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This is to certify that the dissertation entitled, "Resource Use Efficiency of Indian Power Generation Industry : A Case Study of the State Electricity Boards", submitted by Vibha Wadhawan for the Degree of Master of Philosophy (M.Phil) of the University, is her original work according to the best of my knowledge and may be placed before the examiners for evaluation.

(Ashok Guha)
Supervisor

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A C K N O W L E D G E M E N T S

I feel short of words in expressing my gratitude towards Prof. Ashok Guha, from whom I learned the real meaning of economics. His affectionate and courteous guidance never let me feel that my knowledge was too little against the unlimited stock possessed by him. But for his constant encouragement it would not have been possible to submit this dissertation.

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INTRODUCTION

Over the last three decades, the public sector enterprises in India have grown at a phenomenal rate, absorbing a considerably large proportion of productive resources of the economy. It is well known that the performance of public enterprises, as compared to the large quantum of productive resources, has been far from satisfactory. The poor performance of the public enterprises is a clear indication of inefficient use of the productive resources entrusted to them.

The need to utilise productive resources rationally arises due to their scarcity, which requires resources to be (a) allocated optimally, (b) used efficiently. Leibenstein in his well known paper " Allocative vs X-efficiency " provided evidences on the widespread existence of resource use inefficiency, particularly in underdeveloped and developing countries. He maintained that in practice, loss in output and welfare arising due to misallocation of resources is very small as compared to that arising due to " Under Utilisation" of resources.

It is contended in this study that resource use inefficiency is massive in India, particularly, in the public sector enterprises. The object of present study is to evaluate the performance of State Electricity Boards - the public enterprises operating in Indian power generation industry in terms of resource use efficiency criterion. It is strange that the operation of State Electricity Boards has not attracted as much public attention as other public enterprises have done, even though the relative amount of the productive resources involved in them is considerably large.

This study is divided into three parts. Part one discusses importance of Resource use efficiency in context of industrial development in India. It also reviews the general performance of Indian electricity generation industry with a view to emphasise the need to study the resource use efficiency of the industry.

Part two is devoted to the survey of literature on the methodology to measure the resource use efficiency. Part three contains the emperical content alongwith the implications and conclusions arising out of the study.

PART ONE

(A) INDUSTRIAL DEVELOPMENT AND RESOURCE USE EFFICIENCY IN INDIA

The history of economic development shows that a high rate of growth in industrial output has been the leading force behind the rapid and sustained economic development. By contrast, in most of the present developing countries, like India, the industrial growth rate has failed to rise at a rate high enough to ensure sustained development of their economies.

The Indian economy has witnessed a persistent sluggishness in the growth rate of industrial output since the middle sixties. The rate of growth fell from the level of 7.8% during 1955-65 to 3.7% during the decade 1965-75. The inclusion of more recent years, when the performance has been slightly better, takes the rate of growth to the level of 4.3%.

A number of hypothesis have been put forward to explain the deceleration in the growth of industrial output. These can broadly be classified into two groups (a) those emphasising the supply constraints (b) those emphasising the demand constraints. The supply constraints put forward are mainly the non-availability of savings, foreign exchange and agricultural inputs. The constraints mentioned on the demand side are : decline in import substitution possibilities and in public investment for the capital goods industries. For the consumer goods industries, the constraint on demand has been explained by an unequal distribution of income while the hypothesis relating to demand constraints have been refuted,* the position of the economy in terms of supply constraints has been improved considerably. The country has been able to build large reserves of food grains and foreign exchange and has stepped up the rates of savings and capital formation (Table 1) to levels in access of many of the developed countries.

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* See Rangarajan 1982 and AV Desai 1981 for detailed discussions.

Despite a phenomenal increase in the rates of savings and capital formation, the growth rate of industrial output has failed to pick up. A high rate of investment associated with a low output rate implies a high incremental capital output ratio. The incremental capital output ratio in Indian industry has been very high by international standards. The ICOR in the registered industry at constant prices (1970 - 71) was 7.5 and 5.6 in the second and third plans respectively. In the next decade, it increased to about 12. The mean ICOR for twenty two industrialised countries was 4.9 *. The high level of ICOR is indicative of poor utilisation of the most scarce productive factor namely capital. It is quite likely that other productive factors like raw material and labour have not been utilised properly, contributing to slow growth of industrial output.

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* Rangarajan 1982.

The ICOR has been particularly high in the public sector industries. For the same line of manufacturing, the ICOR has been higher for public sector industries than the private sector industries as depicted in table 2.

The high level of ICOR in public sector industries shows massive under utilisation and poor maintenance of capital. High capital to output ratios could, ofcourse, reflect artificially inflated investment costs - which covers bribes and other such factors that lead to escalation of capital good prices. But low utilisation of actual physical capacity is also undoubtedly a factor. There are evidences* of poor utilisation of other productive resources namely raw material and labour, besides that of capital.

* Various Annual Reports on the working of industrial and commercial undertakings of Central Government.

. The costs of almost all public sector undertakings are too high and this bears no relation to the original detailed project report costs or even to the year by year revised standard cost. There have been many instances of unusual delays in setting up plants, an unusually high level of inventories, persistent labour problems recording considerable loss in man hours. All these factors are a pointer to the absolutely chaotic state of management in public sector enterprises and grossly inefficient utilisation of the large proportion of productive resources allocated to public sector enterprises.

It has been argued that incompetance of Indian Corporate enterprise, particularly public enterprise, is due to the pervasiveness of the demonstration effect in the Indian economy. Our long colonial and commercial contact with the West has projected advanced living standards vividly on the minds of our affluent classes and the example has fittered right down our continuous social hierarchy to the masses. The consequence for the development process has been a perpetual clamour for rising wages and growing opportunities for middle class employment regardless of productivity, & provision of these has become a major political imperative. Employment maximisation, at the cost of productivity and profitability is now, consciously or unconciously, an objective of all public enterprises : it constrains managerial decisions and blunts the drive for productive efficiency among workers. It induces a minimum work ethic, since to work hard is to deprive somebody of an additional job, besides reducing the possibility of overtime earnings. Production in this kind of atmosphere, is ruled not by production functions but by Parkinson's law. In private enterprises, the necessities of survival in market operates as a check on inefficiency. No such countervailing force exists in the public sector.

A high level of inefficiency in public sector enterprises, particularly those producing strategic inputs like steel, Cement, Coal and Electricity, has far reaching implications for industrial and overall economic development. Inefficiency in these industries results not only in loss of output due to inadequacy of these inputs, but also to cost escalations and inflation through linkage effect. As the public sector has captured more of the " Commanding heights " of the economy, since 1965, its paralysing effect of the linked industries has become far- reaching and wide ranging throughout the entire industrial system.

Further, the high wage bills, combined with the low productivities, have resulted in massive losses in public sector, so that subsidies for the public enterprises have become a major drain on the budget. Since Government's consumption principally, the cost of bureaucracy,is soaring at the same time (under the impact of the demonstration effect) a fiscal crisis has become inevitable. Government revenues, after paying the salary bills of the Government servents, are so fully absorbed in subsidising existing public undertakings that funds for new public investment become exceedingly scarce. Thus despite record levels to which private savings have climbed, inadequate public investment intensifies the vicious circle of low productivity and inadequate output in the infrastructural industries. Industrial retardation thus spreads cummulatively throughout the economy.

The present study is confined to evaluation of resource use efficiency of Indian electricity generation industry. The power industry is a basic industry providing infrastructure to economic development and its importance for economic development hardly needs to be emphasised. The section below reviews the performance of the power industry with a view to indicate the need to study resource use efficiency of the industry.

TABLE 1

RATES * OF GROSS SAVINGS AND CAPITAL FORMATION AT CURRENT PRICES

YEAR	GROSS SAVING	GROSS CAPITAL FORMATION
1970-71	16.8	17.8
1974-75	18.2	19.1
1975-76	20.0	19.9
1976-77	22.3	20.7
1977-78	21.8	20.1
1978-79	24.3	24.4
1979-80	22.5	23.0
1980-81	21.9	23.8

SOURCE : National Accounts Statistics 1970-71 to 1980-81, February 1983 by C.S.O.

* The rates have been calculated as a percentage of gross domestic product at market prices.

TABLE 2

AVERAGE CAPITAL OUTPUT RATIOS IN GOVERNMENT AND PUBLIC LIMITED COMPANIES

INDUSTRY	GOVT. COMPANIES				PUBLIC LTD. COMPANIES			
	1960-61	65-66	70-71	75-76	1960-61	65-66	70-71	75-76
1.Mining & Quarrying	-	3.01	7.42	3.42	1.94	1.80	1.74	1.26
2.Processing & manufacture of Engg. goods,metals, chemicals etc	-	5.91	7.77	7.72	3.98	3.68	3.84	3.31
3.Engineering	3.5	3.29	5.64	3.22	2.71	2.73	2.95	2.60
4.Chemicals	7.66	3.00	12.25	14.18	4.02	4.23	4.44	3.95

SOURCE : A. Desai (1981) Page 384.

PART ONE

(B) PERFORMANCE OF INDIAN POWER GENERATION INDUSTRY

Most of the Electricity generation industry of India is in public sector, with State Electricity Boards accounting for about 74% of total electricity generated.

Investment in the power generation industry has increased at a very rapid rate since the inception of planning in the country. The amount of investment in power generation industry and its share in total investment in public sector is given in table 3. The investment in power generation industry has grown from the level of Rs. 260 Crores at the end of 1955 to Rs. 2472.75 Crores at the end of 1979-80. The sixth plan has allocated an amount of Rs. 19265 Crores which accounts for about 23% of the total planned investment on public sector during the period. Despite the huge investment and large magnitudes of other inputs which have gone into the power generation industry, the performance both financial and physical has been very poor. The State Electricity Boards have made huge amounts of losses and most of them have not been able to pay even the interest on the loans extended to them. The accumulated losses of the SEBs upto 1977-78 were of order of Rs. 816.42 Crores. The Board wise distribution of losses is given in table 4. An important question in this connection is whether the use of commercial profitability is a correct criterion to assess the performance of a public sector enterprise. It is often contended that the public enterprises have been set up with a wider objective to serve to the nation and there are social benefits arising out of them in the form of externalities. The right criterion, therefore, to judge their performance is the social profitability. But in a country like India, suffering from acute shortage of capital, it is not possible to adhere to the traditional concept of no profit no loss in public sector enterprises on the basis that they are meant to serve public and not to make profits. Lack of commercial considerations tends to breed over capitalisation, delays, poor maintenance, underutilisation of capacity and high costs.

The need to operate public enterprises along commercial line has been recognised even by the Government. The fifth plan document states " In order that the public sector performs its due role in economic development, it must not only fill physical gaps in the output of goods and services but also contribute to national svaings commensurate with its size." * The poor financial performance is indicative of inefficiency and the public sector enterprises should not be allowed to wallow in bad management and justify their poor performance in the pretext of social profitability.

Apart from poor financial performance the physical performance has also been very bad. There has always been acute shortage of power in India. The nation has suffered heavy losses in terms of loss of output due to non availability of adequate power. The inefficient working of the power industry has also contributed to cost and price escalations in the economy through linkage effect.

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* Draft Fifth Plan, 1974-79 Volume I

The short falls in achievements of the industry have been substantial both in terms of building of capacity to generate power and utilisation of existing capacity to generate power. The actual capacity installed, during the plans, against the target capacity is given in the table 5. The extent of short fall has been increasing over the years i.e. from the level of 18% in First Plan it increased to as high a level as 65% in the Fifth Plan.

A great deal of emphasis in the Plans has been given to erection of new capacity to meet the shortage of power, while little attention has been paid to utilisation of existing capacity. The conditions in utilisation of existing capacity have really been deplorable. Since power is a highly capital intensive industry, the economy can ill afford to keep adding the capacity while ignoring the utilisation of existing capacity. The average level of utilisation of capacity in the country has been around just 45%.Thus the power shortages have coexisted with considerable excess capacity. Given the overall poor performances it is of particular importance from the policy point of view, to find out whether there are marked disparaties in efficiency of SEBs. and what are the factors behind it.

Another indicator of physical performance is the amount of electricity lost in transformation, transmission & distribution depicted in table 6. The total electricity lost as a percentage of total electricity available has been around 19% during 1974-79. The board wise distribution of electricity lost (table 7) indicates that it has been even as high as 48% in some cases. Such high degree of losses can not be explained only in terms of technical factors and are clearly suggestive of a chaotic state in utilisation of physical resources.

TABLE 3

TRENDS IN INVESTMENT IN POWER SECTOR
(Rs.CRORES)

PLAN PERIOD	INVESTMENT IN POWER SECTOR (1)	OVERALL PUBLIC SECTOR INVESTMENT (2)	% of (1) TO (2)
1951-56	260.00	1960.00	13.27
1956-61	460.00	4600.00	10.00
1961-66	1252.29	8576.50	14.60
1966-69	1208.14	6756.50	17.88
1969-74	2931.45	16160.00	16.02
1974-79	7540.88	19303.00	19.19
1979-80	2472.75	12549.63	19.63
1980-85	19265.00	97500.00	22.93

SOURCE : Power Development in India published by CEA.

TABLE 4

ACCUMULATED LOSSES OF THE STATE ELECTRICITY BOARDS UPTO 1977-78

NAME OF THE ELECTRICITY BOARD	ACCUMULATED LOSS RS. CRORES
1. UTTAR PRADESH	199.75
2. BIHAR	144.00
3. PUNJAB	137.00
4. ANDHRA PRADESH	34.58
5. ASSAM	32.46
6. GUJARAT	28.52
7. HARYANA	6.46
8. HIMACHAL PRADESH	17.39
9. KARNATAKA	5.80
10 KERALA	42.11
11 MADHYA PRADESH	8.30
12 MEGHALAYA	19.49
13 ORISSA	8.16
14 RAJASTHAN	60.85
15 TAMIL NADU	25.45
16 WEST BENGAL	46.10
TOTAL	816.42

TABLE 5

ACHIEVEMENTS OF POWER INDUSTRY IN TERMS OF CAPACITY INSTALLED
(FIGURES IN MILLION K.W.)

PLAN PERIOD	TARGET (1)	ACHIEVEMENTS (2)	% of (1) TO (2)
FIRST PLAN	1.30	1.10	18.0
SECOND PLAN	3.50	2.25	35.7
THIRD PLAN	7.04	4.52	35.8
ANNUAL PLANS	5.43	4.12	24.1
FOURTH PLAN	9.26	4.58	50.0
FIFTH PLAN	12.13	4.84	65.02

SOURCE : Patriot dated 19/12/1980.

TABLE 6

TRANSFORMATION, TRANSMISSION AND DISTRIBUTION LOSSES AND ELECTRICITY UNACCOUNTED FOR

YEAR	LOSS IN GWH	% OF TOTAL AVAILABLE POWER
1974	10663	19.50
1975	10893	19.08
1976	12142	18.51
1977	13839	18.61
1978	14613	18.59
1979	16269	18.42

SOURCE : State Electricity Boards : Finanacial Performance Review, February 1983, CEA.

TABLE 7

BOARD WISE DISTRIBUTION OF TRANSFORMATION, TRANSMISSION AND DISTRIBUTION LOSSES AND POWER UNACCOUNTED FOR DURING 1979 – 1980

NAME OF THE BOARD	LOSS IN GWH	% OF TOTAL AVAILABLE POWER
1. HARYANA	958.14	28.14
2. HIMACHAL PRADESH	111.69	18.55
3. JAMMU & KASHMIR	390.30	47.01
4. PUNJAB	1215.42	22.50
5. RAJASTHAN	1069.10	24.40
6. UTTAR PRADESH	1848.33	19.00
7. GUJARAT	1253.57	16.71
8. MADHYA PRADESH	1260.07	22.40
9. MAHARASHTRA	2126.60	16.10
10 BIHAR	928.11	24.53
11 ORISSA	507.31	18.29
12 WEST BENGAL	426.21	12.29
13 ANDHRA PRADESH	1357.48	22.39
14 KARNATAKA	1382.76	20.97
15 KERALA	816.50	15.90
16 TAMIL NADU	1958.87	19.58
17 ASSAM	152.20	19.23
18 MEGHALAYA	13.41	4.32

SOURCE : PUBLIC ELECTRICITY SUPPLY – ALL INDIA STATISTICS 1979–80, CEA.

P A R T   T W O

MEASUREMENT OF PRODUCTIVE EFFICIENCY

METHODOLOGY AND CONCEPTS

Though there have, since long, been attempts to provide a 'measure' of productive efficiency of an economic organisation, a new direction to the subject was provided by the work of Farrell in 1957. Farrell's work generated a series of studies on both theoretical and emperical measurement of productive efficiency e.g. Aigner and Chu (1968), Seitz (1970 & 71), Timmer (1977), Afrait (1972), Carlson (1972), Richamond (1974), Schmidt (1976), Aigner, Amemiya and Poirier (1976), Aigner, Lovel and Schmidt (1977), Meeusen and Boreck (1977), Forsund and Jansen (1977), Forsund and Hjalmarsson (1979), Schmidt and Lovell (1979) and Greene (1980). For a long time economists relied on partial productivity indicators(i.e. labour productivity, land productivity etc.) to measure efficiency in production. As these indices are ratios of output to input usage of a single factor of production they are conceptually inadequate and emperically misleading.

In order to take account of all factors of production, total productivity indices using weighted average of all inputs were developed, the weights being either factor shares or relative prices. These type of indices have the usual index number problems.

Since the production function depicts the process of transformation of inputs into output, it seems quite appropriate to base the measurement of productive efficiency on the estimation of the production function. The text book definition of the production function states that it indicates the maximum possible output from given inputs, with given technology. Paradoxically, for a long period, this definition was not employed in emparical estimation. The text book definition of the production function was first strictly followed by Farrell (1957), whose approach to measurement of efficiency is discussed below.

FARRELL'S APPROACH TO MEASUREMENT OF EFFICIENCY

Farrell introduced the concept of the " frontier " production function which specifies the maximum output obtainable from given amount of inputs. He proposed to base the frontier production function on the observed best performance of the firms of an industry*, and named it as the " best practice frontier". Assuming only two factors of production - capital and labour, plotting per unit requirements of factors of production results in a scatter of observations like that shown in figure 1.

The frontier production function for the industry can be obtained by fitting a curve like AA' to the scatter of observations in such a way that no obervation lies below it. The frontier isoquant AA' is an envelope of most efficient points and all points lying above it are rendered inefficient.

Farrell divided the overall productive efficiency of a production unit into two separate+ components i.e. technical efficiency and price efficiency. The technical or resource use efficiency refers to the competance of a firm in transforming

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* A Frontier production function can be derived from engineering blueprints showing theoretically efficient production functin. Farrell rejected this in favour of emparical frontier based on best perfomance of firms on two counts (a) the use of engineering data might give a more optimistic picture of attainable efficiency than is possible in reality (b) it is not possible to specify such a function accurately for complex production processes.

\+ Though technical efficiency and price efficiency are not mutually exclusive as far as impact of policy decisions of an organisation is concerned, Farrell maintained that emparically it is possible to measure separately the effect of policy decisions on both these components.

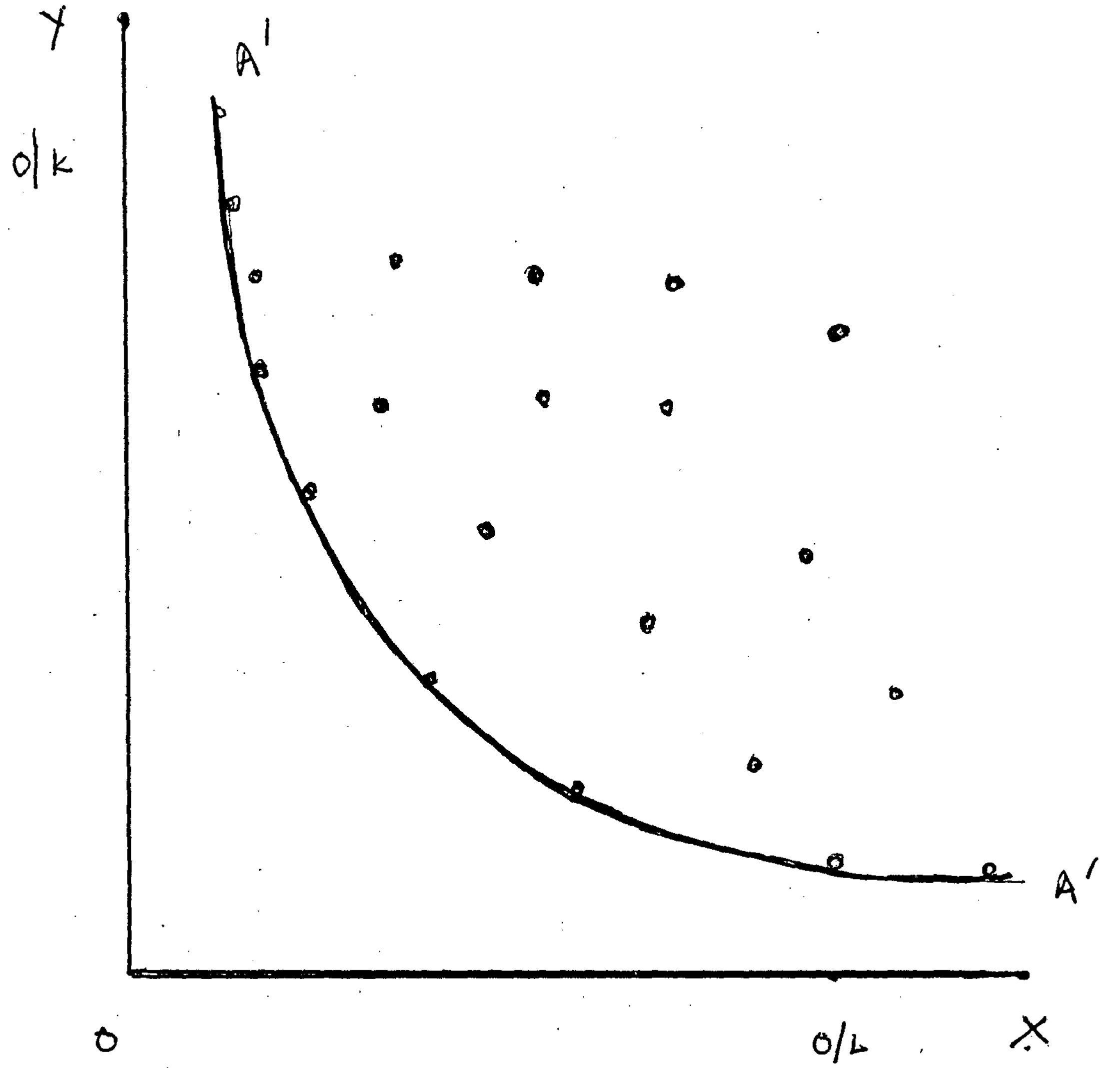

FIGURE 1

inputs into output, whereas price efficiency or allocative efficiency refers to optimality in allocation of factors of production at given prices. The difference between technical and allocative efficiency and their relation with the frontier production function is illustrated in figure 2.

The technical efficiency of a firm like E can be measured by the ratio OC/OE. This index of technical efficiency is input based i.e. it measures the difference between frontier input usage and actual usage, keeping the output constant.*

Measurement of allocative efficiency within the frontier framework requires additional information on factor prices. Assuming perfect competition in the factor market, the relative prices of factors can be presented in the form of unit cost line which is represented by line TT in figure 2.

The overall economic efficiency is highest for the firm O which not only minimises use of factor (per unit of output) but also minimised the unit cost of production. The extent of allocative efficiency of firm E is given by ratio OG/OC.

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* Technical efficiency can also be measured by taking the difference between the frontier output and actual output, keeping the inputs fixed. Such a measure of technical efficiency was first used by Timmer (1971).

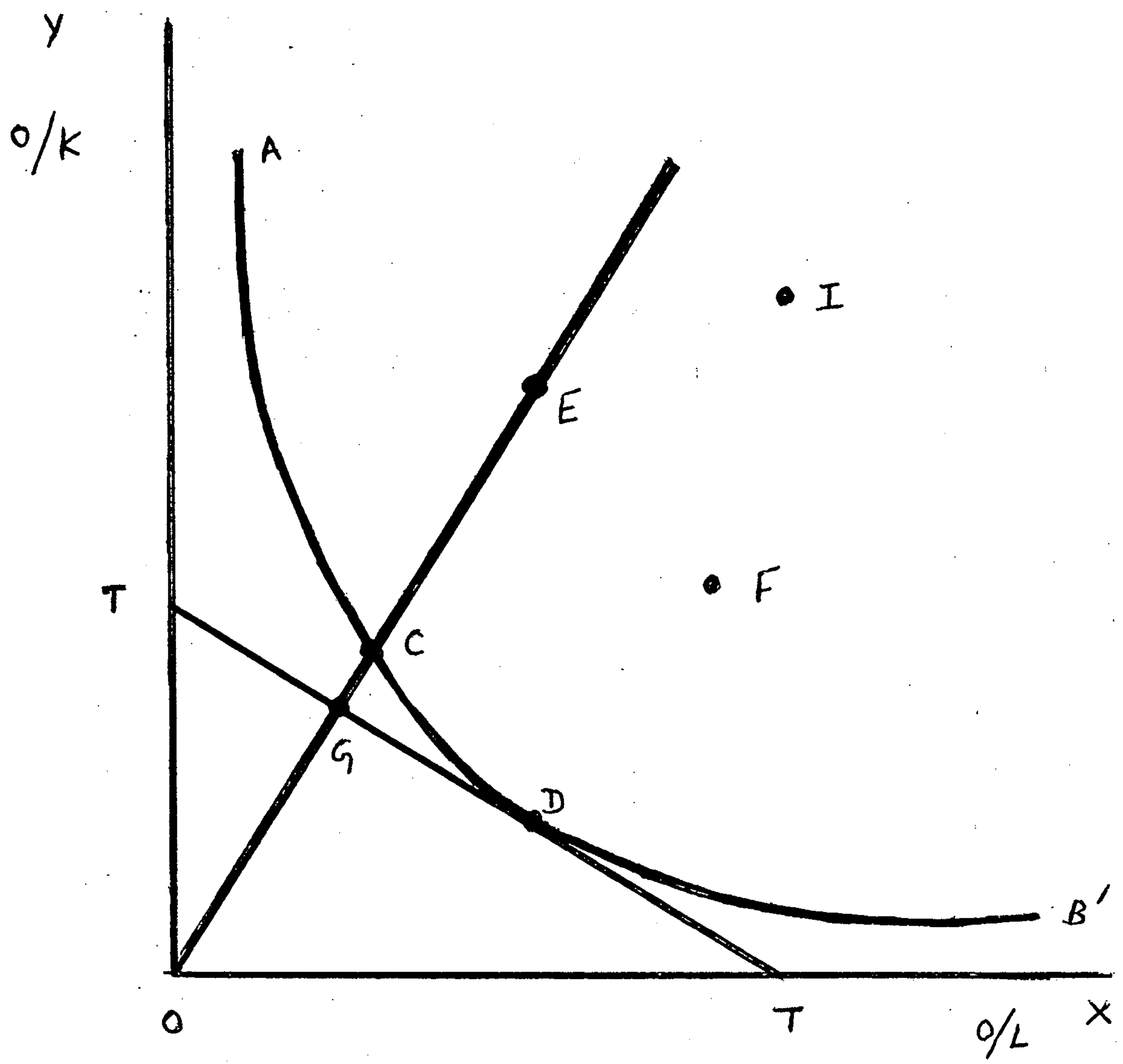

FIGURE 2

All measures of efficiency suggested by Farrell are radial in nature i.e. they are made along the factor proportions ray from the origin. Under the assumption of continuity and strict monotonicity, measurement along the ray ensures distinction between technical and allocative efficiency and enables the indices of efficiency to be interpreted in terms of total factor cost e.g. 1- technical efficiency is the reduction in total cost associated with elimination of technical efficiency.

Farrell's approach to the estimation of the frontier production function is deterministic and non-parametric. It is deterministic because all the observations are forced to be on or below the frontier. It is non-parametric as without using any specific parametric specification, Farrell constructed a free disposal convex hull of the observed input output ratios by using linear programming techniques. The advantage of a non-parametric approach lies in its general applicability and its freedom from the errors of wrong specifications. The disadvantage is the inability to represent the frontier in an explicit form.

Farrell assumed the production function to be linear homogeneous.* But the measurement concept underlying his procedure is is quite capable of being generalised to the technologies

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* In his subsequent paper with Field House 1962, Farrell proposed segmentation of firms according to size and separate estimation

- cont. page 28

other than linear homogeneous as has been shown by subsequent studies along the lines.[+] Farrell did not identify another source of inefficiency, namely scale inefficiency.[++] A firm that is technically and allocatively efficient may be inefficient because it is producing in an inoptimal scale. The technically optimal scale exists where elasticity of scale is equal to one. A measure of scale efficiency along the lines of the technical efficiency measure of Farrell may be calculated representing relative reduction in input coefficients possible by producing in optimal scale on the frontier production with the

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* of frontier production function for each size group. But this technique does not permit estimation of a production function applying to all scales of production.

\+ Aigner & Chu (1968) extended Farrell's methodology to non-linear homogeneous production functions by using C-D form. For specification, Forsun and Hjalmasson (1979) used homothetic and Green (1980) used translog specifications for estimation of frontier production functions.

++ Linear homogeneous assumed by Farrell and non-linear homogeneous production functions do not permit study of scale efficiency as they assume elasticity of scale to be equal to one.

observed factor proportions. Forsund and Hjalmarsson (1979) computed the measure of efficiency as ' the ratio of an input coefficient evaluated at technically optimal scale for the observed input ratios and the corresponding observed input coefficient * and then eliminate technical inefficiency from it to obtain a measure of "pure" scale efficiency.

Another limitation of Farrell's approach is that estimation of frontier production is based on a sub-set of samples of observations and hence sensitive to extreme observations. This problem is discussed later.

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* Forsund and Hjalmarsson (1979) pp 299

DEVELOPMENTS SUBSEQUENT TO FARRELL

As mentioned earlier, the path breaking paper of Farrell (1957) stimulated a series of studies on both theoretical and emperical estimation of Frontier production functions and measurement of efficiency. Salient features of some important frontier production studies are given in Appendix I.

These studies are based on the following three approaches to the estimation of frontier production functions :-

(a) Direct estimation of production functions.

(b) Direct estimation of Cost functions.

(c) Indirect estimation of production function (via cost functions)

Since the production technology can be uniquely determined by production as well as cost function, frontier production can be obtained by estimating either of these. Application of duality theory to production economics has shown that given certain regularity conditions, there exist cost and production functions that are dual to each other. Therefore, the parameters of a production function can be derived from the estimated cost function.

Each of the above mentioned approaches is based on different assumptions and requires different set of data. The direct estimation of production function is based on the Zellner - Kmenta - Dre'ze assumptions of expected profit maximisation implying input quantities to be exogenous. It requires data on quantity of inputs used and gives information about technical efficiency only. On the other hand, direct estimation of cost function is based on (Averch and Johnson 1962) hypothesis assumption of cost minimisation with output determined exogenously. This requires data on prices of inputs and permits measurement of overall productivity.

The indirect estimation of production function requires data on both prices and qunatities of inputs used and allows separate measurement of technical efficiency and allocative efficiency.

The choice of approach for estimation of frontier production function depends upon the objective of the study and availability of data.

Studies on estimation of frontier production function and measurement of efficiency can broadly be devided into two groups - deterministic and Stochastic.

DETERMINISTIC OR FULL FRONTIER MODELS

A frontier is known as deterministic or full frontier when all the observations are constrained to lie on or below the frontier. The full frontier models attribute all variations in the output across the firms to their ability to utilise the " best practice " technology. On the basis of assumptions about efficiency distribution, approaches to estimate deterministic frontier may be devided into two groups :-

(a) Aigner and Chu - Timmer Type, based on consttaining residuals to be one sided (non-positive) *without explicit specification of efficiency distribution.

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* In literature, there seems to be a little confusion between one sided error term and one sided residuals. The former assumption forces observed output to be less than or equal to forntier output making the forntier deterministic. The later assumption is required to apply programming technique to estimation of frontier. The idea of a frontier function is perfectly consistent with the phenomenon of positive sign of residuals.

(b) Afrait - Richamond type, based on explicit specification of efficiency distribution.

The model based on first approach may be written as

$$y_i = a \sum_{i=1}^{n} \beta_i x_i + e_i \qquad e_i \leq 0$$

where y_i is the log output, x_i is the log of observed inputs' usage, β_i are unknown parameters to be estimated and e_i is the error terms and constraint. $e_i \leq 0$ forces all observations to lie on or below the frontier.

The observations may be forced to lie as close to frontier as possible by minimising either the sum of absolute values or sum of squared values of residulas by the techniques of linear programming and quadratic programming respectively.

The programming estimates are sensitive to extreme outliers. In order to remove the sensitivity of linear programming estimates to extreme observations, Timmer (1971) proposed removal of all observations used in estimation of the frontier and then re-estimation of the frontier. This procedure is to be followed until the estimates stabilise.

This method can not be applied where the sample is of small size. More over this method of removal of observations is purely arbitrary and does not have any statistical justification . Forsund Hjalmarsson (1979) first removed one largest plant, then four smallest plants from their data to test the sensitivity of their linear programming estimates. Broeck et al (1980) have removed the unit with highest shadow price on or below the frontier.

The sensitivity of frontier estimates to outliers should not be considered as a problem so long as the data are accurate and outliers do not show abnormally low values of input requirements because the very purpose of frontier estimation is that most efficient units should count unproportionately.+

+ See Broeck et al (1980) page 137.

A limitation of the programming techniques is that the parameters estimated by them do not have any statistical property e.g. standard error, t-ratio etc.

In order to obtain the estimates of frontier production with known statistical properties, it is required to specify the distribution of error term explicitly. Afrait (1972) specified two paramter beta distribution for the error term and estimated the frontier production function by the technique of maximum likelihood estimation (MLE). Schmidt (1976) showed that the programming estimates of Aigner and Chu are MLE under certain assumptions about the distribution of efficiency. If exponential distribution is assumed then linear programming procedure is maximum likelihood, if half normal distribution is assumed then quadratic programming procedure is maximum likelihood.

One basic limitation of MLE for estimation of full frontier is that it violates one of the regularity conditions namely independence of the range of random variable from the parameters to be estimated *.

Since the very defination of full frontier requires distribution of efficiency to be one sided, the range of output becomes dependent on the parameters to be estimated. In such a case the statistical properties of MLE remain uncertain.

Another disadvantage of MLE is that they are very sensitive to the form of distribution chosen. Different distributions yield different results and there are no a-priori grounds for selection of a particular distribution.

Richamond (1974) used the technique of adjusted ordinary least squares (AOLS). He used gamma distribution for specifying efficiency distribution. Assuming mean of the disturbance term equal to variance, he utilised variance of OLS residuals to correct the intercept.

A problem with AOLS is that some residuals may have theoritically wrong sign even after the correction of intercept

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* Dhyrmes (1970)

thus preventing observation specific measures of technical efficiency to be calculated.

Another problem is that different distributions of disturbance term yield different corrections in intercept.

Greene (1980) obtained a consistent, though biased, estimate of constant term by imposing sign uniformity on the residuals. The method of estimation is to estimate production function by OLS and then shift the intercept upwards until no residual is positive and one is zero. Adjustments made to constant term, in this fashion are independent of efficiency distribution and permit calculations of observation specific measure of efficiency.

All the above discussed studies are based on homogeneous form of production functions. Forsund and Jansen (1977) extended the deterministic approach to homothetic production functions and estimated production forntier via cost function. Their model may be written as

$$y^a e^{by} = Y \prod_{j=1}^{n} x_j^{\alpha_j} \quad \text{—— (1)}$$

Which is the zellner-Revankar's specification of production function y is the output, x_j s are inputs, γ, a, b, and α_j are the parameters to be estimated where γ is a constant, a and b are the scale function parameters and α_j represent Kernal elasticities for inputs.

The cost function corresponding to above production function is linear in logs which may be written as

$$\log c = a \log y + by + \log B + \sum_{j=1}^{m} \alpha_j \log q_j \qquad (2)$$

where q_j represent input prices and B is a multiplicative constant in the price function. Equation 2 can be estimated by linear programming. The problem becomes to

Maximise

$$n \log B + a \sum_{i=1}^{n} \log y_i + b \sum_{i=1}^{n} y_i + \alpha_i \sum_{i=1}^{n} \sum_{j=1}^{m} \log q_{ij}$$

Subject to

$$(\log B + a \log y_i + by_i + \alpha_i \log q_{ij}) \leq \log e_i$$

$$i = 1 \ldots n$$
$$j = 1 \ldots m$$

$$B, a, b, \alpha_j \geq 0$$

One advantage of using homothetic form of production function is that it enables to study the impact of scale economies on technical efficiency in an easy way due to property of constant scale elasticity along the isoquant and independence of factor ratios.

Another advantage of using homothetic production function is that by virtue of property of constant scale elasticity the impact of scale economies on production can be studied in an easy way.

While Forsund and Jansen used data from mechanical pulp industry of Norway, work along the similar lines has been carried by Forsund and Hjal marssen (1979 a and b) in Swedish milk processing industry.

STOCHASTIC MODELS

A frontier is called Stochastic if some observations are allowed to lie above the frontier due to random factors. Work in the direction of stochastic models was started by Aigner, Amemiya and Poirier (1976), though their stochastic term was confined to measurement errors only and did not take account of pure random shocks. Their error structure may be written as

$$e_i = \begin{cases} e_i^* / \sqrt{1-\theta} & \text{if } e_i^* > 0 \\ e_i^* / \sqrt{\theta} & \text{if } e_i^* \leq 0 \end{cases}$$

$$i = 1 \ldots\ldots n$$

They assumed e_i^* to be independently and normally distributed with zero mean and variance σ^2 for $0 < \theta < 1$, when $\theta = 1$, e_i^* has negative truncated normal distribution. The parameter θ shows the relative variability between measurement errors and inefficiency errors. When θ takes value $\frac{1}{2}$ then it represents " full " frontier, when $\theta = \frac{1}{2}$ the impact of both sources of errors is equal.

A fully stochastic model was developed by Aigner, Lovell and Schmidt (1977) and Meeusen and Broeck (1977). Their error structure may be written as

$$e_i = u_i + v_i \qquad i = 1 \ldots n$$

The component u_i is assumed to be one sided (as in case of deterministic models). It shows the inefficiency of a firm in utilising its productive resources. This inefficiency is attributable entirely to factors within a firms control like will, effort and skills of managers and employees, utilisation of capital etc. (sources of technical efficiency are discussed in detailed later).

Component v_i may be positive or negative $v_i \gtreqless 0$ and constitutes (a) errors in measurement (b) impact of pure random shocks resulting due to factors out of firms control like climate, topography, power breakdowns etc.

Both Aigner Lovell and Schmidt and Meeusen and Broeck estimated the frontier production function by using MLE. Aigner Lovell and Schmidt used half - normal distribution for u_i and log normal for v_i whereas Meeusen and Broeck used exponential for u_i and log normal for v_i. MLE in case of stochastic frontier models has usual stastistical properties due to presence of stochastic error term v_i, ensyring all regularity conditions.

The stochastic frontiers can also be estimated by the use of adjusted ordinary least square methods.

In a recent study, Schmidt and Lovell (1979) developed stochastic frontier models of production, cost of associated factor demand. Their production function may be written as

$$\log y_i = A + \sum_{i=1}^{n} \alpha_i \log x_i + v - u \qquad (1).$$

where y_i is output, x_i are inputs, $v \sim N(0, \sigma_v^2)$ and u is the absolute value of $u \sim N(0, \sigma_u^2)$.

Assuming output to be exogenous, firm minimises costs subject to the constraint 1, the first order condition may be written as

$$\log x_1 - \log x_i = \log(\alpha_1 q_i / \alpha_i q_1) + \varepsilon_i \qquad i = 2 \ldots n, \ \varepsilon \gtreqless 0 \quad — (2)$$

where q_i are input prices and ε_i represents allocative inefficiency of the firm and has a multivariate normal distribution with mean zero and covariance matrix Σ.

The associated cost function may be written as

$$\log(q x) = B_0 + \frac{1}{\gamma} \log y + \sum_{i=1}^{n} (\alpha_i / \gamma) \log q_i - \frac{1}{\gamma}(v - u) + E \quad — (3).$$

where $\gamma = \sum_{i=1}^{n} \alpha_i$

The parameters α_i and γ can be estimated by using MLE on the system of n equations on (2) and (3). The mean technical efficiency and its associated costs is measured by the terms $E(u)$ and $[(\frac{1}{\gamma}) E(u)]$ respectively. An advantage of this model is that it permits observation specific measures of allocative inefficiency represented by ε_i and its associated cost, represented by E, to be calculated.

Schmidt and Lovell (1980) extended their model to include a possibility of correlation between technical and allocative efficiency. On a Priori grounds, one expects a technically efficient firm to be efficient allocatively also, which is confirmed by the Schmidt - Lovell's finding of positive correlation between the two efficiencies. Another important finding of their study is that the ways of modelling inefficiency relative to stochastic frontier and the nature of inefficiency do not have any appreciable effect on the shape and placement of the frontier.*

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* Schmidt and Lovell 1980, Page 91.

The main weakness of the stochastic frontier model is that it is possible to estimate average efficiency over the sample, it does not permit individual residuals to be decomposed into their components to obtain an observation specific measure of technical efficiency.

The choice between deterministic and stochastic models depends on the objective of the study. If the objective is to study relative technical efficiency of the firms in an industry, it requires deterministic set up. If the objective is to study "average efficiency" of industry and there are reasons to believe that data are not measured accurately then stochastic set up is appropriate.

The above discussion has been mainly in terms of direct estimation of frontier production function because the aim of this study is to measure technical efficiency emperically by direct estimation of frontier production function.

Since this study is concerned with measurement of technical efficiency it is necessary to define the concept of technical efficiency clearly.

TECHNICAL EFFICIENCY

The Concept of technical efficiency is an ambiguous one and different studies have given different interpretations to it. Leibenstein (1966) attributed technical efficiency to " structure of preferences of managers and workers." Premeaux (1977) found lack of competitive pressure to be the major determinant of technical efficiency of the firms. Shapiro and Muller (1977) attributed technical efficiency to the stock of information with the enterpreneurs.

The technical efficiency of a firm is, in fact, a function of productivity of managerial and non- managerial factors of production. The productivity of management is itself a function of many variables :-

(a) The stock of information available.

(b) Training and Experience

(c) The pressure of competition to make efforts.

(d) Political and legal constraints on decision making.

(e) The organisational structure of the firm andincentives provided by it.

As far as productivity of labour is concerned, given the skill mix of labourers, " getting the results from them" is a task of management, through organisation, allocation, control, co-ordination of labourers and maintenance of good labour relations.

Given the vintage of capital, the productiveness of capital and raw materials is also determined by the management through decisions regarding maintenance of capital, usage of capital and raw materials, promotion of R&D to adopt better techniques in usage of machines, instruments and raw materials.

Thus apart from vintage of capital and skills of labourers, the resource use efficiency of a firm is mainly determined by the efficiency of management, which ofcourse, in turn is function of a number of factors.

MEASURES OF TECHNICAL EFFICIENCY

Frontier production function yields two types of measures of technical efficiency (a) firm specific measures (b) average over the sample. Deterministic production frontiers based on onesideness assumption of residuals, permit calculation of firm specific measures of technical efficiency. These measures can be either input based showing extent of difference between actual and frontier usage of inputs or output based showing extent of difference between actual and frontier output. Each firm of the industry can be ranked according to these two measures and their relative efficiency can be studied. Ranking of firms according to these two measures will differ except in case of constant returns to scale. Stochastic and Deterministic production frontiers estimated with Afrait - Richamond type approach yield measure of mean technical efficiency indicated by E(u) and do not permit calculation of firm specific measures of technical efficiency.

STRUCTURAL EFFICIENCY

Information on relative efficiencies of firms provides an insight into the structure of the industry. A measure of structural efficiency, suggested by Farrell, is the average of efficiencies of individual firms of the industry weighted by output.

Forsund and Hjal Marsson (1974) suggest construction of a hypothetical average firm and compute input saving and output increasing measures for this average unit to serve as measures of structural efficiency. The input saving ~~saving~~ measure would reflect the potential reduction in the amount of inputs needed to produce the observed industry output with frontier technology with the observed factor proportions.

The output saving measure would reflect potential increase in the amount of output produced with observed amount of inputs using frontier technology, with the observed factor proportions.

In case of Stochastic models and deterministic models without sign constraint on residuals, it is not possible to calculate a measure of structural efficiency based on firm specific measures. In these cases average level of efficiency represents structural measure of efficiency.

EFFICIENCY IN DYNAMIC CONTEX

Production decisions are dynamic hence the problem of efficiency in production is also a dynamic one. Resource allocation decisions of a firm are based on expectations over several production periods, therefore, any measure of performance with respect to allocative efficiency, over a single period, may be misleading.

On the other hand, representation of technical efficiency by means of disturbance, though static in nature, is not misleading. Given the allocation of resources, the decisions of a firm to utilise resources are of short term nature, and their impact on production can be fully captured over a span of one year. Measures of technical efficiency, at a point of time, provide useful information about the relative performance of firms and shed light on the structure of the industry. Such measures can be calculated over a number of years to show shifts in the production structure of the industry over time.

A P P E N D I X - 1

SALIENT FEATURES OF SOME IMPORTANT FRONTIER PRODUCTION STUDIES

SN	NAME OF THE STUDY	NATURE OF STUDY	FUNCTION FORM USED	SPECIFICATION OF ERROR	TECHNIQUE OF ESTIMATION	NATURE OF EFFICIENCY MEASURE
1	Aigner & Chu 1968	Deterministic	Homogeneous (Cobb-Douglas)	Unspecified with side constraint $E_i \leq 0$	L.P. Q.P.	Observation specific (though not calculated)
2	Timmer (1971)	Deterministic	Homogenous (Cobb-Douglas)	Unspecified with side constraint $E_i \leq 0$	L.P.	Observation specific
3	Richamond 1974	Deterministic	Homogeneous (Cobb-Douglas)	$E_i = e^{-z}$ $z \sim$ as a gamma	Adjusted OLS	Average efficiency over the sample
4.	Aigner, Amemiya & Poirior 1976	Stochastic	Homogeneous (Cobb-Douglas)	$E_i = \begin{cases} E_i^* / \sqrt{1-\theta} & \text{if } E_i^* > 0 \\ E_i^* / \sqrt{\theta} & \text{if } E_i^* \leq 0 \end{cases}$ $E_i^* \sim N(0, \sigma^2)$ for $0 < \theta < 1$ $\sim$ Negative truncated for $\theta = 1$ $\sim$ Positive truncated for $\theta = 0$.	M.L.E.	Average efficiency over the sample.

APPENDIX – 1 CONT.

5	Aigner, Lovell & Schmidt 1977	Stochastic	Homogeneous (Cobb-Douglas)	$E_i = u_i + v_i$ $u_i \sim N(0, \sigma^2)$ $v_i \sim$ truncated	M.L.E.	Average efficiency over the sample
6	Meeusen & Broeck 1977	Stochastic	Homogeneous (Cobb-Douglas)	$E_i = u_i + v_i$ $u_i \sim N(0, \sigma^2)$ $v_i \sim$ exponential	M.L.E.	Average efficiency over the sample
7	Forsund and Jansen 1977	Deterministic	Homothetic (Zellner and Revankar type)	$E_i = (1+\alpha) u_i^{\alpha}$ $\alpha > -1$, for $0 < u \leq 1$.	L.P.	Observation specific
8	Lee & Tyler 1978	Stochastic	Homogeneous (Cobb-Douglas)	$E_i = u_i + v_i$ $u_i \sim N(0, \sigma_u^2)$ $v_i \sim N(0, \sigma_v^2)$	M.L.E.	Average efficiency over the sample
9	Forsund and Hjalmarssen 1979	Deterministic	Homothetic (Zellner and Revankar type)	Unspecified with side constraint $E_i \leq 0$	L.P.	Observation specific

APPENDIX – 1 CONT.

10	Schmidt and Lovell 1979	Stochastic	Homogeneous (Cobb-Douglas)	$E_i = u_i + v_i$ $u \sim N(0, \sigma_u^2)$ $v \sim N(0, \sigma_v^2)$	M.L.E.	Observation specific for allocative efficiency and average over sample for technical efficiency
11	Greene 1980	Deterministic	Flexible translog	$E_i \leq 0$ $E \sim G(\lambda P)$ $\lambda > 0, P > 2$	M.L.E.	Average efficiency over the sample.

P A R T   T H R E E

MEASUREMENT OF PRODUCTIVITY IN INDIAN POWER GENERATION INDUSTRY

S C O P E

This study proposes to estimate the deterministic production frontier of the electicity generation industry. A non stochastic approach is addopted in the prsent study because the object is to study the relative performance of State Electricity Boards, which is not possible in a stochastic framework. The study is confined to State Electricity Boards of the Indian Electricity generation industry - in particular to steam based electricity generation by the State Electricity Boards. The State Electricity Boards in India have been constituted under the Electricity (Supply) Act 1948. Most of the State Electricity Boards came into being during the decade 1957-67. At present there are 18 State Electricity Boards in operation, the list of which alongwith the dates of establishment is given in table 8.

The State Electricity Boards occupy a central place in our power generation industry. Tables 9 and 10 show the organisational structure of electric power generation industry and place of State Electricity Boards in it.

The public sector accounts for most of this industry, the share of the private sector being only 4.74% and 6.33% capacity and output wise respectively.

The State Electricity Boards account for about 76% of total capacity and 74% of total output of the industry.

Other organisations in the public sector are power corporations, undertakings, electricity departments and municipality undertakings. Power corporations, undertakings and electricity departments account for 18.41% of the total capacity and 18.43% of total output of the industry. Share of municipalities is very small i.e. 0.97% and 1.40% of capacity and output respectively.

The industry consists of five types of prime movers namely (1) Steam (2) Hydro (3) Diesel (4) Gas (5) Nuclear.

Prime moverwise allocation of capacity and output is given in tables 11 and 12. Steam based electricity generation occupies most important place, accounting 56.21% of total capacity installed and 53.25% of total electricity generated. Hydro based electricity occupies place of second importance, representing 40.02% of total capacity and 43.47% of total electricity generated. Nuclear, gas and diesel based electricity generation accounts for 2.25%, 0.94% and 0.58% of the total capacity and 2.75%, 0.48% and 0.05% of total output.

The State Electricity Boards' steam based electricity generation accounts for about 74% of total capacity and 71% of total electricity generated. Thus a study of steam electricity generation by the State Electricity Boards covers a substantial proportion of the industry.

TABLE - 8

SN	STATE ELECTRICITY BOARDS	DATE OF ESTABLISHMENT
1.	Andhra Pradesh	1. 4.59
2.	Assam	1. 6.58
3.	Bihar	1. 4.58
4.	Gujarat	1. 5.60
5.	Haryana	3. 5.67
6.	Himachal Pradesh	31. 8.71
7.	Jammu and Kashmir	5. 9.72
8.	Karnataka	30. 9.57
9.	Kerala	31. 3.57
10.	Madhya Pradesh	1. 4.57
11.	Maharashtra	20. 6.60
12.	Meghalaya	21. 1.75
13.	Orissa	1. 3.61
14.	Punjab	3. 5.67
15.	Rajasthan	1. 7.57
16.	Tamil Nadu	1. 7.57
17.	Uttar Pradesh	1. 4.59
18.	West Bengal	1. 5.56

T A B L E - 9

ORGANISATIONAL STRUCTURE OF INDIAN ELECTRICITY GENERATION INDUSTRY (1979-80)

(IN TERMS OF INSTALLED CAPACITY)

SN	NAME OF THE ORGANISATION	INSTALLED CAPACITY IN MW.	% OF SHARE IN TOTAL INSTALLED CAPACITY
1.	State Electricity Boards	21545.77	75.74
2.	Power Corporations/Undertakings/ Electricity Departments	5236.66	18.41
3.	Municipality Undertakings	276.52	0.97
4.	Private Licensees	1388.88	4.74
	TOTAL	28447.83	100.00

T A B L E - 10

ORGANISATIONAL STRUCTURE OF INDIAN ELECTRICITY GENERATION INDUSTRY (1979-80) IN TERMS OF OUTPUT GENERATED

SN	NAME OF THE ORGANISATION	OUTPUT GENERATED	% SHARE IN TOTAL OUTPUT GENERATION
1.	State Electricity Boards	77255.89	73.84
2.	Power Corporations/ Under-takings/ Electricity Departments	19287.01	18.43
3.	Municipality Undertakings	1466.74	1.40
4.	Private Licensees	6617.62	6.33
	TOTAL	104627.26	100.00

TABLE - 11

PRIME MOVERWISE CAPACITY INSTALLED IN ELECTRICITY GENERATION INDUSTRY (1979-80)

PRIME MOVER	CAPACITY INSTALLED (M.W.)	% SHARE IN TOTAL CAPACITY INSTALLED
Steam	15991.13	56.21
Hydro	11383.97	40.02
Diesel	164.73	0.58
Gas	268.00	0.94
Nuclear	640.00	2.25
TOTAL	28447.83	100.00

TABLE - 12

PRIME MOVERWISE ELECTRICITY GENERATED
(GROSS 1979-80)

PRIME MOVER	ELECTRICITY GENERATED (G.W.H.)	% SHARE IN TOTAL ELECTRICITY GENERATED
STEAM	55719.83	53.25
HYDRO	45477.55	43.47
DIESEL	53.32	0.05
GAS	499.97	0.48
NUCLEAR	2876.59	2.75
TOTAL	104627.26	100.00

METHODOLOGY

The study proposes to use homogeneous form to estimate the frontier production function in the electric power generation industry. Other more desirable forms e.g. homothetic and flexible can not be used due to inadequacy of data and non-availability of computer programmes for such forms.

The model may be written as :-

$$Y_i = A K_i^{\alpha} L_i^{\beta} R_i^{\gamma} \qquad i = 1 \ldots n \qquad \text{— (1)}$$

Where Y = Output

K = capital

L = labour

R = raw material

A, α, β, γ are the parameters to be estimated.

Taking natural logarithms (1) becomes linear

$$Y_i = a + \alpha K_i + \beta L_i + \gamma R_i \qquad \text{— (2)}$$

The estimating form of can be written as :-

$$Y_i = a + \alpha k_i + \beta L_i + \gamma R_i + e_i \qquad \text{— (3)}$$

$$e_i \leq 0$$

Where e_i is the disturbance term assumed to reflect efficiency differences. Assuming all e_is to be non positive, eq. (3) can be written as :-

$$\hat{a} + \hat{\alpha} K_i + \hat{\beta} L_i + \hat{\gamma} R_i = \hat{Y}_i \geq Y_i \qquad \text{— (4)}$$

OR

$$\hat{a} + \hat{\alpha} K_i + \hat{\beta} L_i + \hat{\gamma} R_i - \hat{e}_i = Y_i \qquad \text{— (5)}$$

Summing equation (5) over n

Observations and solving for $\sum_{i=1}^{n} \hat{e}_i$

$$\sum \hat{e}_i = \sum_{i=1}^{n} \hat{a} + \sum_{i=1}^{n} \hat{\alpha} K + \sum_{i=1}^{n} \hat{\beta} L + \sum_{i=1}^{n} \hat{\gamma} R - \sum Y_i \qquad \text{— (6)}$$

Since term $\sum Y_i$ is a constant, it can be droped. Dividing equation (6) by n observations, one obtains objective function to be minimised i.e.

Minimise

$$\hat{a} + \hat{\alpha}k + \hat{\beta}\,l + \hat{\gamma}\,r$$

S.t.

$$\hat{a} + \hat{\alpha}K_i + \hat{\beta}L_i + \hat{\gamma}R_i \geq Y_i$$

$$i = 1 \ldots\ldots n$$

$$\hat{a}, \hat{\alpha}, \hat{\beta}, \hat{\gamma} \geq 0$$

Equation(3)can also be estimated by using corrected ordinary least squares. Equation(3)could have been estimated by MLE. But MLE is not used in this study because (a) it gives only mean efficiency over the sample (b) the statistical properties of MLE in case of estimation of full frontier are uncertain due to non-fulfilment of the regularity conditions (c) use of MLE requires specification of efficiency distribution which should ideally be based on the economic mechanism generating cross section efficiency differences. In absence of such information the choice between specifying a distribution and not specifying is not clear cut.*

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* Broeck et al 1980.

D A T A

Since a production function represents transformation of inputs into output, all data used for estimation of production function should be in physical terms. Most of the frontier production and average production function estimation studies have utilised data expressed in value terms allowing the impact of prices to creap in.

All data used in this study are in physical units. The output - electricity generated is expressed in Giga Watt Hours (G.W.H.). Electricity generated is clearly a homogeneous product and the assumption of homogeneity required for production function estimation is satisfied in strict sense. Capital is represented by the capacity installed to generate electricity, measured in megawatts. Labour is defined in terms of number of labourers employed. Since the prime moverwise break up of labour employed in State Electricity Boards is not available, data on labour employed in steam stations is obtained by allocating total number of labourers employed in the Electricity Boards according to output of steam stations. In order to check whether allocation of labour according to output of steam stations is justified, the ratios of employment to output were corelated and regressed to ratios of steam output to to total output of State Electricity Boards. The results of correlation and regression analysis for the year 1980-81 are given in table 13.

The ratios are poorly correlated and are not statistically significant. The regression coefficient is also not statistically significant with R^2 .41. Therefore, the labour can be allocated to steam stations according to their outputs.

T A B L E - 13

CORRELATION COEFFICIENT	0.39 (1.1205)
REGRESSION COEFFICIENT	8.53 (0.0774)
R^2	0.41

t values of the coefficients are shown in the parenthesis.

There are seven types of fuel that are being used in steam based electricity generation. These are coal,lignite, furnace oil, light diesel oil, low sulphur heavy stock, Hot heavy and natural gas. The proportion in which these fuels are used, varies across the State Electricity Boards. In order to take account of different fuel mix, the fuel consumption is measured by the total heat input used in electricity generation. The heat input is measured in K callories X 10^9 and calculated by taking coal equivalent of other fuels in terms of calorific value.

R E S U L T S

The features of estimated average & frontier production function are given in tables 14 and 15. The $\bar{R}^2$ in case of ordinary least square estimates is 0.93 indicating that the fit is good. Both production functions exhibit increasing returns to scale.

T A B L E – 14

FEATURES OF ESTIMATED AVERAGE PRODUCTION FUNCTION

A	•	•	•	$\bar{R}^2$	RTS
1.2019	0.8773	0.1232	0.0733	0.93	1.0738
	(7.269)	(0.945)	(1.307)		

NOTE : The figures in paremthesis indieate the t values of the estimates. *What about t values? Is it significant?*

T A B L E – 15

FEATURES OF ESTIMATED FRONTIER PRODUCTION FUNCTION

A	•	•	•		RTS
2.6549	0.8403	0.0545	0.1143	–	1.0091

The intercept of the frontier is higher than the average production function implying that units on the frontier are technically more efficient. The output elasticity of labour and capital is lower and that of raw material is higher on the frontier than the average production function. This implies that units on the frontier achieve higher productivity of raw material and the improvements in technical efficiency are not labour and capital (to a lesser extent) augmenting.

The indices of technical efficiency are calculated as ratio of actual to estimated output and the units are ranked according to level of efficiency in table 16. The units of the sample appear to be falling into 4 major groups. The first and relatively most efficient group comprises of the Electricity Boards of Gujarat and Andhra Pradesh and D.E.S.U..

The second and relatively more efficient group consists of Electricity Boards of Maharashtra and Madhya Pradesh. The third group at a medium level of efficiency includes the Punjab Electricity Board and D.V.C. The last and relatively most in-

TABLE - 16

RANKING OF STATE ELECTRICITY BOARDS, D.E.S.U., D.V.C. ACCORDING TO LINEAR PROGRAMMING INDECES OF TECHNICAL EFFICIENCY

SN	NAME OF THE BOARD/UNDERTAKING CORPORATION	INDEX OF TECHNICAL EFFICIENCY
1	GUJARAT	1.00
2	D.E.S.U.	0.99
3	ANDHRA PRADESH	0.99
4	MAHARASHTRA	0.86
5	MADHYA PRADESH	0.82
6	PUNJAB	0.76
7	D.V.C.	0.74
8	WEST BENGAL	0.68
9	ORISSA	0.67
10	BIHAR	0.60
	MEAN	0.79

efficient group consists of the Electricity Boards of Bihar, Orissa and West Bengal.

The corrected ordinary least square estimates of frontier production are also calculated and indices of technical efficiency based on them are shown in table 17.

The ranking of units according to corrected least squares based indices of technical efficiency is almost the same as in case of linear programming based indices of technical efficiency.

The matter of concern from policy point of view, is to find out the sources for variation of efficiency across the firms. As discussed earlier, technical efficiency of a firm is mainly dependent on (1) vintage of capital (2) skills of labour (3) efficiency of management which in turn is a function of a number of economic and non-economic factors. The information on the variables like vintage of capital and direct measures of managerial efficiency like education, training and experience of managers, is not available. The ratio of technical and scienti-

T A B L E - 18

RANKING OF THE STATE ELECTRICITY BOARDS, DESU & DVC ACCORDING TO CORRECTED ORDINARY LEAST SQUARE INDICES OF TECHNICAL EFFICIENCY

SN	NAME OF THE BOARD/UNDERTAKING/ CORPORATION	INDEX OF TECHNICAL EFFICIENCY
1	Gujarat	1.00
2	D.E.S.U.	0.94
3	Andhra Pradesh	0.84
4	Maharashtra	0.81
5	Madhya Pradesh	0.78
6	Punjab	0.78
7	D.V.C.	0.75
8	Orissa	0.72
9	West Bengal	0.68
10	Bihar	0.57
	Mean	0.78

fic officers to non-technical staff is taken as an index of skill intensity of labour. Some of the indirect measures of managerial efficiency like capacity utilisation, production workers per supervisor, auxilary consumption are taken to represent managerial efficiency. The results of Spearman correlation of the above mentioned variables with the L.P. indices of technical efficiency are given in table 18. All the coefficients show expected signs and are satistically significant.

The skill intensity of labour is positively and highly correlated with the level of technical efficiency implying units having higher level of technical efficiency are having a high proportion of skilled labour.

The capacity utilisation is also highly and positively correlated with the level of technical efficiency. The ratios production workers/supervisor and auxillary consumption/ gross generation, as expected, are negatively correlated to the level of technical efficiency indicating that inefficient units are

T A B L E - 18

SPEARMAN CORRELATION BETWEEN TECHNICAL EFFICIENCY AND OTHER VARIABLE

SN	VARIABLE	COEFFICIENT OF CORRELATION	t VALUE
1.	Technical and Scientific officers/ non-technical staff	0.93	2.278
2.	Capacity/ gross generation	0.98	2.9459
3.	Production workers/ Supervisor	6.81	18.017
4.	Auxillary consumption/ gross generation	8.76	23.192

charaterised by poor supervision of labour and high consumption of power in their auxilieries.

Thus managerial efficiency does appear to be an important determinant of technical efficiency though skill intensity of labour also is important.

The section above has discussed the distribution of relative efficiency and factors accounting for difference in relative efficiency across the units. From the individual indices of technical efficiency, it is possible to calculate the mean level of efficiency of the industry. The mean level of efficiency from both Linear programming and corrected Least square estimates comes to around 78%. This implies that about 22% increase in the electricity output can be obtained by the efficient use of existing resources of the industry, and the power deficit of the country which is around 16% can be very easily wiped out from the existing resources.

Since power is a highly capital intensive industry, aiming to bridge the power deficit through addition of new capacity, which has been the area of major thrust in our power policy, would mean incuring huge amount of additional costs for what could be achieved from existing resources.

There are a number of reasons for low level of technical efficiency in the industry. First, the rate of capacity utilisation is very low. As mentioned earlier also, the All India MW utilisation in the country is about 45% implying 55% of the available capacity is not utilised during peak hours. The low level of utilisation of capacity in electricity generation industry can be attributed to (1) outages - planned and forced (2) partial unavailability (3) Lack of demand.

As the country is suffering from shortage of power, the possibility of lack of demand during peak hours is ruled out. The capital equipment by the nature of production process in this industry requires regular maintenance. Therefore plants are not available for generation due to planned shut downs for maintenance. Such shut downs do not reflect operational inefficiency. The factor that reflects inefficiency in utilisation of installed capacity is infact the unscheduled plant shut downs due to forced outages or partial unavailability.*

The statistics regarding various components of rates of utilisation are given in table 19.

TABLE - 19

UTILISATION OF INSTALLED CAPACITY IN 1979-80

1.	Planned Outages	12.3%
2.	Forced Outages	18.8%
3.	Plant Availability	68.9%
4.	Partial Unavailability	23.52%
5.	Capacity Utilisation	45.41%

SOURCE :- Rajadhyaksha Committee 1980.

* The ' partial unavailability' of the plants is defined as less than full load generation due to break downs of some part of the equipment, lack of raw materials etc.

The percentages of forced outages and partial unavailability are 19% and 23% which are very high and explain the inefficiency in utilisation of installed capacity.

Besides a high incediance of forced outages and partial unavailability, the plant availability is further reduced due to unusually long time taken for planned shut downs. For example, the average time taken for the annual overhaul of boiler is about 60 days whereas it requires 4 weeks time according to experts.

Further, there is negligence in doing overhaul of capital like boilers, turbines generators at their due time. This not only leads to a higher pcercentage of unscheduled outages but also reduces their life span.

Another factor accounting for the poor performance of the power industry is the low productivity of labour. A very large number of people in this industry, as in other public sector industries, have been employed apparently on the premise that as long as the marginal productivity of labour is not zero or minus , employment can be increased. The employees lack the sense of belonging to the enterprises which leads to apathetic attitude towards work, low morale and lack of willing co-operation and strikes.

The consumption of raw materials in steam based plants in India is also on high side. This is partly due to poor quality of raw material e.g. high ash content of coal and partly due to human failures in proper utilisation e.g. the size of coal fed into the boilers is not proper, the foreign material present in the coal is not removed, the water used is not treated adequantly for silica content leading to rusting of the turbines.

The poor maintenance and utilisation of capital, poor management and usage of labour and raw materials clearly point to the inefficient management of public sector enterprises in the industry. The State Electricity Boards wallow in almost feudal culture. The boards are in overall control of State Governments and are run as extentions of bureaucracy. All important appointments are political and the interference with working of the Boards is too much.

Also, there is lack of sense of belonging to the Boards among the managers which leads to apathy and lack of interest in work. Moreover, in absence of competition, there is no stimules to exert, innovate and improve.

Perhaps, the most important requirement of the power industry, at present is the replacement of existing bureacratic system by the professionalised autonomous management equipped with skills and motivation to ensure effective and efficient management. In fact, the Electricity Act 1948,under which the State Electricity Boards came into being,envisaged them to be professionally managed, autonomous agencies running on quasi - commercial lines. The policy of operation on non-commercial lines i.e. the consumers, specially so called priority sectors, are to be supplied electricity without reference to cost of generation has not only made the industry insolvent but also provided a protection to inefficiency. If only the Boards are allowed to work as conceived by the Act, the efficiency of the industry can be increased considerably.

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