) = \pi^o \quad ......(9.20)$$

Since, GEB earns revenue from other sources, we need to incorporate OR in the equation,

$$[PX + OR] - C^m(X) = \pi^o \quad ....(9.21)$$

Solving for P,

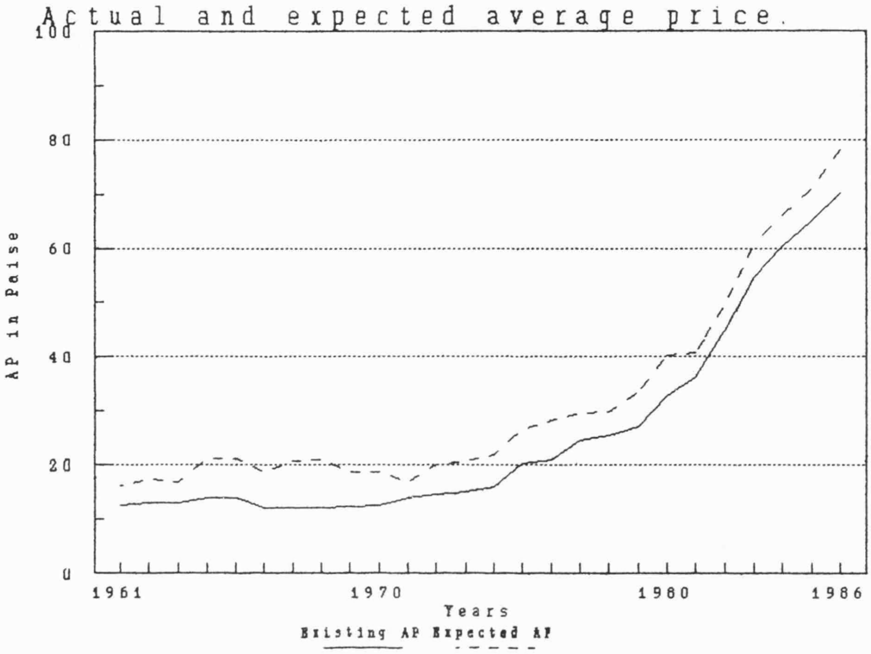
$$P= \frac{[\pi^o + C^m] - OR}{X} \quad ....(9.22)$$

One can derive prices using this simple approach assuming that the output is predetermined.

The prices that we derived using this simple approach and the prices charged by GEB, can be compared in Graph IX.1. We can observe that the estimated prices were higher than the prices charged by GEB.

Both assumptions in fact summarise important results in the analysis of the bases of GEB's pricing policy. The implication is that GEB's financial constraint approach is largely a by-product of the criteria on which its pricing policies are based. Since the assumptions (or at least one of them) are untenable, the financial constraint approach is unlikely to lead to an optimal pricing policy.

Graph IX.1



IX.4 Conclusion.

The comparison of estimated prices and the price charged suggested mispricing. Also, comparison of estimated price under the assumption that output is predetermined, and the price charged, indicated the same. This estimation of prices in this study is based on restrictive assumptions. It is important to take into consideration the real value of assets and not historical values, inflation, the social opportunity cost of capital, and shadow prices of fuel. It is also important to take into consideration the cost of each plant, the cost of generating electricity at different times of day on the basis of using different plants in increasing order of cost i.e., the plant that generates electricity at the lowest unit cost is used the first and so on. It would be important to know the cost of providing electricity by consumer group at different times of day. It should be noted that these important aspects were not incorporated in this study due to the lack of detailed data, required time and finance. But considering the technological advancement in the field of computer packages to-day, if reliable data were available, and the finance to compile the data on the sophisticated computer packages were available, it is possible to work out an LRMC based tariff for different consumer groups at different times of the day. The main consideration in doing so, would be again the ability of the supply system to implement the recommended tariff at little/no extra cost. Considering this fact and the limitations on the resources, time and ability to get the data, though this study is restricted, it gives a guideline to the supply system regarding the lower bound of the average revenue that it is necessary to earn. Also, although this study is restricted to Gujarat State, any State Electricity Board in India, may, of course, use a similar method.

Appendix to Chapter IX.

Explanation of the data used.

Total electricity sales in Gujarat:($GTsale_t$).

The data on electricity demand by all consumers include electricity sales to all consumers by Gujarat Electricity Board. We need to keep in mind that this is not the demand. In India, as we have seen in Chapter IV and V, the frequency of electricity cuts (planned and unplanned), have been increasing. Gujarat is no exception to this phenomenon and hence it is important to realise that electricity demand could be higher than sales. The data were collected from Gujarat Electricity Board.

Real average price of electricity in Gujarat:(APg_t).

Data on total revenue earned on electricity sales every year were collected from the Gujarat Electricity Board. The revenue earned from electricity sales in any particular year was divided by the electricity sales in that year to get average revenue earned per unit of electricity sold. The series of average revenue earned for the years 1961 to 1986 was taken as a proxy for average price of electricity in the state. The series of average revenue earned was deflated by the wholesale price index (All India) to get the real average price of electricity in the state.

Real marginal price of electricity in Gujarat:(MPg_t).

Different consumer groups in Gujarat were charged a different set of tariff schedules. In order to compare the tariff charged to different consumer groups in various states each state electricity board is asked to send an indicative tariff charged to different consumers to the Central Electricity Authority. For this purpose, GEB uses the tariff charged to different consumer group in its tariff schedule. Similarly in order to compare the tariff charged to all consumers in different states, a weighted average of the tariffs charged to all consumers was prepared by GEB. This weighted average of tariff charged to all consumers was taken as a proxy for marginal price charged to electricity consumers. The series on marginal price for the years 1961 to 1986 was deflated by the wholesale price index in India to get the real marginal price charged to electricity consumers in Gujarat.

Number of consumers in Gujarat:(NCg_t).

The number of consumers include all the consumers served by the Gujarat Electricity Board. The data on the number of consumers for the years 1961-86 were collected from GEB. The number of consumers do not indicate the potential number of consumers; rather it indicates only the connected number of consumers.

Uniqueness of Root of the equation.

Given a function $f(x) = 0$, it has a unique root over $a \le x \le b$ if and only if following conditions are true:

(1) $f(x)$ is continuous over $a \le x \le b$.
(2) $f(a)$ has opposite sign than $f(b)$.
(3) $f'(x)$ is not zero in $a \le x \le b$.

Now in our case,

$$f(x) = x^{z'}e^{a2x} + x^{z'}E - G = 0. \text{ And } 0 \le x \le \infty.$$

We can observe from $f(x)$ that it is a continuous, exponential function. To satisfy condition (2), we compute $f(0)$ and $f(\infty)$,

$$f(0) = -G \text{ and } f(\infty) = +\infty.$$

So condition (2) is also satisfied. And $f(x)$ has at least one root in the interval $0 \le x \le \infty$.

To check the third condition,

$$f'(x) = z'x^{z'-1}e^{a2x} + x^{z'}a_2e^{a2x} + z'x^{z'-1}E.$$

Let $z' = -(b_1+1)/b_1$, and $b1 = -0.3165$ (from our demand equation). Therefore, $z' = 2.16$. Thus,

$$f'(x) = 2.16x^{1.16}e^{a2x} + x^{2.16}a_2e^{a2x} + 2.16x^{1.16}E.$$

Given that $E>0$, $a_2>0$ and $x>0$($x>0$, because the shift parameter i.e. the income, number of consumers are always positive), we can conclude that $f'(x) \neq 0$ in the interval $0 \le x \le \infty$.

Hence, $f(x)=0$, has only one root in the interval $0 \le x \le \infty$. Thus, the equation has only one solution for x.

Results.

Table 9.1

The value of the parameter A, G and E using the expected rate of return as 6%.

Years	A_t	G_t in million	E_t
1961	0.00488148	0.594296	0.958359
1962	0.00411313	0.886690	1.03135
1963	0.00345564	1.335180	0.977128
1964	0.00274327	2.40481	1.31507
1965	0.00213542	4.60846	1.28579
1966	0.00187844	6.00163	1.47817
1967	0.00156135	9.3484	1.72434
1968	0.00130759	14.2191	1.80174
1969	0.00128602	13.0157	1.74052
1970	0.00105806	20.9392	1.66183
1971	0.00081113	42.11115	1.6395
1972	0.000689638	61.0686	1.65117
1973	0.000692003	52.4668	1.79124
1974	0.000510054	119.472	1.64822
1975	0.000487536	119.67	1.62508
1976	0.000394628	202.701	1.54513
1977	0.000343437	273.068	2.10394
1978	0.000300451	361.844	2.19096
1979	0.000261875	485.121	2.1355
1980	0.000229304	641.009	2.39653
1981	0.000202352	826.428	2.30686
1982	0.000170464	1,233.9	2.39047
1983	0.000165579	1,174.73	2.41233
1984	0.000149742	1,401.71	2.34426
1985	0.000133674	1,742.5	2.33664
1986	0.000133411	1,522.81	2.61705

Note: The demand function (8.9) and cost function (6.3) were used. The data on the variables like income, number of consumers, wholesale price index are given in the Appendix to Chapter IX. The values of B_t were taken from Table (VII.2). The expected return on capital[(the rate of return as 3% till 1980, column (7) of Table VII.3, and 6% from 1981 column (8) of Table (VII.3)], revenue from other sources [column (3) of Table (VII.3)], total fixed costs [from Table VII.1a]. Using these data and the computer program to solve the equation we have obtained this result.

Table 9.1a
The estimated level of output and price using the expected return, the marginal variable cost based on the estimated output, the marginal fixed cost (= AFCS in Table VII.1b), the ratio of total marginal cost and the price.

Year	X1 MKWH	Pn1 Paise/KWH	MVCe1 Paise	MFC = AFCS	MTC1 (MVCE1+MFC)	Ratio (Pn1:MTC1)	λ Shadow price of budget constraint.
1961	341.46	19.9029	00.48	5.31	05.81	3.42	0.2889
1962	403.376	20.1961	00.57	5.83	06.42	3.14	0.2754
1963	491.978	18.6983	00.67	5.06	05.75	3.25	0.2806
1964	600.038	20.7073	00.79	6.63	07.44	2.78	0.2543
1965	810.176	17.6939	00.94	5.81	06.78	2.61	0.2427
1966	881.761	20.3045	01.11	7.27	08.40	2.41	0.2278
1967	1,034.17	22.005	01.32	9.11	10.46	2.1	0.1992
1968	1,233.92	22.0584	01.52	9.08	10.68	2.06	0.1950
1969	1,196.99	25.5914	01.82	8.19	10.05	2.54	0.238
1970	1,497.75	23.3479	02.89	7.84	10.08	2.31	0.2193
1971	2,043.67	20.2524	02.72	7.71	10.50	1.92	0.1799
1972	2,396.81	20.4367	03.31	8.03	11.42	1.78	0.1623
1973	2,201.2	26.4568	03.76	8.38	12.22	2.16	0.2052
1974	3,189.04	21.5011	04.92	8.12	13.18	1.63	0.1392
1975	3,200.83	24.5107	05.73	8.28	14.17	1.73	0.1542
1976	4,015.63	23.3492	07.36	8.65	16.23	1.43	0.1068
1977	4,258.73	30.0796	08.82	11.99	21.06	1.42	0.1048
1978	4,731.62	32.9056	10.86	12.97	24.17	1.36	0.0917
1979	5,342.69	34.6074	13.6	13.97	28.03	1.23	0.0640
1980	5,822.87	40.1164	16.76	15.28	32.62	1.22	0.0629
1981	6,462.1	42.852	21.07	16.44	37.85	1.13	0.0383
1982	7,447.52	47.047	27.6	18.29	46.4	1.01	0.0043
1983	7,304.95	54.8214	31.56	20.5	52.6	1.04	0.013
1984	7,819.83	60.7356	39.07	20.48	60.23	1.00	0.0026
1985	8,443.46	68.2194	49.00	22.15	72.04	0.95	-0.018
1986	7,916.64	84.1434	53.48	26.67	80.99	1.03	0.012

Source: Calculated on the basis of the data presented in Table 9.1.

Table 9.2
The value of the parameter A, G and E using the actual rate of return.

Years	A_t	G_t in million	E_t
1961	0.00488148	0.594296	0.492042
1962	0.00411313	0.88669	0.458408
1963	0.00345564	1.33518	0.359091
1964	0.00274327	2.40481	0.388767
1965	0.00213542	4.60846	0.406111
1966	0.00187844	6.00163	0.570402
1967	0.00156135	9.3484	0.395905
1968	0.00130759	14.2191	0.379986
1969	0.00128602	13.0157	0.612076
1970	0.00105806	20.9392	0.582703
1971	0.00081113	42.1115	0.508909
1972	0.000689638	61.0686	0.771131
1973	0.000692003	52.4668	0.848761
1974	0.000510054	119.472	0.727729
1975	0.000487536	119.67	0.646113
1976	0.000394628	202.701	0.59132
1977	0.000343437	273.068	1.39546
1978	0.000300451	361.844	1.59172
1979	0.000261875	485.121	1.24962
1980	0.000229304	641.009	1.44055
1981	0.000202352	826.428	1.07735
1982	0.000170464	1,233.9	1.78537
1983	0.000165579	1,174.73	1.61871
1984	0.000149742	1,401.71	1.79177
1985	0.000133674	1,742.5	1.35724
1986	0.000133411	1,522.81	1.03775

Table 9.2a
The estimated level of output and price using the actual return, the marginal variable cost based on the estimated output, the marginal fixed cost (= AFCS in Table VII.1b), the ratio of total marginal cost and the price.

Year	X2 MKWH	Pn2 Paise/KWH	MVCe2 Paise	MFC = AFCS Paise	MTC2 (MVCE1+MFC) Paise	Ratio (Pn2:MTC2)	λ Shadow Price of budget constraint.
1961	385.09	13.6119	0.607	5.31	5.90	2.31	0.69
1962	466.41	12.7654	0.707	5.83	6.52	1.96	0.58
1963	578.25	11.2223	0.822	5.06	5.87	1.91	0.56
1964	745.972	10.4089	0.958	6.63	7.58	1.37	0.3
1965	990.613	09.3729	1.12	5.81	6.94	1.35	0.28
1966	1,065.25	11.1735	1.32	7.27	8.58	1.3	0.25
1967	1,353.54	09.4024	1.58	9.11	10.69	0.87	0.13
1968	1,627.87	19.1912	1.88	9.08	10.97	0.83	0.18
1969	1,480.05	13.0867	2.27	8.19	10.32	1.27	0.22
1970	1,828.41	12.4314	2.72	7.84	10.42	1.19	0.17
1971	2,491.0	10.836	3.29	7.71	10.97	0.99	0.01
1972	2,757.94	13.1169	3.86	8.03	11.93	1.09	0.09
1973	2,553.33	16.5542	4.76	8.38	12.74	1.3	0.24
1974	3,643.58	14.1131	5.64	8.12	13.98	1.00	0.009
1975	3,695.11	15.5708	7.03	8.28	15.08	1.03	0.03
1976	4,561.12	15.6132	8.45	8.65	17.51	0.89	0.11
1977	4,602.38	23.5389	10.81	11.99	22.25	1.06	0.05
1978	5,025.67	27.1983	13.31	12.97	25.52	1.06	0.06
1979	5,819.32	26.4186	17.05	13.97	30.15	0.88	0.13
1980	6,326.05	30.8739	20.7	15.28	35.31	0.87	0.014
1981	7,149.5	31.1359	24.8	16.44	42.39	0.73	0.32
1982	7,765.76	41.2206	30.87	18.29	50.92	0.81	0.21
1983	7,727.01	45.9067	36.56	20.50	57.84	0.79	0.24
1984	8,110.77	54.115	47.6	20.48	65.89	0.82	0.2
1985	8,968.09	56.3888	58.94	22.15	81.26	0.69	0.38
1986	8,773.14	60.8219	72.35	26.67	92.81	0.65	0.45

Source: Calculated on the basis of the data presented in Table 9.2.

Data used.

Table 1.
Data used for the estimation of the demand function.

Year	GTsale	SDPg	NCg	PN	I
1961	441.0	14,054.2	0.1403	0.1258	0.9984
1962	509.0	15,461.5	0.1666	0.1291	1.0000
1963	577.0	15,340.1	0.2047	0.1301	1.038
1964	657.0	16,358.7	0.2507	0.1397	0.102
1965	764.0	17,796.9	0.3164	0.1400	1.223
1966	945.0	16,519.4	0.3897	0.1212	1.316
1967	1,175.0	16,933.8	0.4526	0.1213	1.499
1968	1,404.0	18,535.8	0.5077	0.1204	1.673
1969	1,752.0	17,253.5	0.559	0.1241	1.654
1970	2,013.0	18,990.1	0.6416	0.1255	1.716
1971	2,346.0	21,892.4	0.7822	0.1401	1.811
1972	2,469.0	22,561.8	0.9258	0.1470	1.9124
1973	2,949.0	18,005.0	1.0994	0.1510	2.1044
1974	3,144.0	22,022.2	1.2534	0.1597	2.53
1975	3,678.0	18,980.7	1.3945	0.2026	3.1674
1976	3,974.0	24,391.9	1.4634	0.2158	3.133
1977	4,692.0	25,973.8	1.6409	0.2468	3.1982
1978	5,155.0	27,604.7	1.8171	0.2544	3.3648
1979	5,883.0	29,215.5	2.0639	0.2707	3.3648
1980	6,243.0	29,244.9	2.301	0.3278	3.9407
1981	6,516.0	30,400.0	2.439	0.3627	4.6597
1982	7,047.0	33,824.0	2.6718	0.4489	5.0943
1983	7,240.0	32,620.6	2.8403	0.5468	5.2284
1984	8,080.0	33,144.2	3.0841	0.6034	5.7228
1985	8,578.0	34,610.0	3.3438	0.6519	6.1284
1986	9,015.0	31,107.8	3.6223	0.7004	6.4798

Note: GTsale = Total Electricity Sales in Million KWH in Gujrat, SDPg = State Domestic product in Gujarat in Million Rupees, at 1970-71 prices. NCg = Number of electricity consumers in Gujarat in million.
Pn = Nominal price of electricity in Rupees per unit (i.e.KWH).
I = Wholesale Price Index at all India; 1962 = 1.

Source: Personally collected from unpublished sources at Gujarat Electricity Board.

CONCLUSION.

The organisational structure of the electricity industry changed substantially after Independence. The ownership and control of the industry moved from the private sector to the public sector. The industry grew at a fast rate. Installed capacity increased fast, as a result of availability of capital in the public sector. Having created the capacity to generate electricity various incentives were given to increase electricity demand (KWH). Hence KWH sales also grew rapidly. In fact the KWH sales grew so fast over the period that the capacity was not enough to fulfil the growing demand. Thus electricity cuts became a predominant feature of the electricity industry in the later period (i.e., mainly after 1972). The change in the control of the industry did not affect the diversity of the regions. Despite the difference in the ownership, the difference in per capita consumption of electricity of different regions still prevails. High system losses also continued till 1986.

One of the expected benefits of the change in control and ownership of the plants was to protect consumers' interests. But from the frequent electricity cuts (i.e., brown-outs and black-outs), it is self evident that the neglect of consumers' interests did not change much. The electricity cuts led to one more problem. Electricity utilities did not know the true/spontaneous electricity demand (KWH). This led to problems in planning the additional capacity. We had to use the data on electricity sales in our analysis.

In our attempts to study the reasons for the observed fast growth of electricity sales, the need to study different consumer groups was realised. Also the need to observe the effects of independent variables in two sub-periods (i.e. before and after obvious electricity cuts) ?

was realised. Comparing the effects of income and price on three different consumer groups at all-India level, the income elasticity of industrial consumers was found to be higher than the agricultural and 'other' consumers. Comparing the sub-periods, it was observed that in the first sub-period the income elasticity was higher (in the case of those consumers where the effects of independent variables was different in two periods i.e., per capita sales and industrial consumers) than in the second sub-period. High income elasticity suggests that the electricity demand (KWH) may continue to grow at a faster rate than the growth in income. As far as the price elasticity were concerned, it was negligible in the case of 'other' consumers, and it was the highest in the case of industrial consumers. Comparing the price elasticity in the sub-periods, the price elasticity in the second period is not different from zero. This indicates that with the existing pricing policy it would not be possible to use price as a tool to manage electricity demand.

Due to differences in the combination of economic activities, income, plant mix in different regions of a vast country like India, it was important to study electricity demand at state-level. Like at all-India level, we found high income elasticities and low price elasticities also at state-level. Despite the differences between the four states in our sample, we gathered that the agricultural consumers were more sensitive to changes in price and income than industrial consumers. There was a case of positive price elasticity suggesting possibilities of mispricing. Thus, high income elasticities at state-level indicate that electricity demand would continue to grow fast. Since the pricing policy was different in four states it is difficult to generalise on price effects. It is also not possible to say anything about the states' ability to manage demand at different time of the day.

On the basis of the study for only one state, it can be said that pricing as an instrument was not properly used by the (Gujarat) State Electricity Board. The public electric utility failed to spread awareness amongst its consumers regarding the true cost of electricity at different times of the day. The State Electricity Board might have been affected in two ways: firstly in reliability, and secondly in its financial performance. The demand during the peak increased faster than at off-peak periods. The utility failed to supply electricity at the peak and as a result the consumers had to experience inconvenience and/or loss in production. The lack of reliability in this manner led many consumers (mainly industrial units) to invest in their own generating sets.

From the financial performance of one electricity board (Gujarat Electricity Board), it was observed that though they were expected to cover full (historical) cost of supply; Gujarat Electricity Board failed to do so. When on historical costs it was making a loss, it would have made a huge loss on replacement cost. Therefore tariffs were a lot less than average, up-to-date accounting costs, and there is a strong presumption that tariffs were less than marginal economic costs.

Observing particular features of tariff structure, the following points were thought to be noteworthy.

1) The classification of consumers and the structure of tariffs to various consumers were found to be extraordinarily complex. One reason for complexities in the administrative structure could be in the simple form of metering. In the absence of time-of-day metering it is possible that the classification of consumers would be such that it can capture similarities amongst consumers and charge the same rate.

2) Gujarat Electricity Board offers block tariffs. It charges decreasing block tariffs and it was observed in

Chapter VII[199] that though there are several reasons in defence of such a tariff, in a situation where there is no excess supply any policy that promotes sales is not rational. It is difficult to justify decreasing block tariff.

3) Gujarat Electricity Board's tariffs are characterised by differential pricing across consumer groups and differences in charges should reflect only differences in cost and demand. Costs varies across consumer groups mainly because consumers are supplied at different voltage and at different times of the day. Gujarat Electricity Board's multi-part tariff is very complex. Firstly, charges are divided into two, namely power demand charge (or capacity charge) and energy charge (or operating charge). Secondly, for most of consumers, both the charges are further broken down into a fixed charge (or minimum charge) and a set of variable charges. Thirdly, the fixed and variable charges vary across consumer groups.

Thus, not only was the level of electricity price too low, but the tariff structure was also not based on appropriate concepts.

In our attempts to design a level of price on the basis of cost and demand functions of Gujarat Electricity Board, it was found that, at aggregate level, given GEB's targets, the estimated "optimal" price of electricity in each year between 1961 and 1986 was higher than the actual price. There are two cases of mispricing. The first case of mispricing arises because of GEB's failure to take cognizance of the aggregate demand and cost functions when determining the desired average revenue. The second is mispricing of a given output.

Though the estimated electricity price in this study is based on aggregate demand and cost functions and that it

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[199] Chapter VII, page 287.

is too simplistic it is possible to derive the prices at disaggregate level by extending the same basic model. But the determination of price differentials among consumer groups should be based on the groups' demand and cost functions. Though this is a case of only one State Electricity Board and the conclusions cannot be generalised for all states, it remains important for all states to design a pricing policy that allows the consumer to be aware of the costs and help State Electricity Board to eliminate financial losses.

BIBLIOGRAPHY

GOVERNMENT DOCUMENTS.

Census of India, Report on Bengal, Bihar, Orissa and Sikkim, Volume V, (New Delhi, 1911).

Government of India, Electrical undertakings in India, Corrected up to 1912, 1913 and 1918, (Calcutta).

Government of India, Report on Electric Power (Protective Clauses), (India, 1893).

Government of India, Public Works and Electric Power, Record of the 1st and 2nd meetings of Policy Committee no. 3c, Reconstruction Committee of Council held in October 1943, February 1945, (New Delhi, 1945).

Government of India, Department of Works, mines and Power, Report of the Advisory Board on the Principles for the control of public utility electricity finance, (Delhi, 1947).

Government of India, Rules regulating the generation, transmission, supply and use of electrical energy, by Public Works Department, Issued on 23 December, 1910, (Calcutta, 1911).

Government of India, Report of the Advisory Board on the Principles for the control of public utility electricity finance, Department of Works, mines and Power, (Delhi, 1947).

Government of India, Report by Calcutta Electric Supply Corporation charges Enquiry Committee, (India, 1935-36).

Government of India, Report by Delhi Electric Supply Enquiry Committee, (India, 1936).

Government of India, Report on Electrical Energy (Generating Stations and Supply), (India, 1898).

Government of India, Advisory Board on Energy, Towards a perspective on Energy demand and supply in India in 2004/05, (New Delhi, May 1985).

Government of India, Ministry of Energy, Department of Power, Report of the Committee on Power, (New Delhi, 1980).

Government of India, Ministry of Irrigation and Power, Report of the Power Economy Committee, (New Delhi, 1971).

Government of India, Ministry of Energy, Report of the Fuel Policy Committee, Also known as Chakravarti Committee Report, (New Delhi, 1974).

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

Government of India, Central Electricity Authority, Public Electricity Supply - All India Statistics, (New Delhi, 1947-87).

Government of India, Electrical Undertakings in India, Corrected up to 1930, 1932, 1934, (Lahore 1030-1934).

Government of India, Planning Commission, Second Five-Year Plan, (New Delhi, 1956).

Government of India, Report by Delhi Electric Supply Enquiry Committee, (India, 1936).

Gujarat Electricity Board, The Annual Statement of Accounts, (Baroda, 1961-88).

Gujarat Electricity Board, Tariffs For Supply of Electricity, (Baroda, 1981), p.12.

Power Finance Corporation Ltd. and Tata Energy Research Institute, Seminar on Financial Performance of State Electricity Boards, 20-21 February, 1989, (New Delhi, 1989), p.20.

Reserve Bank of India, "Agriculture productivity in Eastern India" in the Report of the Committee on Agricultural productivity in Eastern India, (New Delhi, 1984), Volume II, pp 251.

ARTICLES

Alexander Barbara J., "The Welfare Analysis Approach to the Time-of-day Pricing Decision", Public Utilities Fortnightly, (December 4, 1980), pp.26-32.

Anderson Kent P., "Residential Demand for Electricity Econometric Estimates for California and the U.S.", Journal of Business, V.46, n.4, (Oct. 1973), pp.526-553.

Andersson Roland, "Electricity Tariffs in Sweden: A Reply", Energy Economics, V.8, n.1, (Jan. 1986), pp.54-56.

Andersson Roland, "Electricity Tariffs in Sweden", Energy Economics, V.6, n.2, (April 1984), pp.122-130.

Archibald Robert B., Finifter David H. and Moody Carlisle E. Jr., "Seasonal Variation in Residential Electricity Demand: Evidence from Survey Data", Applied Economics, V.14, n.2, (April 1982), pp.167-181.

Asplund Rita, "Residential Demand for Electric Space Heating in Finland", European Economic Review, V.31, n.5, (July 1987), pp.981-993.

Baestra P. and Nerlove M., "Pooling Cross Section and Time series Data in the Estimation of a dynamic Model: The demand for Natural Gas", Econometrica, 34, (1969), pp.585-612.

Bagchi Amiya, "Foreign Capital and Economic development in India:A Schematic View", in K.Gough and H.P.Sharma(ed). Imperialism and revolution in South Asia, (1973).

Barnes Roberta, Gillingham Robert and Hagemann Robert, "The Short-Term Residential Demand for Electricity", Review of Economics and Statistics, V.63, n.4, (Nov. 1981), pp.541-552.

Battalio Raymond C, Kagel John H., Winkler Robin C., and Winett Richard A., "Residential Electricity Demand: An Experimental Study", Review of Economics and Statistics, V.61, n.2, (May 1979), pp.180-189.

Baumol W. and Bradford D.F., "Optimal Departures from Marginal Cost Pricing", American Economic Review, Vol.60, (June, 1970), pp.129-142.

Baxter R.E. and Rees R., "Analysis of the Industrial demand for Electricity", Economic Journal, vol. 78, (June 1968), pp.277-298.

Berndt Ernst R. and Samaniego Ricardo, "Residential Electricity Demand in Mexico: A Model Distinguishing Access from Consumption", Land Economics, V.60, n.3, (Aug. 1984), pp.268-277.

Bosworth Derek and Pugh Clive, "Industrial and Commercial Demand for Electricity by Time of Day", The Energy Journal, Vol.6, No.3, (1985), pp.101-107.

Box G.E.P. and Cox D.R., "An Analysis of Transformations", Journal of the Royal Asiatic Society, Series B, Vol.26, No.2, (1964), pp.211-243.

Buglass Karen, "How to Forcast Demand for Electricity", American Demographics, V.9, n.10, (Oct. 1987), pp.58-60.

Cargill T.P. and Meyer R.A., "Estimating the Demand for

Electricity by Time-of-Day", Applied Economics, Vol.3, No.4 (December 1971), pp.233-246.

Chamberlin Edward, Theory of monopolistic competition, First ed., (Cambridge, 1933), pp.10-77.

Chang H.S. and Chern Wen S., "A Study on the Demand for Electricity and the Variation in the Price Elasticity for Manufacturing Industries", Journal of Economics and Business, V.33, n.2, (Winter 1981), pp.122-131.

Chern Wen S. and Bouis Howarth E., "Structural Changes in Residential Electricity Demand", Energy Economics, V.10, n.3, (July 1988), pp.213-222.

Chung Chinbang and Aigner Dennis J., "Industrial and Commercial Demand for Electricity by Time-of-Day: A California Case Study", Energy Journal, V.2, n.3, (July 1981), pp.91-110.

Cicchetti Charles J., "The Design of Electricity Tariffs", Public Utilities Fortnightly, V.96, n.5, (Aug. 28, 1975), pp.25-33.

Clapham J.H., "Of Empty Economic Boxes", Economic Journal, Vol.XXXII, (1922), pp.305-14.

Clemens E.W., "Price discrimination in decreasing cost industries", American Economic Review, Vol.31, (1941), pp.794-802.

Davis Patricia A., "Time-of-use Electrical Demand Pricing", Public Utilities Fortnightly, V.106, n.12, (Dec. 4, 1980), pp.23-25.

Dennerlein Rudolf K. H., "Residential Demand for Electrical Appliances and Electricity in the Federal Republic of Germany", Energy Journal, V.8, n.1, (Jan. 1987), pp.69-86.

Dickinson H.D., "Price Formation in a Socialist Community", Economic Journal, Vol.XLIII, (1933), pp.237-50.

Dobesh Larry J. and Kauffman Richard V., "Service Area and Jurisdictional Variations in Factors Influencing Residential Electric Demand", Public Utilities Fortnightly, V.110, n.3, (Aug. 1982), pp.33-38.

Donnelly W. A. and Diesendorf M., "Variable Elasticity Models for Electricity Demand", Energy Economics, V.7, n.3, (July 1985), pp.159-162.

Fraser L.M., "Taxation and Returns", Review of Economic Studies, Vol.I, (1933-34), pp.45-59.

Frisch Ragnar, "The Dupuit taxation theorem", Econometrica, Vol.7, (1939), pp.145-50.

Garbacz Christopher, "Electricity Demand and the Elasticity of Intra-Marginal Price", Applied Economics, V.15, n.5, (Oct. 1983), pp.699-701.

Garbacz Christopher, "Seasonal and Regional Residential Electricity Demand", Energy Journal, V.7, n.2, (April 1986), pp.121-134.

Garbacz Christopher, "A National Micro-Data Based Model of Residential Electricity Demand: New Evidence on Seasonal Variation", Southern Economic Journal, V.51, n.1, (July 1984), pp.235-249.

Garbacz Christopher and Roth T. P., "Electricity Demand and the Elasticity of Intra-Marginal Price/Electricity Demand Estimation Using Proxy Variables: Some Reservations", Applied Economics, V.15, n.5, (Oct. 1983), pp.699-701.

Garbacz Christopher, "A Model of Residential Demand for Electricity Uing a National Household Sample", Energy Economics, V.5, n.2, (April 1983), pp.124-128.

Garbacz Christopher, "Residential Electricity Demand: A Suggested Appliance Stock Equation", Energy Journal, V.5, n.2, (April 1984), pp.151-154.

Glakpe Emmanuel and Fazzotare Rocco, "Economic Demand Analysis for Electricity in West Africa", Energy Journal, V.6, n.1, (January, 1985), pp.137-144.

Hartan Raymond S., "The Estimation of Short-Run Household Electricity Demand Using Pooled Aggragate Data", Journal of Business and Economic Statistics, V.1, n.2, (April 1983), pp.127-135.

Helden Van, Jan G., Lang Leaf, Peter S.H., Serker, Elmer, "Estimation of the Demand for Electricity", Applied Economics, V.19 n.1, (January 1987), pp.69-82.

Henderson J. Stephen, "The Economics of Electricity Demand Charges", Energy Journal, V.4, (Supplement 1983), pp.127-140.

Hendricks Wallace and Koenker Roger, "Demand for Electricity by Time of Day: An Evaluation of Experimental Results", Issues in Public-Utility Pricing and Regulation, (1980), pp.165-181.

Henson Steven E., "Electricity Demand Estimates Under Increasing-Block Rates", Southern Economic Journal, V.51, n.1, (Jul. 1984), pp.147-156.

Hjalarsson Lennart and Veiderpass Ann, "Electricity Tariffs and Sweden: A Comment", Energy Economics, V.8, n.1, (Jan. 1986), pp.51-53.

Hotelling H., "The relation of prices to marginal costs in an optimum system", Econometrica, Vol. 7, (1939), pp.151-155.

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

Houthakker H.S.,"Electricity Tariffs in Theory and Practice", Economic Journal, Vol.61, No.241, (1951) pp.1-25.

Hyndman Richard, Kotowitz Y. and Mathewson F., "The Residential Demand for Electric Energy and Natural Gas in Canada", Energy Policy Modelling: United States and Canadian Experiences, V.1, (1980), pp.86-102.

Iqbal Mahmood, "Residential Demand for Electricity and Natural Gas in Pakistan", Pakistan Development Review, V.22, n.1, (Spring 1983), pp.23-36.

Jackson Gary L., "The Residential Demand for Electricity in the TVA Power Service Area: Appliance Consumption from 1979 to 1986", Enery Journal, V.9, n.1, (Jan. 1988), pp.89-93.

Jaffee Bruce L., Houston Douglas A. and Olshavsky Richard W., "Residential Electricity Demand in Rural Areas: The Role of Conservation Actions, Engineering Factors and Economic Variables", Journal of Consumer Affairs, V.16, n.1, (Summer 1982), pp.137-151.

Kahn R.F., "Some notes on Ideal output", Economic Journal, Vol.XLV, (1935), pp.1-35.

Kaserman David L. and Mayo John W., "Advertising and the Residential Demand for Electricity", Journal of Business, University of Chicago, V.58, n.4, (Oct. 1985), pp.399-408.

Kerry Smith J., "Estimating the Price Elasticity of US Electricity Demand", Energy Economics, (April, 1980), pp.81-85.

Knight H.F., "Fallacies in the Interpretation of social cost", Quarterly Journal of Economics, Vol.XXXVIII, (1923), pp.582-606.

Knight H.F., "On decreasing cost and Comparative Cost", Quarterly Journal of Economics, Vol.XXXIX, (1925), pp.331-33.

Koenker R. and Hendricks W., "Estimation of the residential Demand Cycle for Electricity", in J.W. Boyd, ed. Proceedings on Forecasting Methodology for Time-of-Day and Seasonal Utility Loads, Electric Power Research Institute, Special Report 31, (Palo Alto, March 1976).

Kulp Stan, "Load Management: It's Helping Electric Utilities Contain Demand", Barron's, V.61, n.43, (Oct. 26, 1981), pp.11,24-28.

Lee Albert Yin-Po, "Voluntary Conservation and Electricity Peak Demand: A Case Study of the Modesto Irrigation District", Land Economics, Vol.57, No.3, (Aug. 1981), pp.436-447.

Lere John C., "Planning for Electricity Demand and Electric Energy Comsumption in the 1980s", Managerial Planning, V.30, n.3, (Nov/Dec. 1981), pp.21-25,41.

Lerner A.P., "The concept of monopoly and measurement of Monopoly Power", Review of Economic Studies, Vol.I, (1933-34), pp.157-75.

Leve John C., "Planning for Eectricity Demand and Electrical Energy Consumption in 1980s", Managerial Planning, V.30, n.3, (Nov-Dec, 1981), pp.21-25.

Lewis W.A., "The two-part tariff", and "Two-part tariff:A reply", Economica, Vol.8, (1941), pp.249-70 and 399-408.

Lifson Dale P., "Practical Considerations in Modelling the Demand for Electricity", Electric Rate Demonstration Conference: Papers and Proceedings, (April 1980), pp.166-186.

Lillard Lee A. and Acton Jan Paul, "Seasonal Electricity Demand and Pricing Analysis with a Variable Response Model", Bell Journal of Economics, V.12, n.1, (Spring, 1981), pp.71-92.

Maddigan Ruth J., Chern W . S. and Rizy C. G., "The Irrigation Demand for Electricity", American Journal of Agriculture Economics, (November 1982), pp.673-680.

Maddigan Ruth J., Chern Wen S. and Rizzy Colleen Gallagher, "Rural Residential Demand for Electricity", Land Economics, V.59, n.2, (May 1983), pp.150-162.

McFadden D., Puig C. and Krishner D., "Determinants of the

Long-Run Demand for Electricity", Proceedings of the Business and Economic Statistics Section, Part 2, American Economic Association, (1977), pp.109-117.

Michael P., Murray, Spann Robert, Pulley Lawrence and Beauvais Edward, "The Demand for Electricity in Virginia", Review of Economics and Statistics, (November 1978), pp.585-600.

Morris M.D., "Towards Reinterpretation of Nineteenth Century Indian Economic History", Journal of Economic History, (December 1963).

Mountain Dean C. and Hsiao Cheng, "Estimating the Short-run Income Elasticity of Demand for Electricity by Using Cross-sectional Categorised Data", Journal of American Statistical Association, (June 1985), pp. 259-265.

Mountain Dean C. and Hsiao Cheng, "Peak and Off-peak Industrial Demand for Electricity: The Hopkinson Rate in Ontrio, Canada", Energy Journal, (Jan. 1986), pp.149-168.

Munasinghe Mohan, "Integrated National Energy Planning (INEP) for the Developing Countries", National Resources Forum, Vol.4, (October 1980), pp.359-73.

Murry Michael P. et.al., "The Demand for Electricity in Virginia", Review of Economics and Statistics, (Nov, 1978), pp.585-600.

Naughton Michael C., "The Efficiency and Equity Consequences of Two-Part Tariffs in Electricity Pricing", Review of Economics and Statistics, V.68, n.3, (Aug. 1986), pp.406-414.

Nehru Jawaharlal, "Address to the League against Imperialism", quoted in Seminar, Vol.LIX, (1962-4).

Neufeld John L., "Price Discrimination and the Adoption of the Electricity Demand Charge", Journal of Economic History, V.47, n.3, (Spet. 1987), pp.693-709.

Panzar John C. and Willig Robert D., "Theoretical determinants of the industrial demand for electricity by time of day", in Journal of Econometrics, 9, (1979), pp.193-207.

Parti Michael and Parti Cynthia, "The Total and Appliance-Specific Conditional Demand for Electricity in the Household Sector", Bell Journal of Economics, V.11, n.1, (Spring 1980), pp.309-321.

Pouris A., "The Price Elasticity of Electricity Demand in

South Africa", Applied Economics, V.19, n.9, (Sept. 1987), pp.1269-1277.

Robertson D.H., "Those empty Boxes", Economic Journal, Vol. XXXIV, (1924), pp.16-31.

Robinson J.(Mrs), "Mr. Fraser on taxation and returns", Review of Economic Studies, Vol.I, (1933-34), pp.137-43.

Roth T.P., "Average and Marginal Price Changes and the Demand for Electricity: An Econometric Study, Applied Economics", V.3, (September 1981), pp.377-388.

Roth T. P., "Electricity Demand Estimation Using Proxy Variables: Some Reservations", Applied Economics, V.15, n.5, (Oct. 1983), pp.703-704.

Ruggles Nancy, "Recent Developments in the Theory of Marginal Cost Pricing", Review of Economic Studies, Vol.17, (1949-50), pp.107-26.

Ruggles Nancy, "The Welfare Basis of the Marginal Cost Pricing Principle", Review of Economic Studies, Vol.XVII (1), (1949-50), pp.29-47.

Rushdi Ali Ahmed, "Industrial Demand for Electricity in South Australia", Australian Economic Papers, V.23, n.43, (Dec. 1984), pp.259-280.

Ruth M.J., Chern W.S., and Rizy C.G., "The irrigation demand for electricity", American Journal of Agriculture Economics, (November 1982), pp.673-680.

Schwarz Peter M., "The Estimated Effects on Industry of Time-of-Use Demand and Energy Electricity Prices", The Journal of Industrial Economics, V.32, n.4, (June 1984), pp.524-539.

Shankar T.L., "India", in Gerard J. Mangone(ed), Energy Policies of the World, Vol.III, (New York, 1979).

Sharma R., "The Legacy of the British Rule in India", Journal of Indian History, Vol.XXXIV, Part III (December 1956).

Shin Jeong-Shik, "Perception of Price When Price Information Is Costly: Evidence from Residential Electricity Demand", Review of Economics and Statistics, V.67, n.4, (Nov. 1985), pp.591-598.

Spangler Gordon L. and Wright Vincent P., "Another Look at Growth in Demand for Electricity", Public Utilities Fortnightly, V.113, n.9, (April 26, 1984), pp.25-26.

Stampe William, "Some Aspects of cheap power development under the new constitution in India", The Asiatic Review, Vol.34, (1938), pp.650-710.

Studness C. M., "The Long Term Outlook for Electric Demand", Public Utilities Fortnightly, V.112, n.6, (Sept. 5, 1983), pp.47-48.

Studness C. M., "Management's 10 year Projections of Electric Demand and Capacity; 1989-98", Public Utility Fortnightly, V.124, n.4, (Aug 17, 1989), pp.35-36.

Studness C. M., "The Price Elasticity of Electric Demand and Utility Forecasts", Public Utility Fortnightly, V.122, n.7, pp.36-37, (Sept 29, 1988).

Studness C. M., "Electric Demand and Aggregate U.S. Energy Consumption", Public Utilities Fortnightly, V.106, n.3, (July 31, 1980), pp.38-39.

Studness C. M., "Electric Demand and the Nation's Energy Consumption", Public Utility Fortnightly, V.111, n.12, (June 1983), pp.54-56.

Studness C. M., "Accelerating Electric Demand Growth and the Long-term Utility Outlook", Public Utility Fortnightly, V.122, n.11, (Nov 24, 1988), pp.31-32.

Sutherland R. J., "Instability of Electricity Demand Functions in the post oil-embargo period", Energy Economics, (October, 1983), pp.267-271.

Taylor L. D., "The Demand for Electricity: A Study", Bell Journal of Economics, V.6, n.1, (Spring 1975), pp.74-110.

Taylor L. D., " Time-of-Day and Seasonal Demand for Electric Power", Growth and Change, V.10, n.1, (Jan. 1979), pp.105-110.

Terza Joseph V., "Determinants of Household Electricity Demand: A Two-Stage Probit Approach", Southern Economic Journal, V.52, n.4, (April 1986), pp.1131-1139.

Tishler Asher, "The Industrial and Commercial Demand for Electricity Under Time-of-Use Pricing", Journal of Econometrics, North-Holland, V.23, n.3, (Dec. 1983), pp.369-384.

Turvey, R., "Marginal Cost", Economic Journal, vol.79, 1969.

Turvey R., "The Second Best Case for Marginal Cost Pricing", in J Margolis and H.Guitton (eds), Public

Economics: An Analysis of Public Production and Consumption and their Relations to the Private Sectors, Proceedings of a Conference held by The International Economic Association, (1969).

Uri Noel D., "Long Run Supply and Demand of Electrical Energy and Market Stability", Journal of Economics and Business, V.29, n.1, (Fall 1976), pp.46-52.

Uri Noel D., "Price Expectations and the Demand for Electric Energy", Energy Systems and Policy, V.3, n.1, (1979), pp.73-83.

Uri Noel D., "Directional Causality in the Demand for Electrical Energy in the United States", Energy Systems and Policy, V.3, n.4, (1980), pp.353-365.

Uri Noel D., "The Growth in the Demand for Electrical Energy in the United States", Journal of Energy and Development, (Autumm, 1977), pp.153-163.

Uri Noel D., "Expected Price as a Determinant of the Demand for Electrical Energy", Journal Behavioral Economics, V.9, n.1, (Summer 1980), pp.73-88.

Van Helden, G. Jan, Leaf Lang, Peter, S.H., Serker, Elmer, "Estimation of the Demand for Electricity", in Applied Economics, V.19, n.1, (January 1987), pp.69-82.

Veall Michael R., "Industrial Electricity Demand and the Hopkinson Rate: An Application of the Extreme Value Distribution", Bell Journal of Economics, V.14, n.2, (Autumn 1983), pp.427-440.

Wenders John T. "The Welfare Economics of Optimal Seasonal Time-of-Day Electricity Tariffs", Energy Economics, V.3, n.2, (April 1981), pp.102-104.

Westley G. D., "Electricity Demand in a Developing Country", in Review of Economics and Statistics, (Netherlands), V.66, n.3, (August, 1984), pp.459-467.

Williamson O. E., "Peak Load Pricing and Optimal Capacity Under Indivisibility Constraints", American Economic Review, Vol.56, No.4, (1966), pp.810-827.

Willis John, "Residential Demand for Electricity", Energy Economics, V.3, n.4, (Oct. 1981), pp.249-255.

Wilson T., "Price and Output policy of state enterprise;A Comment", Economic Journal, Vol.50, (1945), pp.454-461.

Wiseman, "The theory of Public Utility Price: An Empty

Box", Oxford Economic Papers, Vol.9, 1973.

Yang Yung Y., "Temporal Stability of Residential Electricity Demand in the United States", Southern Economic Journal, V.45, n.1, (July 1978), pp.107-115.

Young Allyn, "Pigou's Wealth and Welfare", Quarterly Journal of Economics, Vol.XXVII, (1913), pp.672-86.

Young Trevor, Stevens Thomas H. and Willis Cleve, "Asymmetry in the Residential Demand for Electricity", Energy Journal, V.4, (Supplement 1983), pp.153-162.

BOOKS

Adela Maria Bolet, Forecasting US Electricity Demand, Published in cooperation with the Centre for Strategic and International Studies, Georgetown University, (Washington D.C., 1985).

Anderson K.P., Residential Energy Use: An Econometric Analysis, The Rand Corporation, (R-1297-NSF), (October 1973).

Bagchi A., Private Investment in India:1900-1939, Cambridge University Press, (1972).

Balasubramanyan V.N., The Economy of India, Weidenfeld and Nicolson, (October, 1984).

Banerjee Nirmala, Demand for Electricity, A monograph published for Centre for studies in social sciences, (Calcutta, 1979).

Barrington-Moore Jr., Social Origins of Dictatorship and Democracy, (1967).

Buchanan D.H., Development of Capitalistic Enterprise in India, (1st edition, new impression, 1934, 1966).

Charlesworth N., British rule and the Indian Economy:1800-1914, Prepared for the Economic History Society by Neil Charlesworth, Macmillan, (1982).

Chaterjee B.C., The hydro-electric practice in India, Volume I and II, (1936).

Chaudhari P., The Indian Economy:Poverty and Development, (1978).

Cicchetti C.J., The Marginal Cost and Pricing of Electricity: An Applied Approach, (1977).

De Graff J., Theoretical Welfare Economics, Cambridge University Press, (1957).

Desai Meghnad, and Dharma Kumar(eds), Cambridge Economic History of India, Vol.2, Cambridge University Press, (...).

Digby William, "Prosperous" British India, (1901).

Dubin Jeffrey A., Consumer Durable Choice and the Demand for Electricity, The Netherlands:Elsevier Science Publishers, (Amsterdam, 1985).

Electricity Council, Price Elasticity and Electricity Demand, (1974).

Fisher F.M. and Kaysen C., A Study in Econometrics: The demand for electricity in U.S., Amsterdam, North Holland Publishing Co., (Amsterdam, 1962).

Gadgil D.R., Industrial Revolution in India, Fourth Edition, (1942).

Gerschenkron A., Economic backwardness in historical perspective: A book of Essays, The Belknap Press of Harvard University Press, Cambridge, (Massachusetts, 1962).

Hall A.R., The export of Capital from Britain 1870-1914, Debates in Economic History, Edited with an introduction by A.R.Hall, (1968).

Hans Asha, The Power Sector in India, Sterling Publishers, (New Delhi, 1986).

Horsley Anthony and Andrzej J. Wrobel, The Formal Theory of Electricity Pricing and Investment, Suntory Toyota International centre for economics and related disciplines, London School of Economics, (1986).

Jenks L.H., The migration of British Capital to India, (First published in 1927, reprinted in London, 1963).

Judd J.P., The Search for Stable Demand Function, ,...

Khazzom J.Daniel, An Econometric Model Integrating Conservation Measures in Residential.....,

Kothari V.N. and Dadi M.M, Economic Benefits of Rural Electrification in Gujarat, Department of Economics, M.S. University of Baroda, (Baroda, 1979).

Layman R.A., Price elasticities in the electric power Industry, Department of Economics, University of Arizona, (Arizona, October, 1973).

Lerner A.P., The Economics of Control, (New York, 1914).

Little Ian, A Critique of Welfare Economics, Oxford University Press, (1957).

Maheshwari B.P., Industrial and agricultural development in India since 1914, (1971).

Mann Harold, Annals of the American Academy of Political and Social Science, part II, (1934).

Meade J.E., An Introduction to Economic Analysis and policy, Second Edition, (1937).

Mears J.W., The law relating to electrical energy in India, being the electricity supply Act, 1910, (Calcutta, 1910).

Mears J.W. and Bull R.D., Hydro-electric Survey of India, 3 Volumes, (Calcutta 1919-1922).

Mears J.W., Lectures on Electrical Engineering, (Six lectures delivered at the Civil Engineering College, Sibpur in March 1902), Lecture 1 on "Electric Traction", (Calcutta, 1913).

Mitchell Bridger M., Rolla Edward Park and Francis Laborne, Projecting Demand for Electricity: a survey and forecast, Rand, Santa Monica, "Prepared for the Private Sector Sponsors Program", February 1986, (California, 1986).

Morris M.D., Toru Matsui et el, Indian Economy in the Nineteenth Century:A Symposium, Delhi School of Economics and Indian Economic and Social History Association, (New Delhi, 1969).

Mount T.D., Chapman L.D. and Tyrrell T.J., Electricity demand in the United States: An Econometric Analysis, Oak Ridge National Laboratory (ORNL-NSF-49), Oak Ridge, (Tenn, June 1973).

Mukherjee M., National Income of India and Structure, Statistical Publication, (Calcutta, 1969).

Munasinghe Mohan, Electric Power Economics: Selected Works, (1990).

Munasinghe Mohan and Warford J., Electricity Pricing, Theory and Case studies, John Hopkins Press, (Baltimore, 1982).

Munasinghe Mohan and Rungta Shyam, (eds.), Regional Power Utility Tariff Symposium, Manila, (Philipines, August 1982).

Munasinghe Mohan, Rural Electrification for Development: Policy Analysis and Application, Westview Press, (1987).

Munasinghe Mohan, The Economics of Power System Reliability and Planning: Theory and Case Study, Published for World Bank, John Hopkins Press, (Baltimore, 1979).

Pachauri R.K., Energy and Economic Development in India, Praeger Publishers, (New York, London, 1977).

Pachauri R.K., Energy and Economic Development in India, Praeger Publishers, (New York, 1977).

Parikh Jyoti, Modelling Energy Demand for Policy Analysis, Planning Commission, (New Delhi, 1981).

Pillai P.P, Dynamics of Electricity Supply and Demand in Kerala-A macro econometric Analysis, Agricole Publishing Academy, (New Delhi, 1981).

Prest A.R. and Barr N.A., Public Finance in Theory and Practice, Chapter 16, (1979).

Ranade M.G., Essays on Indian Economics (Madras, 1906).

Ray R.K., Industrialisation in India 1914-1947, Oxford University Press, (New Delhi, 1979).

Ruffel, Robin John, An Econometric Analysis of the Household Demand for Electricity in Great Britain, Scottish Academic Press, (Edinburgh, 1977).

Samuelson, P.A., The Foundations of Economic Analysis, (Cambridge, 1947).

Sharma T.R. and Chauhan S.D.Singh, Indian Industries: Development, Management, Finance and Organisation, (Agra, India, 1965).

Stamp L.Dudley, Asia, (1929).

Stiglitz J. and Atkinson A.B., Lectures on Public Economics, Mcgraw Hill Book Company (U.K.) Limited, (1980).

Taylor L.D., Demand for Electricity:A Survey, Study by the Electric Power Research Institute, Palo Alto, (California, 1968).

Thakurdas Purshotamdas and other members, A brief

Memorandum Outlining a Plan of Economic Development For India, Part 1 and 2, (Bombay, 1944).

Thomas R.L., Applied Demand Analysis, Longman, (1987).

Tomilson B.R., The Political Economy of the Raj:1914-47, Macmillan, Cambridge Commonwealth Series, (1979).

Turvey R. and Anderson Dennis, Electricity Economics: Essays and Case studies, A World Bank Publication, Second Edition, (Washington D.C., 1981).

Turvey, R., Optimal Pricing and Investment in Electricity Industry, Allen and Unwin, (1969).

Venkatraman K., Power Development in India:The Financial Aspects, (1972).

Wagle Dilip and Rao, N.V., Power Sector in India, Tata Economic Consultancy Services, (Bombay, 1978).

Yoon Hyung Kim and Kurk R. Smith,(eds), Electricity in Economic Development: the experience in northwest Asia, Westport Corporation, (Greenwood, 1989).