INSTITUTIONS, INERT AREAS AND X-EFFICIENCY: An Analysis of State Transport Undertakings in India

DISSERTATION
SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE
AWARD OF THE DEGREE OF
MASTER OF PHILOSOPHY
IN APPLIED ECONOMICS OF THE
JAWAHARLAL NEHRU UNIVERSITY, NEW DELHI

BINOY JOHN K. V.

CENTRE FOR DEVELOPMENT STUDIES
THIRUVANANTHAPURAM
1997

DECLARATION

July 18, 1997.

I hereby affirm that the research for this dissertation titled "**Institutions, Inert Areas and X-Efficiency: An Analysis of State Transport Undertakings in India**" being submitted to the Jawaharlal Nehru University for the award of the Degree of Master of Philosophy, was carried out entirely by me at the Centre for Development Studies, Thiruvananthapuram.

Binoy John K.V.

Certified that this dissertation is the bonafide work of Binoy John K.V. This has not been considered for the award of any other degree by any other university.

K. Pushpangadan
Associate Fellow
(Supervisor)

Achin Chakraborty
Associate Fellow
(Supervisor)

Chandan Mukherjee
Director

CENTRE FOR DEVELOPMENT STUDIES
Thiruvananthapuram

Acknowledgement

First and foremost,

With a deep sense of admiration, may I acknowledge that insights received from the works of Leibenstein, R H Coase and Oliver Williamson form the basis of this thesis.

I was fortunate to have Dr. K Pushpangadan and Dr. Achin Chakraborty as my supervisors. I thank Dr. K Pushpangadan for initiating me to this area of research and lending all sorts of help at every stage of the work. I thank Dr. Achin Chakraborty for critical comments and insightful interactions, which made many micro concepts clearer to me. The freedom of work I enjoyed with my supervisors was great. I thank both of them for their patience and confidence they have shown towards me.

I am indebted to Dr. U Shankar, Madras School of Economics, for the invaluable comments on different aspects of the study.

I express my sincere gratitude towards Dr. Chandan Mukherjee, Director of C D S, Dr. D. Narayana the M.Phil course co-ordinator of our batch and Dr. P Mohanan Pillai, the present co-ordinator for their help and support.

The principal and my colleagues at St. Joseph's College, Devagiri, Kozhikode gave me all the moral support and facilities to do this work. I thank them all.

The help, encouragement and care I received from Dr. M H Suryanarayana are beyond a few words of thanks. The research aptitude in me was cultivated at the post graduate classes at Department of Economics, University of Kerala, Kariavattom. I am grateful to all my teachers at Kariavattom especially Dr. K. Ramachandran Nair, Dr. S Umadevi, Dr. M. Kunhaman and Dr. M K Saralamma. I express my heartful thanks to Mr. Hemanth Kumar, City University of New York, who was my senior at Kariavattom, for the guidance and intellectual stimulations.

I record my heartful thanks to Mr. D Ramarajan, Executive Director, KSRTC, for making the data available and giving useful directions. I thank Dr. Shirley Shmerling of 1 Consulting, Amherst, U S A for the timely help to make available the software to run DEA at a critical time.

I thank all my classmates for their company and useful interactions. Father Charles was a friend to rely upon any time; Charvak spent a lot of time giving comments. The help received from Renu, Lekha, Mallika and Uma are greatfully acknowledged.

The discussions with my seniors were very helpful. I thank G. Murugan, Antonyto, Harikurup, Suresh and Dennis for their help. Pinaki was always there to depend upon.

I thank all my friends for their encouragement and support in different dimensions. Mathew, Biju, Seemon, Antony Mathews, Sunil, Ajith, Sojan, Amir and Resmi are thanked from heart. Rajkishan took the pain to go through the different chapters; Varghese sat with me to decipher many mathematical formalisations. Words fail to thank them. I don't know how to thank Sam and Johnson for their company and help at all stages of my work. Rajesh was always there with me to extend all sorts of help at all stages of work - from collection of data to printing of thesis. His computer skills helped me to overcome many problems. Heartful thanks to him.

At home, the affection of Binu and Boby for me was always my strength. The expectations my Pappa and Mummy have in me and their prayers were my inspiration and source of energy. I don't know the words or language to thank them. I dedicate this thesis to my Pappa and Mummy.

C D S **Binoy John**

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

I

ASRTU	-	Association of State Road Transport Undertakings
STU	-	State Transport Undertaking

II

APSRTC	-	Andhra Pradesh State Road Transport Corporation
ASTC	-	Annai Sathya Transport Corporation Limited
ATC	-	Anna Transport Corporation Limited
CRC	-	Cholan Roadways Corporation Limited
CSTC	-	Calcutta State Transport Corporation
CTC	-	Cheran Transport Corporation Limited
DCTC	-	Dheeran Chinnamalai Transport Corporation Limited
GSRTC	-	Gujarat State Road Transport Corporation
JTC	-	Jeeva Transport Corporation Limited
KDTC	-	Kadamba Transport Corporation Limited
KnSRTC	-	Karnataka State Road Transport Corporation
KSRTC	-	Kerala State Road Transport Corporation
KTC	-	Kattabomman Transport Corporation Limited
MGRTC	-	Puratchi Thalaivar MGR Transport Corporation Limited
MPSRTC	-	Madhya Pradesh State Road Transport Corporation
MPTC	-	Marudhu Pandiyar Transport Corporation Limited
MSRTC	-	Maharashtra State Road Transport Corporation
NBSTC	-	North Bengal State Transport Corporation
NTC	-	Nesamony Transport Corporation Limited
OSRTC	-	Orissa State Road Transport Corporation
PATC	-	Pattukkottai Azagiri Transport Corporation Limited
PRC	-	Pandiyan Roadways Corporation Limited
PRTC	-	Pepsu Road Transport Corporation Limited
RMTC	-	Rani Mangammal Transport Corporation Limited
RSRTC	-	Rajasthan State Road Transport Corporation
SBSTC	-	South Bengal State Transport Corporation
STHAR	-	State Transport Haryana
STPJB	-	State Transport Punjab
TPTC	-	Thanthai Periyar Transport Corporation Limited
TTC	-	Thiruvalluvar Transport Corporation Limited
UPSRTC	-	Uttar Pradesh State Road Transport Corporation

III

PK	-	Passenger Kilometers
SK	-	Seat Kilometers
CL	-	Capital & Liabilities
BU	-	No. of Buses
FU	-	Fuel (HSD Oil) Consumption
MC	-	Material Cost Other than Fuel
TS	-	No. of Traffic Staff
WS	-	No. of Workshop Staff
AS	-	No. of Administrative Staff

IV

@	Departmental Undertaking
*	Statutory Corporation
#	Government Company

...military science assumes the strength of an army to be identical with its numbers. Military science says that the more troops the greater the strength. *Les gros battailons ont toujours raison* (Large battalions are always victorious)...

In military affairs the strength of an army is the product of its mass and some unknown x...

That unknown quantity is the spirit of the army...

the spirit of an army is the factor which multiplied by the mass gives the resulting force. To define and express the significance of this unknown factor - the spirit of an army - is a problem for science.

This problem is only solvable if we cease arbitrarily to substitute for the unknown X itself the conditions under which that force becomes apparent - such as the commands of the general, the equipment employed, and so on - mistaking these for the real significance of the factor, and if we recognize this unknown quantity in its entirety as being the greater or lesser desire to fight and to face danger.

Leo Tolstoy, *War and Peace*

Chapter 1
INTRODUCTION

1.1 The Theme

Efficiency lies in the heart of economics. Right from the time of classicals, the analysis of efficiency has been a central concern for economists. Unlimited wants constrained by limited resources make efficiency the goal for households, firms and governments; and the theme for economists. As Leibenstein (1966, p.392) states "At the core of economics is the concept of efficiency".

1.2 The "Fundamental insight"

Firms, left with limited resources and other constraints face the question of efficiency in maximising output. They are engaged in the process of transforming inputs into output(s). Conceptually, a productive activity transforms a vector of non-negative inputs into a vector of non-negative outputs subject to the constraint of fixed technology. Shephard (1974, 1970, 1953) models this process by an input correspondence and by an output correspondence[1]

The inputs $\underline{x} = (X_1, X_2, X_3, \ldots, X_n) \in \mathbb{R}_+^n$ are transformed into net outputs $\underline{y} = (Y_1, Y_2, Y_3, \ldots, Y_m) \in \mathbb{R}_+^m$. The input correspondence is denoted by $L(\underline{y})$ and the output correspondence by $P(\underline{x})$. The inverse relationship between L and P is given by:

$$\underline{x} \in L(\underline{y}) \iff \underline{y} \in P(\underline{x}) \qquad (1.2.1)$$

An input correspondence defines the subset of input vectors $\underline{x} \in \mathbb{R}_+^n$ which yield at least output levels of $\underline{y}$. Analogously an output correspondence specifies the subset of all output vectors $\underline{y} \in \mathbb{R}_+^m$ obtainable from input levels $\underline{x}$. (Ganley and Cubin, 1992).

It may be computed as (Fare. Gasskopf and Lovell (1985)):

$$P(\underline{x}) = \{ \underline{y} : \underline{x} \in L(\underline{y}) \} \quad (1.2.2)$$

and:

$$L(\underline{y}) = \{ \underline{x} : \underline{y} \in P(\underline{x}) \} \quad (1.2.3)$$

The input correspondence $L(\underline{y})$ and the output correspondence $P(\underline{x})$ for the simple case of n=m=2 are illustrated in Figure 1.2.1a & 1.2.1b.

Figure 1.2.1a The Input Correspondence, n=2

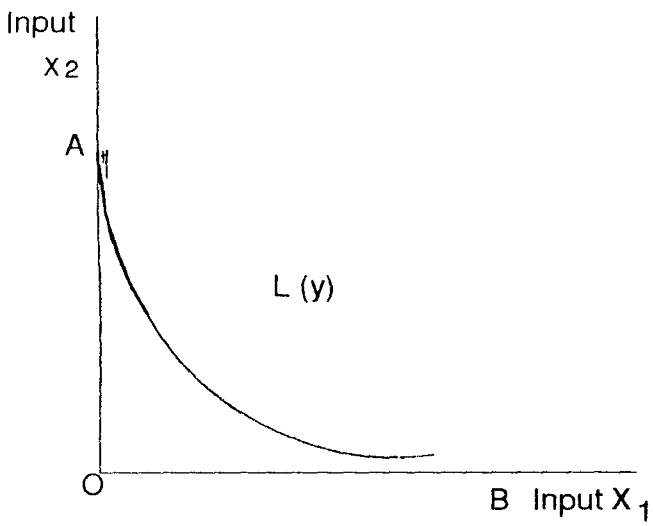
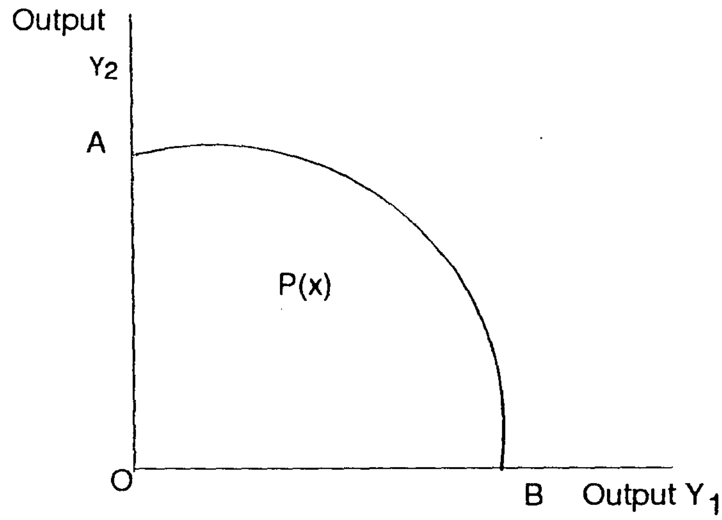


Figure 1.2.1b The Output Correspondence, m=2



In Part A of Figure 1.2.1 the boundary of the input correspondence AB is the conventional isoquant and analogously AB in Part B is the production possibility frontier for the given technology and input vector $\underline{x}$. A transformation process of inputs into output can be called efficient only if the firm is on the curve AB. If inefficiency exists, then the specification of the production function will be an inequality:

$$y_i < f(\underline{X}_i ; \underline{\beta}) \quad (1.2.4)$$

where y_i is the observed output and $\underline{X}_i$ is the vector of inputs and $\underline{\beta}$ the vector of parameters which describes the transformation process. If $y_i < y_{max}$; where $y_{max} = f(.)$ has the interpretation of a frontier, the difference between y_i and y_{max} raises the question of (in)efficiency in the firm for which the answer requires a detailed enquiry into the complexities of the production process in firms. It turns to an interesting enquiry when some firms are doing the transformation process in a better way compared to others.

Definitely this sort of an enquiry requires an approach different from the firm analysis in mainstream economics which considered firm as a " black box" (Coase, 1992). Now, the attempt is to have a look into the "black box". This should help us to understand, in a better way, the variability in the capabilities of firms in the transformation process of inputs into output(s).

A firm is conceptualised as a bundle of resources and capabilities (Penrose, 1959). These tangibles and intangibles are co-ordinated by an 'x' factor in a unique way to be transformed as outputs. The orchestration of these inputs in the transformation process co-ordinated by an 'x' factor gives rise to a unique mode of interaction of these inputs and their metabolic process in a firm. This tempts us to see the firm as an organism rather than an organisation.

Now, Marshall called the 'x' factor, organisation and introduced it as the fourth factor of production. Later J. B. Clark gave the job of 'x' factor to the entrepreneurs and Professor Knight identified managers as the 'x' factor[2]. This 'x' factor together with the interaction of other factors, determines what happens in between the purchase of the factors of production and the sale of the goods that are produced by these factors. The

---

2 Both Alfred Marshall and Frank Knight considered intrafirm elements. However these considerations have certainly dropped out of modern micro economic analysis. They do not appear to be necessary elements of the main-line neoclassical economics (Leibenstein, 1979).

understanding of the emergence, existence and importance of organisation, often described as the 'fundamental insight', gives a detailed account of the working of the system in a firm. This 'fundamental insight' reduces (or widens?) the analysis of the firm to the analysis of the institutional structure of production in the firm. Different studies by Oliver Williamson, Harold Demsetz, Steven Cheung, Thrian Eggertsan, Ronald H Coase et al initiated and emphasized the role of institutions in the production process.

The institutional structure of production within the firm is formed by the interrelations and interaction of tangible and intangible resources; which is determined by the nature of organisation; and is revealed by the principal-agent relations, the contractual agreements, the conventions etc. These institutional arrangements create costs to the firm which Coase refers to as "transaction costs"[3] (Coase, 1937). A particular organisational form (dictated by the nature of ownership) and the resulting institutional set-up set a definite level of transaction costs in a firm which is not easy to change (especially, downward) without interferences from some external forces. This defines some 'inert areas' of production. Movement from 'these inert areas' is resisted by one or more inputs which in turn becomes the resistance from all the inputs as they interact and are interrelated. In short, these 'inert areas', prevent the firm from achieving the potential output(s) from their resources and capabilities in the most productive way. And this explains why firms differ in their ability to transform inputs into output(s); in other words why some firms are more efficient than others.

This sort of an outlook towards the efficiency variations in firms requires a paradigm other than the neo-classical (the mainstream) economics. An attempt to peep into the

---

3 Transaction costs can be defined as the costs to undertake negotiations, to draw up contracts, to make inspections and to arrange for setting disputes etc.(Coase, 1992). Matthews (1986, p.906) defines it as the costs for arranging the contracts *ex ante* and monitoring and enforcing it *ex post*, as opposed to production cost, which are the costs of executing the contract. To a large extent transaction costs are the costs of relations between people and people and production costs are costs are costs of relations between people and things. In short, it is the cost for running the *system*.

"black box" itself is not facilitated by the main stream. The understanding of the existence of positive transaction costs again drifts us away from the mainstream economics where zero transaction cost is assumed. What we need is a paradigm which can allow an inside analysis of firms considering their institutional aspects and thus facilitating an intrafirm and interfirm analysis. And this is what X-Efficiency theory and paradigm try to facilitate.

X-efficiency theory and the paradigm tries to make a micro-micro analysis. In its approach the basic decision making unit is not the firm; but the different inputs in the firm. Taking each input as the decision making unit, the paradigm helps us to go beyond the conceptualisation of the firm as a "black box" in the standard micro theory. With its fundamental postulates like the Relaxation of the maximisation behaviour, Inertia of the dependent variable to the changes in the independent variable(s), Incomplete contracts between the principal and the agents, The effort discretion of the agents and the wage discretion of the principal, the paradigm helps us to incorporate the institutional factors into the analysis of the firm. While the inclusion of these assumptions and postulates leads to the collapse of the neo-classical paradigm, X-efficiency offers a better picture of the 'system' within the firm. Recognition of the institutional factors and thereby the existence of the transaction costs facilitates the understanding of the cost the firm incurs in transforming the inputs into output(s). With all these merits this paradigm can identify the inert areas and thereby the difficulties the firm encounters in achieving the potential level of output(s). The conceptualisation of efficiency as the difference between the maximum possible level of output(s) and the actual or observed level of output(s) gives a more comprehensive picture of (in)efficiency other than any other measure. In short, X-efficiency paradigm offers a better conceptualisation of (in)efficiency in a firm and the reasons behind it.

The only limitation which X-efficiency paradigm had been facing was its empirical estimation. It was because, it is argued, the factors which X-efficiency paradigm identifies for the analysis were not able to be quantified; and there was no adequate tool to capture the degree of X-efficiency. But the development of frontier measurement using econometric method of Stochastic Frontier Production Function and later the development of Data Envelopment Analysis (DEA) have helped to overcome this limitation. The latest developments in the DEA methodology allowing for flexibility scale assumptions and the disposability assumptions offers it as an excellent quantitative tool for the measurement of X-efficiency.

1.3 The Search and the Re-Search

It is from this perspective we would like to take a look at the efficiency aspect of the State Transport Undertakings (STUs hereafter)in India. Evaluation of the performance of public sector undertakings has been an attractive research area for economists in developed as well as underdeveloped countries. There are quite a large number of studies available for the literature survey. In the Indian context itself the studies like Ramaswamy and Renforth (1994), Jha and Sahni (1992), Basu (1991), Naidu (1990), Ahluwalia (1985), Ramaswamy (1972), Khera (1977), Paranjpe (1971), Ramanadhan (1963) etc constitute a very small sample of the existing literature. Almost all of these studies have been using the conventional measures of performance like total value added, net value added, capacity utilisation, profitability, return on asset etc. for their assessment.

But the evaluation of the public enterprises should have to be different from that of the private enterprises simply because of the differences in their objectives. Amartya Sen (1983) is quite right when he says "In the absence of any well formulated alternative criterion, the public tends to judge success or failure of public enterprises by profits. This might be at least partly unjustified, but it is fairly inescapable in the absence of a different system of performance evaluation". Similar concern has been expressed by Bhaya(1990). What remains logical is a measurement of how efficiently the resources at hand are utilised.

There has been many attempts to measure the performance of different Transport undertakings in India. The studies like Bagade and Paranjpe (1994), Mariamma (1993), Misra and Nandagopal (1991), Arora (1987), Chand (1982), Rao (1982), Vijayakumar (1982), Bagade (1981), Ibrahim (1978), Prakash (1977), Keshava (1972), Jayadevadas (1971), Pillai (1956), Collins (1949), Ramanadhan (1948) attempted to measure the performance of different state transport undertakings. They all relied upon the conventional measures for their assessment.

The search is to examine the concept, postulates and the paradigm of X-efficiency as an alternative to the neo-classical (mainstream) paradigm in analysing the performance of the STUs. This analysis should enable us to shed more light into the nature and causes of inefficiency in different STUs. The intra firm analysis which it makes possible should help us to study the micro unit by analysing its micro-micro units and enable us to make a more meaningful inter firm analysis.

The re-search is to evaluate the efficiency of different STUs in the new paradigm using the Data Envelopment Analysis (DEA).

In India, STUs are formed with different organisational set up. These organisational set up include Departmental Undertakings, Municipal Undertakings, Corporations and Companies. The organisational set up of these STUs define a particular institutional arrangement for each of them, which in turn critically determine their level of efficiency. In our alternative paradigm we try to find out the effect of each organisational set up and the 'pressure' it exerts on the effort level offered by the different inputs. This sort of an analysis enables us to enquire into the Averch-Johnson result that efficiency rises as the degree of government regulation falls. To this result to be true in the case of STUs in India, efficiency should increase from Departmental Undertakings to Companies. From the DEA results we try to get quantitative indicators to the existence and magnitude of the institutional factors determining the efficiency level in STUs.

1.4 The Data Source

The study is based on the cross section data of different STUs for the year 1994-95. The data was collected from the "State Transport Undertaking: Profile and Perfomance" published by Central Institute of Road Transport Undertakings (CIRT) for the Association of State Road Transport Undertakings. The study is confined to STUs conducting mofussil services for the sake of uniformity in demand and road conditions. The data for the thirty STUs analysed and the explanations of the variables used are given in the Appendix I and II respectively.

1.5 The Outline

The study is presented in Six chapters. A brief outline of the thesis can be presented as follows:

Chapter 2, titled "X-Efficiency: The Concept and The Paradigm" sets the theoretical framework. It starts with the enquiry into the different conceptualisations of efficiency and the definition of X-efficiency. The basic postulates of the X-Efficiency theory and its difference from the neo-classical economics paradigm are discussed in detail. The institutional set up and the inert areas which determine the efficiency level in the firms are analytically examined.

The X-efficiency paradigm had been hounded by the impossibility of its measurement. Chapter 3, "X-Efficiency: The Question of Empirical Estimation" examines the concept of the frontier estimation of efficiency and explains the three frequently used methods. The meaning and the methods of Parametric Stochastic Frontier Production Function method, Non-Parametric Programming and Parametric Programming are briefly presented in the first part. The method used in this study, DEA, is explained in detail in the second part. The merits of this non parametric study over other methods of frontier estimation are also discussed. Definitely, the limitations are not forgotten.

Chapter 4, "Estimation of X-Efficiency in STUs in India Using DEA" presents the results of the analysis done in this study. Thirty STUs conducting mofussil services are taken for the analysis. The cross section data refers to the year 1994-95. Apart from the measurement of the magnitude of inefficiency in these STUs, partitioning of the X-inefficiency also is attempted. For the inefficient firms, an attempt is made to identify the peer groups which can offer blue prints for improvements. An examination of scale efficiency and returns to scale in each firm is also made.

In Chapter 5, titled "Behind X-Inefficiency in STUs", search is made to look into the different reasons behind the inefficiency in STUs.

Chapter 6, "Summary and Conclusion", summarizes the study, gives the conclusions, points to the limitations and highlights the scope for further research. The Appendix given at the end presents the data set used and detailed definitions of the variables used. It also presents the reports of programme execution for DEA.

Chapter 2
X-EFFICIENCY: THE CONCEPT AND THE PARADIGM

2.1 Efficiency: Different Conceptualisations

There are a variety of notions of efficiency conceptualised by economists. A firm is considered technically efficient if it can produce the maximum feasible level of output from the inputs. It can be allocatively efficient if it can produce the maximum feasible output from a combination of minimum inputs, given the input prices. These concepts are implicit in the input and output correspondences as given in Shephard (1974, 1970, 1953).

Many attempts have been made by economists to quantify productive efficiency in a firm. They include the conceptualisation of efficiency as:

(1) The difference between the values of the outputs and inputs in constant prices.

Davis (1955) defined the absolute measure of efficiency E to be:

$$E = y - l - k - m$$

where, y is the value of output and l, k, m are the values of different inputs at constant prices. This measure of efficiency is nothing more than a profit - cost analysis.

(2) The ratio between the values of outputs and inputs.

As in Schmookler (1952), Solow (1957), Kendrick (1961), efficiency can be quantified as the ratio between the values of outputs and inputs.. This gives us the "partial productivity" of each input since it is calculated by comparing output with each input(Kendrick, 1961). But this measure fails to give an overall measure of productive efficiency. The reason is that it does not take the composition of inputs or factor substitution into consideration(Kendrick, 1956). To solve this problem, Total Factor

Productivity (TFP) was conceptualised. It is constructed by making an index that consists of a weighted average of inputs, using either relative prices or relative factor shares [Schmookler (1952), Pagin (1965), Bennett (1967), Pack (1984)].

TFP, invariably a ratio between inputs and output can be expressed as:

$$TFP = \frac{Y}{\Sigma (w_i X_i)}$$

where, Y is the level of production activity, X_i the quantity of input factor i and wi some appropriate weight, for i = 1, 2, ... , n. The weights can be either exogenously given [Harris and Philips (1984), Tidrick (1986), Jiang and Zou (1990)]or statistically estimated [Nadiri and Schankerman (1981), Greene (1983)]. Different methods have been developed to measure TFP like Kendrick Arithmetic method (Kendrick,1961) and Solow's geometric index (Solow,1957). But all these methods came under fire from Farrell (1957), who pointed to the inappropriateness of the 'weights'. He argued that the selection of weights will be at the convenience of the user and the introduction of prices as weights itself brings in an element of arbitrariness to the measure. Also, this measure fails to distinguish the effects of inefficiency from that of other factors, whether endogenous or exogenous [Farrell (1957), Barrow and Wagstaff (1989)].

These two conceptualisations of efficiency are termed classical approach and the constraints in these led to the frontier approach to efficiency.

(3) The ratio of actual output to the potential output.

This definition of efficiency stems from the production or cost frontier. A firm is inefficient if it lies below the production frontier or lies above the cost frontier. In terms of production function we can say a firm is inefficient if:

$$y_i < f\,(\underline{X}_i\,;\,\underline{\beta}) \tag{1.2.4}$$

where y_i is the actual output and $f(.) = y_{max}$ as given in eqn (1.2.4). Now the residual, ϵ_i, defined as $(y_i - y_{max})$ can give the efficiency ratio in a firm as:

$$\epsilon_i = y_i / f(\underline{X}_i ; \underline{\beta}) \qquad (2.1.1)$$

Similarly, Hamond (1986) gives the efficiency ratio in terms of a cost function. The function is specified as:

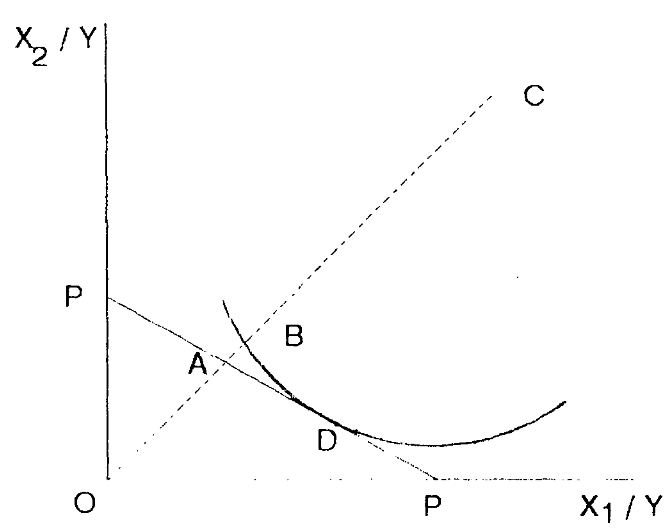
$$c_i > g(\underline{Z}_i ; \underline{\alpha}) \qquad (2.1.2)$$

where, ci is the average cost of the firm and $g(.) = c_{min}$ is defined as the frontier (minimum) cost. Now, the residual, θ_i defines the efficiency ratio of the firm as:

$$\theta_i = g(\underline{Z}_i ; \underline{\alpha}) / c_i \qquad (2.1.3)$$

This approach originated from Shephard (1953), Solow (1957) and Farrell (1957). The path breaking paper by Farrell (1957) identified the technical and allocative efficiency in a firm. The Figure 2.1.1 explains it.

Figure 2.1.1 Farrel Efficiency Measurement



In Figure 2.1.1, the firm using only two inputs X_1 and X_2 to produce output y is presented. The production is specified as $y = f(X_1, X_2)$ and it assumed that the returns to scale is constant, ie, linearly homogeneous. Then the production function can be specified as $1 = f(X_1/y, X_2/y)$. This enables us to draw isoquant II'. Here the firm is producing unit-output at the point C. Technical efficiency, which is defined as the ratio of the actual to the potential, can now be stated as OB/OC. It is clear that:

$$0 \leq TE \leq 1$$

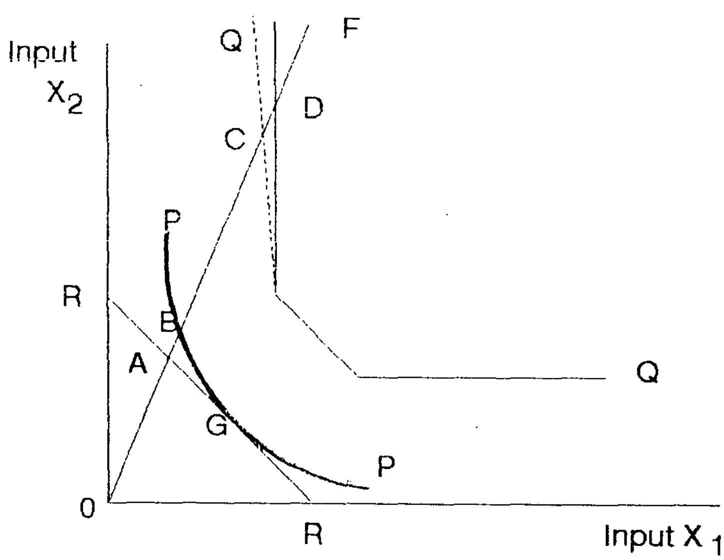
Now, the allocative efficiency can be specified given the isocost line PP' which is defined by the ratio of factor prices. The allocative efficiency ratio can be given by OA/OB, whereby the firm is producing output in the most price efficient way. It can, now be seen that the overall efficiency is the product of technical and allocative efficiencies, ie,

$$OE = TE \, . \, AE$$

ie,

$$OA/OC = OB/OC \, . \, OA/OB$$

Figure 2.1.2 FGL Efficiency Decomposition



Later, Fare, Grosskopf and Lovell (1985) have tried to decompose total efficiency further. They have shown that total efficiency can be split into purely technical, structural, scale and allocative components. This decomposition of total efficiency can be explained with the help of Figure 2.1.2.

Production is carried out with an inferior set of inputs, F, where the overall efficient input choice is G; given the isocost line RR and the long run reference technology PP. Overall efficiency (OE) can be specified as:

$$OE = OA / OF < 1$$

Now, the pure technical component in overall efficiency is represented by OD / OF. ie,

$$PTE = OD / OF$$

The structural component (C), known as congestion, is due to production on a positively sloped stretch of the isoquant. Tinbergen identified it in the non-economic region and called it counter production[1]. It can be specified as

$$C = OC / OD$$

Scale efficiency (S) is defined as the discrepancy between the short run technology production, QQ and the long run technology production (ie, the constant returns to scale) PP. Therefore, S can be specified as:

---

1 Counter production is the situation in which the marginal products of factor services are negative. Tinbergen (1985) coined this term when he faced the problem of negative marginal products for the blue collar workers in United States while estimating a production function. In effect it is a situation of production decision on a positively sloped segment of the isoquant.

$$S = OB / OC$$

Allocative efficiency, which is price dependent and defined related to the isocost line RR is represented by

$$A = OA / OB$$

Now, the total efficiency can be seen as the multiplicative identity of all these components, ie,

$$OE = PTE . C . S . A$$

ie,

$$OE = (OA / OF) = (OD / OF) . (OC / OD) . (OB / OC) . (OA / OB)$$

In the absence of price information, the OE measure reduces to Overall Technical Efficiency (OTE), which can be defined as:

$$OTE = (OB / OF) = (OD / OF) . (OC / OD) . (OB / OC)$$

The frontier approach initiated by Farrell was essentially concerned with empirical matters and, in particular, with measurement (Button and Weyman-Jones, 1992). As Farrell (1957, p.11) himself states his interest was "to provide a satisfactory measure of productive efficiency... and to show how it can be computed in practice." But keeping a more inquisitive mind to understand the determinants of efficiency along with its magnitude, Leibenstein putforth a more comprehensive conceptualisation of efficiency.

2.2 The Concept of X-Efficiency

Farrell (1957) and Leibenstein (1966) tried to explain why firms are not minimising their costs. Farrell found the reason in total inefficiency which is the product of allocative and technical inefficiencies. Leibenstein, attributed the reason not only to the allocative and technical factors but to all the 'X' factors. Leibenstein (1966) pointed out that non-allocative inefficiencies also exist in the firms, which he called 'X'- Inefficiency. As a concept it is similar to the concept of technical inefficiency. But he remarked, there is nothing "technical" about the organisational inefficiencies in the firms. While similar in their orientation, there are in fact important distinctions in the economic theories underlying X-efficiency and technical efficiency (Button and Weyman-Jones, 1992). As Leibenstein himself pointed out on several occasions:

> The concept of technical efficiency suggests that the problem is a technical one and has to do with the techniques of an input called management. Under X-efficiency, the basic problem is viewed as one that is *intrinsic* to the nature of human organisation, both organisation within the firm and organisation outside of the firm. (Leibenstein, 1977, p.312)

> X-efficiency is not the same thing as technical efficiency, since X-efficiency may arise for reasons outside the knowledge or capability of management attempting to do the managing... In other words, it is not only a matter of techniques of management, or anything else "technical" in carrying out decisions, that is involved in X-efficiency. (Leibenstein, 1980, p.27)

Formally, X-inefficiency can be defined as a situation in which a firm's total costs are not minimised because the actual output from given inputs is less than the maximum feasible level (Pearce,1992). The degree to which actual output is less than the maximum output (for given inputs) is the degree of X-inefficiency, and the increase in the output with the same inputs increases X-efficiency (Leibenstein, 1976). Blois (1974) suggested that it would seem that the degree of X-inefficiency present in a firm could be defined in terms of the ratio of the actual cost per unit of output to the theoretical minimum cost per unit of attaining that output, Accepting this suggestion, Leibenstein (1976) stated that the concept of X-efficiency is best expressed in value terms of both inputs and outputs[2].

The enquiry into the causes of the variability in the level of performance of different firms using more or less same inputs led Leibenstein to the conclusion that there is nothing technical about the most substantial sources of non-allocative inefficiencies in firms. It seemed that no available concept, such as organisational inefficiency or motivational inefficiency, implied all the elements that could be involved in non-allocative inefficiencies. Leibenstein called it 'X' inefficiency.

The X-inefficiency in firms, then, can arise due to many reasons like historical factors, motivational factors, organisational structure, inadequate "pressure" components, or a combination of all these factors generating an "inert area" of production in the firm. The identification of these factors and admittance of their influence on the production process allow us to make an analytical approach to the understanding of the institutional structure of production in the firm.

Invariably, X-efficiency theory then, represents a line of reasoning based on certain postulates that differ from standard micro theory (Leibenstein, 1987, 1985, 1980, 1979, 1978a, 1978b, 1975). These basic postulates can be listed as:

1. Relaxation of the maximising behaviour

Non-optimal decisions are a basic cause of X-inefficiency in the production process of firms (Leibenstein, 1985). It is assumed that *some* forms of decision making such as habits, conventions, moral imperatives, standard procedures, rules of thumb or emulation, can be and frequently are of a non-maximising nature. The reason is that they are not based on careful calculation.

---

2 Suppose a firm maximises output (in physical quantity terms) from given inputs but chooses to produce the wrong quantity. In that case also X-inefficiency exists and is better to express it in value terms.

2. Inertia

It says that functional relations are surrounded by inert areas, within which changes in certain values of the independent variables do not result in changes of the dependent variables.

3. Incomplete contracts

The employment contract is incomplete in that the payment side is fairly well specified but the effort side remains mostly unspecified.

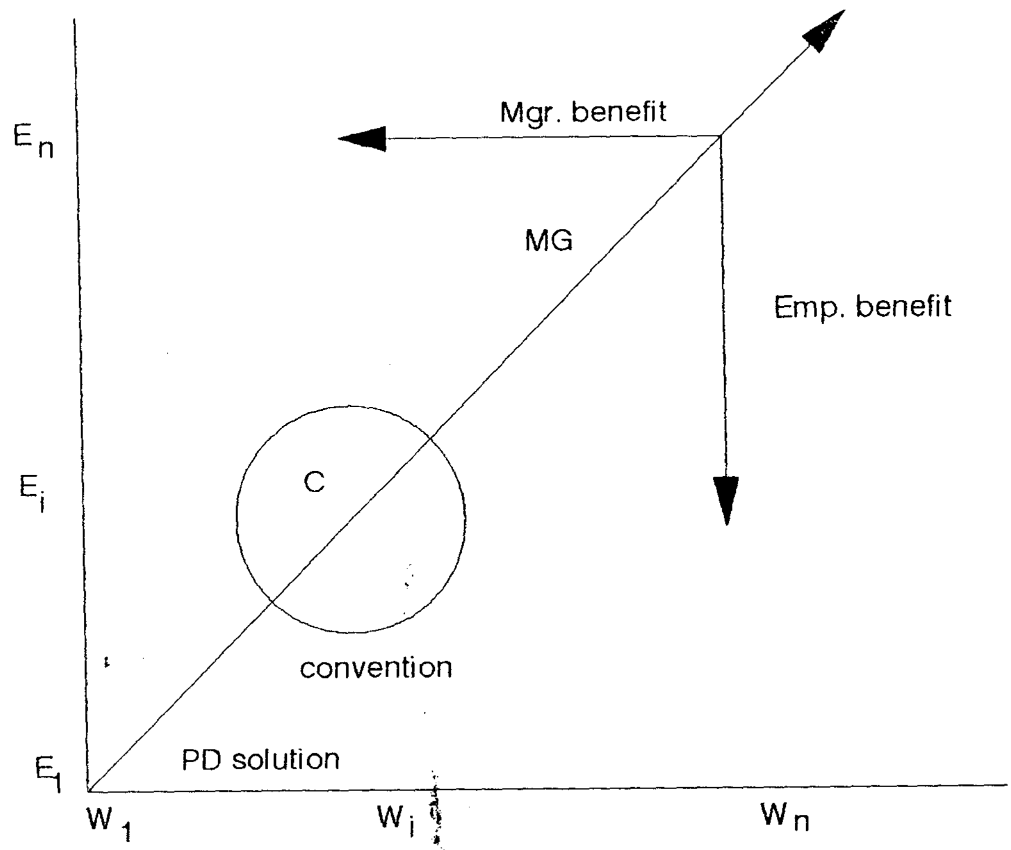
4. Discretion

Employees have effort discretion within certain boundaries, and the firm, through its top management, has discretion with respect to working conditions and some aspects of wages.

Now with these postulates, X-efficiency concept can be better understood by the diagrammatic presentation in Figure 2.2.1 as given by Leibenstein (1987) himself.

Employees have an incentive to move towards the minimum tolerated effort level (E) and the firm has the incentive to move towards the minimum-tolerated working-condition-wage level (W). These are represented on Y and X axes of the figure respectively. Since some variables are controlled by the firm and some by the workers, the problem turns to a standard game theoretic problem. The discretionary effort positions run from E_1 to E_n, $E_1 < ... < E_i < ... < E_n$ and the discretionary wage-options run from W_1 to W_n, $W_1 < ... < W_i < ... < W_n$. Then, E_1 and W_1 offers the Prisoner's Dilemma solution. But effort conventions and working-condition conventions will bring about a solution at point C. The circle surrounding the point represents the inert area surrounding the solution. This inert area resists any movement further through the 'mutual gain' line MG. And the distance between C and E_n W_n represents the degree of X-inefficiency in the system.

Figure 2.2.1 Diagrammatic Presentation of X- Efficiency



2.3 Opening Up the Black Box!

The X-efficiency paradigm gives us an alternative way of looking at the micro units for a better understanding of the transformation processes being carried out. It is mainly facilitated by treating each individual in the firm as the basic Decision Making Unit (DMU). This micro-micro approach allows for *intrafirm* analysis which enable us to explore and explain the organism and the metabolic process in the firm in a closer and more effective way. It helps us to make a more meaningful *interfirm* analysis. Abandoning the cost minimising assumption and taking many deviations from the neo-classical postulates, the X-efficiency paradigm tries to make a bold attempt to look into the 'black box' which has been kept closed for a long time.

The contrast of X-efficiency postulates to that of neoclassical can be summarised as in Table 2.3.1.

Table 2.3.1 Comparison of X-Efficiency Theory with Neo-Classical Theory

Postulates and Basic Variables	Conventional Micro Theory	General X-Efficiency Theory
1. Psychology	1. Maximization or minimization	1. Selective rationality
2. Firm activity contracts	2. Given	2. Incomplete
3. Units	3. Households and firms	3. Individuals
4. Effort	4. Assumed given	4. Discretionary variable
5. Interpersonal interactions	5. None	5. Some
6. Inert areas	6. None	6. Important variable
7. Agent-principal	7. Identity of interests	7. Differential interests
8. Market structure	8. Given	8. Depends on effort
9. Motivation	9. Implicitly constant	9. Variable

2.4 The Institutions and X-Efficiency

By opening up the black box and looking into that, the X-efficiency paradigm tries to derive the intra firm behaviour as it is given in the following schematic presentation.

$$E_i \;\text{---->}\; Pr_i \;\text{---->}\; Ch_i \;\text{---->}\; T_i \;\text{---->}\; C_i$$

It says that the given environment (E_i) will imply a certain amount of pressure (Pr_i), which in turn will imply a choice (Ch_i) of effort level, which in turn implies a certain translation of inputs into outputs (Ti), and this in turn implies a certain cost per unit (C_i).

The environment (E_i) can be thought of as the institutional set-up outside the firm and the institutional set-up within the firm. The inside institutional set up incorporates the organisational form, the norms and the conventions in the firm.[3]

The organisational form will be characterised by the nature of ownership and the resulting contractual relationships. The nature (and in most cases the pattern also) of ownership is defined exogenous to the firm. Incompleteness is the peculiarity with the contractual relationships whatever be the nature of ownership. In contracts, the payment side is well specified but the effort level remains unspecified, or partially specified. This situation generates the principal - agent problem[4]. The principal has to ensure the efforts of the agents by motivating them and avoiding the moral hazards[5] present in the firm. The tightness of the contractual relations (and the principal - agent relations) and the resulting 'pressure' in each firm will be defined by the nature and pattern of ownership of the firm. The norms, conventions and the 'pressure' define a

---

3 The institutional set up *in* a micro level organisation, we define, as a set of all institutional factors like the nature of ownership, contractual relations, norms, conventions etc within the firm. In simple words, it is the aggregation of all the ways in which the activities within a firm are organised. This conceptualisation of institutions is different from that of Leibenstein. He defined institutions as the conventions that go beyond the boundaries of the firm(Leibenstein,1986, p.9). But we call these conventions outside the firm as the institutional factors *out* of the firm. Now, both these inside and outside institutional factors together gives the complete picture of the Environment (E_i).
A norm is defined as some sort of a standard, without considering the extent to which others adhere to this standard, or whether different individuals expect others to adhere to this standard. On the other hand, by convention we mean a regularity of behaviour that has a high degree of adherence and a high degree of expectation that others will adhere to it (Leibenstein, 1984, p.264).

4 Principal-agent problem arises when one person, the principal, hires an agent to perform tasks on his behalf; but can not ensure that the agent performs them exactly the way the principal would like. The agent's performance may differ since the incentives of the agents differ from those of the principal. It is expensive to monitor the efforts of the agent and this expense constitutes a portion of transaction costs in the firm.

5 Moral hazard is the presence of incentives for individuals to act in ways that incur costs that they do not have to bear.

unique effort level in each firm, according to which the cost per unit in the firm is determined.

In short, the institutional set up defines the effort level in the firm and the degree of X-efficiency. The *inside-the -black box* enquiry and the understanding of the role of institutions in determining the degree of X-efficiency enable us to make interfirm analysis more analytically.

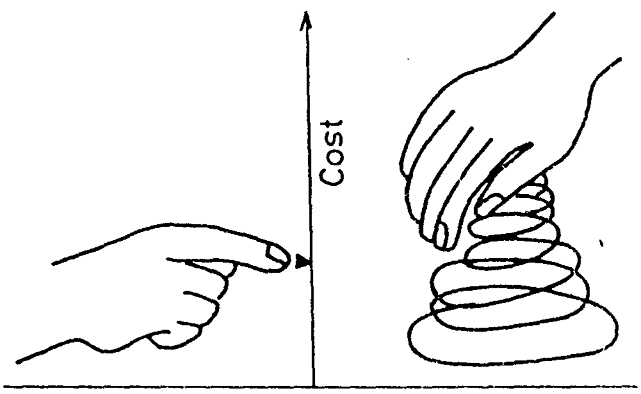
2.5 The Effort Levels, Inert Areas and X-efficiency

The effort level is defined by pressure (Pr_i), which comes either from the institutional setup *outside* the firm, like market, or from the nature and pattern of ownership of the firm. As the pressure builds up, more and more effort is put in the activities in the firm which results in the reduction of cost per unit. Essentially this increases the efficiency of the firm. This theoretical postulate is endorsed by a psychological law, known as Yerkes-Dodson Law, which says that at low pressure levels individuals will not put much effort into carefully calculating their decisions, but as pressure builds they move towards more maximising behaviour. At some point too much pressure can result in disorientation and a lower level of decision performance (Leibenstein, 1987).

But the pressure for more effort input is resisted by the norms, conventions and the institutional set-up within the firm. A specific effort level is defined by the institutional arrangements and it creates an inert area. Leibenstein (1969, p.607) defines an inert area as "a set of effort positions whose associated levels of utility are not equal but in which the action required to go from a lower to a higher (effort) level involves a utility cost that is not compensated". This inert area is represented by the circle in Figure 2.2.1. Therefore the question of increasing X-efficiency is to be answered by altering this inert area in such a way that the agents are made to put more effort. Then, the cost per unit can be reduced and the degree of X-inefficiency lessened.

In short, X-efficiency theory and its paradigm points to the need of "pressures" which can and only can minimise the cost per unit (including transaction cost). The "pressure" element which distinguishes the X-efficiency paradigm from the neoclassical frame can be well illustrated by the following self-explaining figure:

Figure 2.5.1 Neo-Classical and X-Efficiency View of Cost Minimisation.



In short, the conceptualisation of efficiency done by Leibenstein provides a more comprehensive outlook towards the existence, nature and magnitude of non-maximising behaviour of firms. The inquisitive approach of X-efficiency paradigm attempts to open up the black box so far kept closed. Much discussion has been carried out on the content of the box by sitting upon it without knowing what was there inside. Now, we are able to open it up and make a close watch on the process inside. The intra firm analysis which X-efficiency paradigm offers enable us to incorporate the institutional structure of production to the efficiency dimension. It facilitates more analytical and meaningful interfirm analysis which is extremely important when we want to talk about efficiency in *relative* terms.

Chapter 3

X-EFFICIENCY: THE QUESTION OF ESTIMATION

3.1 The Challenge

Deviating from the basic postulates of mainstream economics, the X-efficiency hypothesis stated that firms do no optimise their output and there can be non allocative inefficiencies also within the firm. Then, the immediate concern was to measure the degree of X-inefficiency which was thought quite impractical. The reason is well expressed in the words of Button (1985, p.85) "the problem of the X-efficiency concept is that it focuses on relationships that are essentially unobservable. Traditional economic methodology, involving the establishment of testable hypothesis, is particularly difficult to apply in such circumstances. Leibenstein himself tends to rely upon casual empiricism and cites a series of *ad hoc* case studies, examples and impressionistic findings to support his stance". It was because of this reason that the X-efficiency paradigm remained unexploited for years.

3.2 Frontier Measurement: The Solution

The recognition of the frontier concept of production function at par with the concept of X-efficient production and the possibility of its measurement gave life to the measurement of the latter. For the last 12 years many works have been done on its measurement proving the existence, nature and magnitude of X-efficiency. The literature suggests different methods of the frontier measure of X-efficiency which can be taxonomised into (1) Parametric Stochastic Frontier Estimation, (2) Non-parametric Programming and (3) Parametric Programming. A brief explanation of these methods are following.

3.2.1 Parametric Stochastic Frontier Estimation

This econometric approach is based on specifying a stochastic production function. As Bauer (1990, p.4) explains, "it makes a parametric representation of technology along with a two-part composed error term. One part is statistical noise, generally assumed to follow a normal distribution. The other part represents inefficiency and is assumed to follow a particular one sided distribution". These one sided distributions can be half-normal, exponential, truncated normal or two-parameter gamma.

The parameters of the production function are estimated using regression techniques. The residuals are decomposed into an unobservable random component and an 'inefficiency' component. The magnitude of this inefficiency component ie, the non-noise component of the error term gives the measure of X-inefficiency.

Pointing to the limitations of this method, it is argued that estimation of an explicit functional form imposes unwarranted structure on the technology [Sengupta (1987a), Banker and Maindiratta (1986)]. Similarly the choice of a distribution for the efficiency residuals is usually arbitrary, guided mainly by its computational tractability. Schmidt and Lin (1984) have shown that statistical efficiency comparisons are not invariant to the choice of the distribution.

3.2.2 Non-Parametric Programming

The non-parametric programming approach, also known as Data Envelopment Analysis (DEA), proceeds by constructing the convex hull of observed input-output observations for a given set of firms or organisations, under different assumptions about free disposability and returns to scale. It is non-parametric in the sense that it does not assume that the underlying technology "belongs to a certain class of functions of a specific functional form which depend on a finite number of parameters, such as the well-known Cobb-Douglas functional form"(Diewert and Parkan, 1983, p.131). It is "non-statistical" in the sense that it makes no explicit assumption on the probability distribution of errors in the production function (Sengupta, 1987a).

3.2.3 Parametric Programming

In this method, a deterministic linear programme is used to estimate a frontier technology (Fare, Grosskopf and Lovell, 1985). Its main difference from the non-parametric programming is that the parametric technology is smooth, while its non-parametric counterpart is piecewise linear. But this method is constrained by many limitations, which make it of limited applicability [Forsund and Hjalmarsson (1979), Forsund and Jansen (1977), Aigner and Chu (1968)].

3.3 Data Envelopment Analysis (DEA)

3.3.1 Definition

Built on the earlier work of Farrell (1957), DEA is based on an engineering like approach, comparing a set of outputs to a set of inputs, common to all DMUs. The model determines, for each DMU, a set of virtual multipliers or factor weights, such that the ratio of weighted outputs to weighted inputs for that DMU is maximised. This ratio becomes the DMU's relative efficiency measure.

DEA uses a linear programme based technique to arrive at this efficiency ratio which has the interpretation of X-efficiency. In the programming method, DEA floats a piecewise linear surface to the rest on the top of the observations. The facets of the hyperplane define the efficiency frontier, and the degree of inefficiency is quantified and partitioned by a series of matrices that measure various distances from the hyperplane and its facets (Seiford and Thrall, 1990).

In other words, DEA algorithm calculates an ex-post measure of how efficient each observation was in converting inputs to outputs. This is accomplished by the construction of an empirically-based frontier, by evaluating each observation against others which are included in the data set. The frontier can be oriented for production; specifying maximum possible output given the inputs, or minimum inputs required given the output or can be oriented for cost; describing minimum cost of producing certain outputs or can be oriented for profit; describing the maximum profit attainable, given outputs, input prices and technology. Charnes, Cooper, Lewin and Seiford (1993), Bauer (1990), Lovell and Schmidt (1988), Schmidt (1986), Fare, Grosskopf and Lovell (1985), Kopp (1981), and Forsund, Lovell and Schmidt (1980) give different frontier models possible with DEA.

For a cross section of Z firms, DEA generates Z sets of weights such that the ratio of output to inputs collapses to a summary, scalar measure of productive efficiency for each firm. The constraints in the programme ensure that the efficiency index has an intuitive interpretation in the closed interval [0, 1]. If the index is unity, a firm is relatively efficient or best-practice. A value less than unity indicates a firm is inefficient relative to peer organisations.

3.3.2 The Advantage

Many studies like Banker et al (1986) conclude that DEA has been proved particularly adept in uncovering relationships that remain hidden for other methodologies. Seiford and Lawrence (1990) gives the bibliography of different works done using DEA. DEA presents a measure of efficiency for each firm which allows for intrafirm performance evaluation. This advantage of DEA makes it preferable to the regression techniques, in which a single set of parameters is generated for the entire data set. Moreover, this non-parametric approach imposes no functional form on production and technology. It handles multiple outputs; and qualitative as well as quantitative data can be used as inputs and constraints. Again, DEA allows for the use of real and physical values at the same time as outputs and inputs, since the objective is not to estimate the functional parameters, but a relative measure of performance.

3.3.3 The Model[1]

Based on the Farrell's measure of efficiency, Charnes, Cooper and Rhodes (1979, 1978) formulated the fractional form of DEA as following:

Let there be Z firms producing same outputs (Y_i, i = 1, ... , t) by using similar inputs (X_k, k = 1, ... , m), then, the fractional mathematical programme can be written as:

$$\underset{V_i, W_k}{\text{MAX}} \quad \frac{\sum_{i=1}^{t} V_i Y_{ip}}{\sum_{k=1}^{m} W_k X_{kp}} \qquad (3.3.3.1)$$

subject to Z "less-than-unity" constraints,

$$0 \leq \sum_{i=1}^{t} V_i Y_{ic} / \sum_{k=1}^{m} W_k X_{kc} \leq 1$$

c = 1, ... ,p, ... , Z

and; V_i, $W_k > 0$ $\forall$ i and k

The efficiency score generated by the programme is consistent with a frontier interpretation of performance. A score of unity implies that observed and potential performances coincide. In this case the firm is said to be best-practice. Where observed performance is lower than potential a firm receives a less than unity efficiency. This

[1] The discussion in this part is based on Ganley and Cubbin (1992).

implies that its performance is poorer than that of some of its peer organisations and so it is relatively inefficient.

Because of its intractable non-linear and non-convex properties, this fractional programme was not used for computations (Charnes, Cooper, and Rhodes, 1978). Charnes and Cooper had (1973, 1962) transfomed it into a linear programme which now has two orientations: the output orientation, which computes the output efficiency of the firms and; the input orientation, which computes the input efficiency. In line with all linear programmes, each has two components: primal and dual.

The Primal

The primal of linear programme of output orientation can then be written as:

$$\underset{V_i\, W_k}{MAX} \sum_{i=1}^{t} V_i\, Y_{ip} \qquad (3.3.3.2)$$

subject to

$$\sum_{i=1}^{t} V_i\, Y_{ic} \leq \sum_{k=1}^{m} W_k\, X_{kc}, \qquad c = 1,\ldots,p,\ldots,Z$$

$$\sum_{k=1}^{m} W_k\, X_{kp} = 1$$

$$V_i,\ W_k > 0 \ \ \forall \ \ i \text{ and } k$$

Similarly, the input oriented linear programme can be expressed as:

$$\underset{W_k, V_i}{MIN} \sum_{k=1}^{m} W_k\, X_{kp} \qquad (3.3.3.3)$$

subject to

$$\sum_{k=1}^{m} W_k X_{kc} \geq \sum_{i=1}^{t} V_i Y_{ic}, \quad c = 1,....,p,.....Z$$

$$\sum_{i=1}^{t} V_i Y_{ip} = 1$$

and $V_i, W_k > 0 \ \forall$ i and k

The strict positivity assumption on weights was introduced by Charnes, Cooper and Rhodes (1979) such that

$$W_k > \varepsilon, \ k = 1, ..., m$$

$$V_i > \varepsilon, \quad i = 1, ..., t$$

where ε is an infinitesimal or non-Archimedean constant usually of the order 10^{-5} or 10^{-6}. They were introduced into the primal because under certain circumstances 1978 model implies unity-efficiency ratings in the fractional programme for firms with non-zero slack variables such that further improvements in performance remained feasible.

The Dual

Now, as for any linear programme, we can form the dual for both the output oriented and the input oriented primals. The dual of the output oriented programme is expressed as the minimisation of quantities of the m inputs required to meet stated levels of the t outputs. ie,

$$\underset{\lambda_c}{\mathrm{MIN}}\ h_p - \varepsilon \left(\sum_{k=1}^{m} S_k + \sum_{i=1}^{t} S_i \right) \qquad (3.3.3.2^*)$$

subject to

$$X_{kp} \cdot h_p - S_k = \sum_{c=1}^{Z} X_{kc}\, \lambda_c \qquad k=1,\ldots,m$$

$$Y_{ip} + S_i = \sum_{c=1}^{Z} Y_{ic}\, \lambda_c \qquad i=1,\ldots,t$$

and;

$\lambda_c \geq 0, \quad c = 1,\ldots,p,\ldots,Z$

$S_k \geq 0, \quad k = 1,\ldots, m$

$S_i \geq 0, \quad i = 1,\ldots,t$

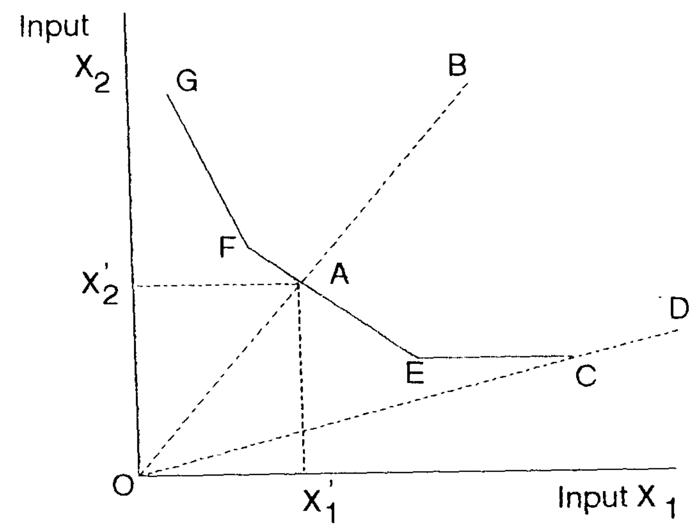
with h_p unconstrained; and ε is an infinitesimal (or non- Archimedean) constant analogous to that used in the primal (Charnes and Cooper, 1984). The *p*th branch is relatively efficient, iff,

$h_p^* = 1$ and $S_k^* = S_i^* = 0 \;\; \forall\; k$ and i

where * indicates the optimal values of the variables in the dual programme.

A diagrammatic presentation of the dual can be made with the help of Figure 3.3.3.1. The frontier for comparison is the lower convex hull of the possibility set in the figure. A branch is technically efficient in its use of inputs if no other branch, or linear combination of branches, is producing equal amounts of outputs for less of atleast one input. This definition is equivalent to the formal efficiency conditions from the dual as given above.

Figure 3.3.3.1 The Dual Technology



The Figure 3.3.3.1 illustrates a hypothetical frontier technology based on 5 firms (G,F,B,E and D) producing a single output Y from two inputs X_1 and X_2. Firms G, F and E, lying on the frontier, are best practice. This implies that no other branch or linear combination of branches can be identified producing the same level of output for less of either of both inputs. These branches have unity efficiency ratios and zero slacks in the solution to the dual. Branches B and D are inefficient relative to frontier performance. That is, for the same level of output it is possible to find a firm, or a linear combination of firms, which are using less of atleast one of the inputs. For the firm B, a linear combination of firms E and F is producing at least as much output as B with less of X_1 and X_2. The firms E and F can be called the peer groups for the firm B since they provide the blueprints to improve performance for firm B. It is because, other things being equal, they are likely to be implementing superior managerial procedures.

From the model (3.3.3.2*) it is clear that there are constraints on inputs and outputs in the dual. The input constraints define a radial contraction in inputs given by the ratio h_p*, with the additional reductions given by the non-zero input slack variables, S_k*, k = 1, ... , m. The output constraints do not include a radial adjustment and are only of importance in so far as any of the optimal output slacks S_i^*, $i = 1, \ldots, t$, are non-zero.

In Figure 3.3.3.1, the solution for firm B has all input and output slacks equal to zero. However, firm D has a non-zero slack on the input X_1. The efficiency ratio for D is OC/OD which defines an initial radial contraction in both inputs. However, at the point C, firm E is producing the same output for less of X_1 and the same amount of X_2. Hence D is not fully efficient until it reduces its consumption of X_1 by the horizontal distance c to E. This distance is given by a non-zero slack S_1 in the final solution of the dual for firm D.

In computation, the dual programme is more tractable than the primal. In the primal, the constraints are indexed on all Z firms. By contrast, in the dual the constraints are indexed on inputs and outputs and summed over firms. The number of inputs and outputs is never likely to exceed the number of firms. Philips, Ravindran and Solberg (1976) have shown that the computational efficiency of the simplex method falls with increase in the size of the constraint set. Hence, the dual programme with only (m+t) constraints on inputs and outputs is computed in preference to its primal with Z constraints.

Similarly, the output maximisation dual of the input minimisation can be expressed as:

$$\max_{\lambda c} f_p + \varepsilon \left(\sum_{k=1}^{m} S_k + \sum_{i=1}^{t} S_i \right) \tag{3.3.3.3*}$$

subject to

$$f_p.Y_{ip} + S_i = \sum_{c=1}^{Z} \lambda_c Y_{ic}, \quad i = 1, \ldots, t$$

$$X_{kp} - S_k = \sum_{c=1}^{Z} \lambda_c X_{kc}, \quad k=1,\ldots,m$$

and;

$\lambda_c \geq 0, \quad c = 1,\ldots,p,\ldots,Z$

$S_k \geq 0, \quad k = 1,\ldots, m$

$S_i \geq 0, \quad i = 1,\ldots,t$

with f_p unconstrained.

Again the dual is the programme used in the computation of the efficiency ratio, although in this case it determines the output efficiency of a firm *p* for a given set of inputs.

3.3.4 The Question of Returns to Scale[2]

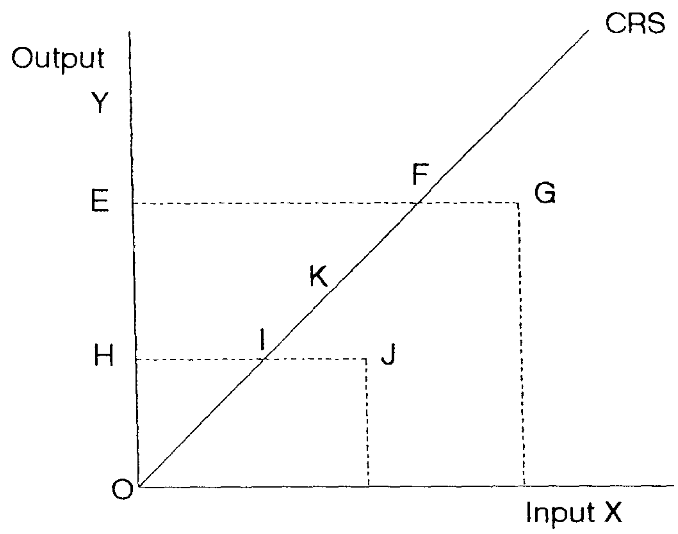
The DEA model presented above, as derived by Charnes, Cooper and Rhodes (1979, 1978) made the assumption of constant returns to scale. It constructs a constant returns to frontier by identifying that branch that maximises the ratio of output to input. This ratio can be interpreted as the maximum average productivity and denotes the scale efficient firm since it is consistent with a position of constant returns to scale.

In Figure 3.3.4.1, firm K (on the frontier) maximises average productivity. A ray drawn from the origin to any of the remaining firms (J or G) would have a lower slope and would not maximise average productivity, i.e. $(Y_K/S_K) > (Y_c/X_c)$, c = K. A constant returns to scale frontier is therefore an unbounded ray beginning at the origin and passing through a point of maximum average productivity such as at firm K. Here K is scale efficient and has a unit weight in the constraints, i.e. $\lambda_K^* = 1$. The ray OCRS can be called the "Ray of Unboundedness"[Banker, Charnesand Cooper(1984)].

---

2 The discussion on returns to scale is followed from Banker (1984).

Figure 3.3.4.1 Average Productivity and Returns to Scale



Banker (1984) pointed out that the weight on the best practice can be used as an indicator of the returns to scale. That is,

$\lambda^*_{bp} < 1 \Rightarrow$ IRS (Increasing Returns to Scale)

$\lambda^*_{bp} = 1 \Rightarrow$ CRS (Constant Returns to Scale)

$\lambda^*_{bp} > 1 \Rightarrow$ DRS (Decreasing Returns to Scale)

For multiple inputs and outputs several firms may be scale efficient on atleast one variable such that the Banker scale indicator would be the sum of the optimal weights on each of those firms; i.e.

$\sum_{c=1}^{z} \lambda_c^* < 1 \Rightarrow$ IRS (Increasing Returns to Scale)

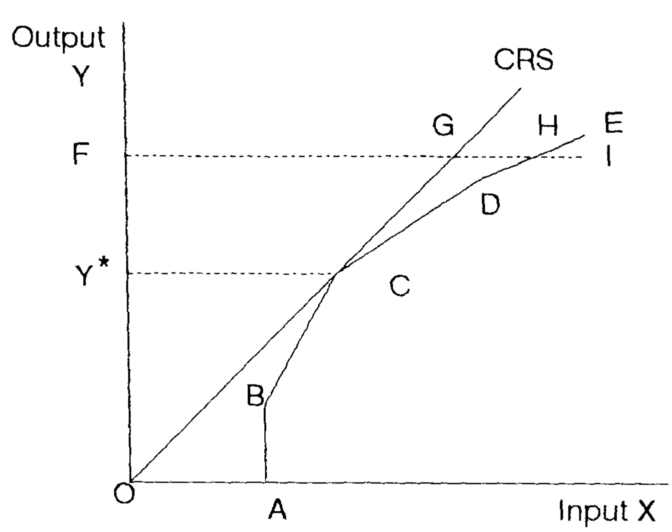
$\sum_{c=1}^{z} \lambda_c^* = 1 \Rightarrow$ CRS (Constant Returns to Scale)

$\sum_{c=1}^{z} \lambda_c^* > 1 \Rightarrow$ DRS (Decreasing Returns to Scale)

The over restrictive assumption of constant returns to scale made the Farrell/ Charnes-Cooper model unpopular. It compelled the economists to continue with the statistical procedures.

Later, Banker (1984) revised the programme of Charnes et al (1979, 1978) to permit the estimation of technologies which allow returns to scale to vary over the production surface. It was made possible by adding one more constraint that the weights on firms sum to unity. This new constraint ensures that the frontier is composed of multiple convex linear combinations of best practice where dominance is now more weakly defined to include regions of increasing and decreasing returns. Since increasing and decreasing returns are possible, the frontier may include scale inefficient operations. It is better understood by Figure 3.3.4.2.

Figure 3.3.4.2 The Varying Returns to Scale Technology



In Figure 3.3.4.2, firms such as B (with increasing returns to scale)and D and E (with decreasing returns to scale) which neverthless are technically efficient for given scale. The result is a piecewise linear frontier ABCDE. The returns to scale vary from facet to facet each of which represents the solution to a constraint in the dual. For combinations of input and output lower than the scale efficient firm, eg. along the facet BC, there are increasing returns; facets reflecting higher levels of production have decreasing returns to scale. The scale efficient firm C is included in both the VRS and the CRS frontiers and indeed represents the point of intersection of the two.

Now, the full revised programme of Banker (1984) can be presented as:

$$\underset{\lambda_c}{\text{MIN}}\ h_p - \varepsilon \cdot \left(\sum_{k=1}^{m} S_k + \sum_{i=1}^{t} S_i \right) \tag{3.3.41}$$

subject to

$$X_{kp} \cdot h_p - S_k = \sum_{c=1}^{Z} X_{kc} \lambda_c, \quad k=1,\dots,m$$

$$Y_{ip} + S_i = \sum_{c=1}^{Z} Y_{ic} \lambda_c, \qquad i=1,\dots, t$$

$$\sum_{c=1}^{Z} \lambda_c = 1$$

and;

$$\lambda_c \geq 0, \quad c = 1,\dots,p,\dots,Z$$

$$S_k \geq 0, \quad k = 1,\dots, m$$

$$S_i \geq 0, \quad i = 1,\dots,t$$

where, λ_c are the weights on firms, S_k are the input slacks, S_i are the output slacks.

With CRS and VRS results before them Grosskopf and Valdmanis (1987) argue that the CRS technology should be interpreted as reflecting long run performance possibilities. Analogusly, the VRS assumption indicates feasible attainment in the short run. On this basis the long run CRS adjustment costs will be greater than those suggested by the VRS technology. The CRS targets are effective adjustments towards long run equilibria, i.e., the minimum point of a U shaped average cost curve. In the short run even the best practice costs will be greater than those attainable in the long run and so VRS cost adjustments will be smaller than their CRS counterparts.

Given the CRS and VRS efficiency scores, Rangan et al (1988) proposed their ratio as an indicator of scale efficiency (S), i.e.,

$$S_i = CRS_i / VRS_i$$

Scale efficiency is discussed more in Chapter 4; Section 4.8.

3.4 X-Efficiency, Inert Areas and DEA

Leibenstein's inquired into the reasons of performance differentials between firms producing same output(s) by consuming more or less same inputs. This led him to the concepualisation of X-efficiency and the inert area. An inert area may be formed out of the organisational form and the resulting institutional factors inside and outside the firm. It is this inert area which prevents the firm to achieve the potential output from the given inputs. Now, DEA facilitates, by an efficiency score, a quantitative guide to the inert area. This in turn facilitates not only the measurement of the magnitude of X-(in)efficiency but also identification of the factors behind inefficiency.

Chapter 4

ESTIMATION OF X-EFFICIENCY IN STATE TRANSPORT UNDERTAKINGS IN INDIA USING DATA ENVELOPMENT ANALYSIS (DEA)

4.1 The Context

Public sector in India has always been accused of inefficiency. Both policy makers and academicians have expressed their concern over it [Bhoothalingam (1993), Bhagwati (1993), Jalan (1991), Marathe (1989), Bardhan (1984)]. To a large extent the inefficiency in public sectors was "justified" by the service objective of the public sector. But we cannot find that sort of a justification for the inefficiency in the use of different inputs in these public units. State Transport Undertakings (STUs) in India are no exception.

In India State Transport Undertakings are organised in three different ways: (1) Departmental Undertakings (2) Corporations; and (3) Companies. Each organisational form is characterised by varying government control in such a way that, autonomy increases from departmental undertakings to Companies. Each organisational form sets different institutional set up in these STUs which inturn forms a particular environment in them. This environment exerts different "pressure" levels upon the agents and their effort level varies accordingly. Lack of adequate pressure leads to lower levels of effort for human inputs which result in excess usage or wastage of non-human inputs also since production is a process in which all the inputs are interacting and interdependent. All these together result in the non-maximising behaviour of the STUs causing X-efficiency not only to exist; but to persist.

There has been many attempts to measure the performance of different Transport undertakings in India. The studies like Bagade and Paranjpe (1994), Mariamma (1993), Misra and Nandagopal (1991), Arora (1987), Chand (1982), Rao (1982), Vijayakumar

(1982), Bagade (1981), Ibrahim (1978), Prakash (1977), Keshava (1972), Jayadevadas (1971), Pillai (1956), Collins (1949), Ramanadhan (1948) attempted to measure the performance of different state transport undertakings. They all used conventional measures like different input productivities, capacity utilisation, profitability, return on asset etc. for their assessment.

None of these studies seems to have measured the magnitude of X-efficiency in the STUs, which would have been more enlightening to enquire into the nature and causes of inefficiency. Now, we try to measure the X-efficiency in these STUs using the frontier measurement technique. Data envelopment Analysis (DEA) is used to make the frontier measurement which can provide relative measure of X-efficiency in these STUs.

4.2 The Data

The study is based on the cross section data of different STUs for the year 1994-95. The data was collected from the "State Transport Undertaking: Profile and Performance" published by Central Institute of Road Transport Undertakings (CIRT) for the Association of State Road Transport Undertakings. We confine the study to STUs conducting mofussil services for the sake of uniformity in demand and road conditions. The data for the thirty STUs analysed are given in the Appendix I.

4.3 The Variables

4.3.1 Output

We have considered two different output concepts, viz, Passenger Kilometers (PK) and Seat Kilometers (SK)both in Lakhs.

Seat Kilometers is obtained by multiplying the effective kilometers (i.e.,the kilometers actually operated for the purpose of earning revenue) by the weighted average seating capacity. This is the total output offered to the public.

Passenger kilometers represents the volume of traffic in terms of carrying capacity kilometers actually occupied. It is the sum total of the length of journeys performed by all the passengers carried. This gives the total output actually used by the public.

4.3.2 Inputs

We have used Seven input variables as listed below:

1. Capital and Liabilities (in Crores)

   It includes the net fixed assets, current assets and current liabilities.
2. No. of buses held

   It represents the total number of buses held by the Undertaking at a particular point of time.
3. Fuel Consumption (HSD consumed in kilotlitres)

   It is the total quantity of fuel (HSD Oil) consumed by the buses for the performance of total kilometers.
4. Material Cost other than for fuel (in Lakhs)

   It includes the variable costs for the operations other than the costs for fuel.
5. No. of Traffic Staff

   Traffic staff includes drivers, conductors, checkers, bus station staff and traffic supervisory staff.
6. No. of Workshop Staff

   It includes the repairs and maintenance staff; and other staff not included in any other category.
7. No. of Administrative Staff

   It includes the staff for personnel, accounts, Audit, Stores, Planning, Legal, Training and public relations.

The detailed definitions and explanations of these variables are given in the Appendix II.

4.4 The DEA Model Used

The analysis is done by models assuming constant returns to scale and varying returns to scale. The analysis assuming CRS is based on the input minimisation dual programme as developed by Charnes, Cooper and Rhodes (1978). The general form of the model, which can consider multitple inputs is given in (3.3.3.3*). But the analysis uses only one ouput variable.

$$\min_{\lambda_c} h_p - \varepsilon \left(\sum_{k=1}^{m} S_k + \sum_{i=1}^{t} S_i \right) \qquad (3.3.3.3^*)$$

subject to

$$X_{kp} \cdot h_p - S_k = \sum_{c=1}^{Z} X_{kc} \lambda_c \quad k=1,\dots,m$$

$$Y_{ip} + S_i = \sum_{c=1}^{Z} Y_{ic} \lambda_c \qquad i=1,\dots,t$$

and;

$$\lambda_c \geq 0, \quad c = 1,\dots,p,\dots,Z$$

$$S_k \geq 0, \quad k = 1,\dots, m$$

$$S_i \geq 0, \quad i = 1,\dots,t$$

with h_p unconstrained; and ε is an infinitesimal (or non- Archimedean) constant analogous to that used in the primal (Charnes and Cooper, 1984). the pth firm is relatively efficient, iff,

$$h_p^* = 1 \text{ and } S_k^* = S_i^* = 0 \quad \forall \; k \text{ and } i$$

where * is the optimal values of the variables in the dual programme.

The analysis assuming VRS is based on the Banker (1984)programme which came as a revision to the Charnes, Cooper and Rhodes programme(1978). It is given by:

$$\underset{\lambda_c}{\text{MIN}}\ h_p - \varepsilon\ (\sum_{k=1}^{m} S_k + \sum_{i=1}^{t} S_i) \qquad (3.3.4.1)$$

subject to

$$X_{kp} . h_p - S_k = \sum_{c=1}^{Z} X_{kc}\, \lambda_c, \quad k=1,...,m$$

$$Y_{ip} + S_i = \sum_{c=1}^{Z} Y_{ic}\, \lambda_c, \qquad i=1,..., t$$

$$\sum_{c=1}^{Z} \lambda_c = 1$$

and;

$\lambda_c \geq 0, \quad c = 1,...,p,...,Z$

$S_k \geq 0, \quad k = 1,..., m$

$S_i \geq 0, \quad i = 1,...,t$

where, λ_c are the weights on firms, S_k are the input slacks, S_i are the output slacks. Again, the pth firm is relatively efficient, iff,

$h_p^* = 1$ and $S_k^* = S_i^* = 0 \ \forall$ k and i

The dual programme is preferred to the primal for computation purpose since it is more tractable than the primal. The dual programme has only (m+t) constraints on inputs and outputs where the primal has Z, the number of firms, as constraints. Computational efficiency of the simplex method increases with decrease in the size of the constraint set.

4.5 The Estimation

The estimation was carried out with the software IDEAS (Integrated Data Envelopment Analysis System) Version 5.1.15 specifically developed for Data Envelopment Analysis.

Analysis was conducted first on the model in which Passenger kilometer was taken as the output. As this output concept was not consistent with the public sector objective, it was changed in the subsequent analysis into seat kilometers.

Again, the estimation used the model (3.3.3.3*) which assumes constant returns to scale (CRS) and the model (3.3.4.1) which allows for varying returns to scale (VRS). Grosskopf and Valdmanis (1987) argue that the CRS technology should be interpreted as reflecting long run performance possibilities. Analogously, the VRS assumption indicates feasible attainment in the short run. On this basis the long run CRS adjustments will be greater than those suggested by the VRS technology. The CRS targets are effectively adjustments towards long run equilibria, i.e., the minimum point of a U shaped average cost curve. As a result, more firms will be termed relatively inefficient under the CRS assumption.

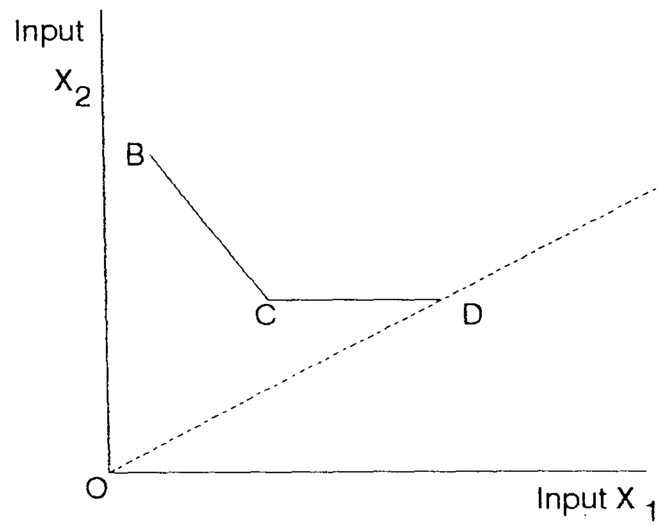
For the cross section of 30 STUs, DEA generates 30 efficiency indices in the closed interval [0, 1]. If the index is unity, a firm is *relatively* efficient or best-practice. A value less than unity indicates that a firm is inefficient *relative* to peer organisations. Again, the efficiency index can be split into two:

(1) theta (θ): It gives the radial reduction in inputs possible in order to obtain the projected input values

(2) iota (ι): It measures the proximity of the data point to the facet of the piecewise linear envelopment surface, equal to the total weighted distance between observed and the projected points, standardised by inputs. In other words, it measures the radial

contraction possible plus the additional reduction in the use of input(s), if there is a slack of that input. Both these measure will be of value 1 for efficient firms. These measures can be clearly understood from Figure 4.5.1

Figure 4.5.1 Radial Contraction Path and Slack



In the figure, for the inefficient firm E to be rated efficient, it should make a radial contraction of inputs X_1 and X_2 to D; *plus* a reduction in the use of input X_1 to reach C. The radial contraction is measured by theta (θ) and this radial contraction plus additional reduction in input(s) is given by iota (ι).

Along with the efficiency scores DEA identifies the peer group and the extent of their influence on each firm under analysis. The peer group for the efficient firms will be those firms itself. For the inefficient firms, there will be a set of efficient firms as peer group, from whom they can accept the 'blue prints' to achieve efficiency.

Apart from these efficiency scores and identification of peer groups, DEA reports the magnitude of inefficiency of each input. It is obtained by the difference in the actual input usage and the required input usage for the firm to be rated efficient. Again, DEA helps us to understand the magnitude of excess in each input even after the radial reduction is made possible in their usage. It will indicate the extra reduction required in the usage of those specified inputs.

4.6 X-Efficiency in STUs: Magnitude and Its Partitioning

The DEA estimation taking Passenger Kilometer as output gives us the frightening picture of existing X-inefficiency in the STUs. Assuming varying returns to scale (VRS), the measure of X-Efficiency that we get is presented in Table 4.6.1.

The results indicate that out of the 30 STUs, only 3 are rated relatively efficient; and all the rest 27 are rated inefficient. NBSTC, DCTC and KDTC are the efficient STUs and they have the efficiency score equal to 1. Again out of the 27 inefficient STUs, eight should cut down their input consumption below 10% of their present consumption, to be rated efficient. For all the inefficient STUs there exists difference between iota and theta which indicate that even after the proportional reduction there are slacks in certain inputs.

From the table it can be observed that KSRTC is a relatively inefficient STU as its efficiency scores are different from 1. Its iota and theta scores are .11289 and .08597 respectively. These scores say that for KSRTC to be rated efficient, it should make a radial reduction of inputs to 11.28% of its current level. Along with that, additional reductions in certain inputs are also required. Altogether KSRTC has to reduce its input usage to 8.6% of its current usage, to be rated efficient.

Table 4.6.1 X-Efficiency Scores of STUs When Output is Passenger Kilometers and VRS is Assumed.

No.	STU	iota	theta
1	MSRTC*	.02094	.02832
2	APSRTC*	.02197	.02704
3	KnSRTC*	.03434	.04040
4	GSRTC*	.04180	.07003
5	UPSRTC*	.04613	.07486
6	RSRTC*	.07184	.08802
7	STHAR@	.07744	.11296
8	KSRTC*	.08597	.11289
9	MPSRTC*	.12962	.13142
10	STPJB@	.33688	.33861
11	PRC#	.38478	.39341
12	CTC#	.43987	.44322
13	PRTC*	.42091	.42228
14	NBSTC*	1.00000	1.00000
15	OSRTC*	.46165	.46640
16	DCTC#	1.00000	1.00000
17	TTC#	.44467	.44911
18	JTC#	.66088	.66780
19	KTC#	.65942	.66404
20	TPTC#	.45871	.46104
21	ATC#	.66160	.66596
22	CRC#	.66273	.66858
23	MPTC#	.82691	.83770
24	PATC#	.59958	.60288
25	MGRTC#	.86489	.87352
26	RMTC#	.68009	.68634
27	NTC#	.96743	.97551
28	ASTC#	.75920	.76554
29	SBSTC*	.98553	.99270
30	KDTC#	1.00000	1.00000

Source: DEA Results

The use of passenger kilometers as output of STUs can be criticised from many angles. First of all, the public transport system is not supposed to operate only in the routes in which there is a passenger rush. It is also operating in routes with low passenger density with the social objective to provide service. Therefore, it is not the total number of passengers carried, but a measure of aggregate service offered is to be taken as output. Secondly, the calculation of passenger kilometers is done by dividing the total number of passengers carried by the average fare per kilometer. Since all STUs are following non-linear price structure, the calculation of passenger kilometer reduces to an approximation.

To avoid all these problems, seat kilometers is taken as output. The results of DEA over this renewed output concept; and assuming varying returns to scale give us the results as presented in Table 4.6.2.

Table 4.6.2 X-Efficiency Scores of STUs When Output is Seat Kilometers and VRS is Assumed.

No.	STU	iota	theta
1	MSRTC*	1.00000	1.00000
2	APSRTC*	1.00000	1.00000
3	KnSRTC*	.84398	.89201
4	GSRTC*	1.00000	1.00000
5	UPSRTC*	.71474	.86204
6	RSRTC*	1.00000	1.00000
7	STHAR@	1.00000	1.00000
8	KSRTC*	.67983	.77566
9	MPSRTC*	.41484	.76087
10	STPJB@	1.00000	1.00000
11	PRC#	.82518	.84490
12	CTC#	.85699	.93889
13	PRTC*	.87791	.88577
14	NBSTC*	1.00000	1.00000
15	OSRTC*	.76656	.78750
16	DCTC#	.96666	.97698
17	TTC#	1.00000	1.00000
18	JTC#	.89779	.96395
19	KTC#	.85865	.86594
20	TPTC#	.86550	.87275
21	ATC#	.89166	.89537
22	CRC#	.75618	.82234
23	MPTC#	.97575	.98979
24	PATC#	1.00000	1.00000
25	MGRTC#	1.00000	1.00000
26	RMTC#	1.00000	1.00000
27	NTC#	1.00000	1.00000
28	ASTC#	1.00000	1.00000
29	SBSTC*	.73666	.99270
30	KDTC#	1.00000	1.00000

Source: DEA Results

With the new measure of output, the efficiency scores of all the STUs go up resulting in the identification of 11 more STUs as efficient. Now, the total number of efficient firms amounts up to 14. The least efficient STU is MPSRTC which has the lowest efficiency score of .41484. It asks MPSRTC to reduce the input usage to 41.5% of its current level. KSRTC stands second in the inefficiency ranking with an efficiency score of .67983. It tells that 32% of the current input usage in KSRTC is unnecessary.

The sensitivity of the efficiency score to the output measure invariably leads to the fact that all the STUs are operating services without regard to the earning aspect. Now, with the Seat Kilometers as output we get the efficiency scores which are consistent with the public sector motive and the existing routes and service pattern.

The VRS assumption indicates feasible attainment only in the short run. By assuming CRS, the adjustment costs become greater than those suggested by the VRS technology since CRS reflects long run performance possibilities. Therefore, the efficiency scores of the STUs turns to be smaller (which means larger reductions in the input usage). It is clear from the efficiency scores obtained from the DEA of STUs assuming Constant Returns to Scale (CRS). Table 4.6.3 presents those scores.

With the assumption of CRS, the number of efficient firms reduces to 5. Even the STUs rated efficient under the VRS assumption, now have to make adjustments in the inputs to be efficient in the long run perspective. KSRTC, which had the second lowest efficiency score under the VRS assumption now has an efficiency score without much difference. It is asked to cut dow the input usage only to 67.6% of the current level; and this requirement under VRS assumption was 67.9%. The little difference in these efficiency scores leads us to the conclusion that KSRTC is scale efficient in its operations. This aspect is discussed more in section 4.8.

Table 4.6.3 X-Efficiency Scores of STUs When Output is Seat Kilometers and CRS is Assumed.

No.	STU	iota	theta
1	MSRTC*	.58060	.85799
2	APSRTC*	.63342	.92158
3	KnSRTC*	.57907	.75237
4	GSRTC*	1.00000	1.00000
5	UPSRTC*	.79136	.85845
6	RSRTC*	.67016	.97310
7	STHAR@	1.00000	1.00000
8	KSRTC*	.67664	.70882
9	MPSRTC*	.36764	.75420
10	STPJB@	.81471	.81657
11	PRC#	.78731	.79396
12	CTC#	.81392	.84127
13	PRTC*	.81650	.85685
14	NBSTC*	.55419	.80459
15	OSRTC*	.39274	.69132
16	DCTC#	.93306	.97514
17	TTC#	1.00000	1.00000
18	JTC#	.89661	.90246
19	KTC#	.85467	.86118
20	TPTC#	.83095	.86132
21	ATC#	.86694	.88409
22	CRC#	.81330	.81411
23	MPTC#	.94775	.98118
24	PATC#	.93332	.95266
25	MGRTC#	1.00000	1.00000
26	RMTC#	1.00000	1.00000
27	NTC#	.84114	.85948
28	ASTC#	.87623	.89665
29	SBSTC*	.26817	.52396
30	KDTC#	.39759	.60546

Source: DEA Results

4.7 Identification of Peer Groups

In the linear programming formulation, the efficient firms form a referent set for calculating the performance scores of the non-efficient firms. For each firm which is a non-optimal performer, one or more firms similar in operational capabilities are identified, and the actual proportion by which each such optimal or efficient firm influences one which is non-optimal is given. The efficient firms have only themselves as fully dominating referent set.

The identification of peer group helps to recognise the firms with the same level of operation and still performing well. From those efficient firms, the non-efficient firms can borrow 'blue prints' of managerial techniques to improve their efficiency. The peer groups for the inefficient STUs under theVRS assumption are listed in table 4.7.1.

Table 4.7.1 Inefficient firms and their peer Groups Under VRS Assumption

Inefficient STU	Peer Group
3 KnSRTC*	GSRTC*(.80475) RSRTC*(.19525)
5 UPSRTC*	GSRTC*(.59498) MGRTC#(.40502)
8 KSRTC*	TTC#(.51726 GSRTC*(.13824)STPJB@(.30116) MGRTC#(.04333)
9 MPSRTC*	GSRTC*(.08168) MGRTC#(.91832)
11 PRC#	TTC#(.0258)GSRTC*(.0215)STPJB@(.07818)MGRTC#(.79773)
12 CTC#	TTC#(.17538) GSRTC*(.02052) STPJB@(.03261)MGRTC#(.7715)
13 PRTC*	KDTC#(.07384) RMTC#(.70124) MGRTC#(.22492)
15 OSRTC*	KDTC#(.59769) RMTC# (.03523) MGRTC#(.36708)
16 DCTC#	MGRTC#(.96451) GSRTC*(.00678) PATC#(.02871)
18 JTC#	GSRTC*(.00789) STPJB@ (.01471) MGRTC#(.97740)
19 KTC#	GSRTC*(.00232) TTC#(.05866) MGRTC#(.93903)
20 TPTC#	MGRTC#(.78703) GSRTC*(.00235) PATC#(.21063)
21 ATC#	MGRTC#(.61015) RMTC#(.38985)
22 CRC#	MGRTC#(.95787) KDTC#(.04213)
23 MPTC#	PATC#(.05378) KDTC#(.01990) MGRTC#(.92632)
29 SBSTC*	KDTC#(1.00000)

Source: DEA Results

According to Smith and Mayston (1987) an important supplementary measure in assessing the robustness of this result is the number of inefficient authorities for which the best practice authority forms the efficient frontier. If this number is high the authority is considered genuinely efficient with respect to a large number of authorities. The citations for the best practice STUs under VRS assumption are given in the table 4.7.2. Thus according to the Smith and Mayston rule, we should come to the conclusion that MGRTC and GSRTC are the "bests in bests".

Table 4.7.2 Citations for Best-Practice STUs.

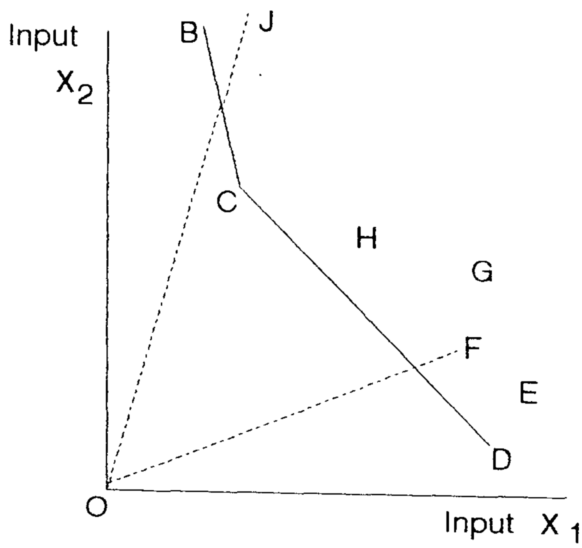
No.	STU	Citations in Peer Groups
1	MSRTC*	1
2	APSRTC*	0
4	GSRTC*	10
6	RSRTC*	0
7	STHAR@	0
10	STPJB@	4
14	NBSTC*	0
17	TTC#	4
24	PATC#	3
25	MGRTC#	14
26	RMTC#	3
27	NTC#	0
28	ASTC#	0
30	KDTC#	5

Source: Computed from Table 4.7.1

But the Smith-Mayston interpretation of the best practice STUs will stand only if the inefficient STUs are spread evenly through the feasible production space. It is clear from the Figure 4.5.2.

In the figure, B, C and D are the best-practice STUs with efficiency score equal to unity. STUs E, F, G, H and J are relatively inefficient. It is clear from the figure that most of the inefficient STUs, other than J, are C and D as peer group. But STU J has unusual input proportions such that its target is an interpolation of STUs B and C. Clearly best practice authorities such as B which have relatively unusual input proportions will lie on the extreme parts of the isoquant. They will be cited infrequently, since, with unusual input proportions, there is a lower probability of finding comparable inefficient STUs.

Figure 4.7.1 Interpretation of Citations for Best Practice



Now, it can be observed that MGRTC and GSRTC are cited frequently, mainly because of the fact that they have more common input combinations. Many of the efficient STUs not at all appear as a peer group other than their own. It points to the fact that many of the STUs have their own unique combinations of inputs which inturn carries a significant role in determining their efficiency score both in short run and long run.

The identification of the peer groups assuming VRS, presents the "good models" in the short run. But to have a look on the long run adjustments to be made in the input proportions, the peer groups identified in the model assuming CRS will be more helpful. The peer groups under the CRS assumption is presented in the table 4.7.3.

Table 4.7.3 Inefficient Firms and Their Peer Groups Under CRS Assumption

Inefficient STU	Peer Group	
1 MSRTC*	MGRTC#	
2 APSRTC*	MGRTC#	
3 KnSRTC*	MGRTC#	
5 UPSRTC*	MGRTC#	GSRTC*
6 RSRTC*	MGRTC#	
8 KSRTC*	MGRTC#	GSRTC*
9 MPSRTC*	MGRTC#	
10 STPJB@	MGRTC#	STHAR@
11 PRC#	MGRTC#	GSRTC*
12 CTC#	TTC#	MGRTC#
13 PRTC*	MGRTC#	GSRTC*
14 NBSTC*	MGRTC#	
15 OSRTC*	MGRTC#	
16 DCTC#	GSRTC*	MSRTC#
18 JTC#	MGRTC#	RMTC#
19 KTC#	MGRTC#	GSRTC*
20 TPTC#	GSRTC*	MSRTC#
21 ATC#	MGRTC#	GSRTC*
22 CRC#	MGRTC#	STHAR@
23 MPTC#	GSRTC*	MGRTC#
24 PATC#	GSRTC*	MGRTC#
27 NTC#	MGRTC#	GSRTC*
28 ASTC#	MGRTC#	RMC#
29 SBSTC*	MGRTC#	
30 KDTC#	MGRTC#	

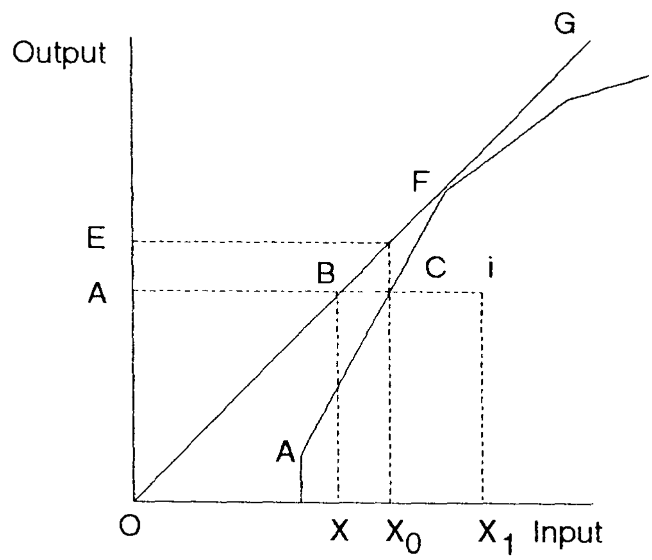
Source: DEA Results

MGRTC becomes the peer group for almost all STUs under the CRS assumption. The input combinations and the managerial technique adopted by MGRTC are to be advised to all the inefficient STUs and even to the efficient STUs under VRS assumption.

4.8 Scale Efficiency and Returns to Scale in STUs

An attempt to distinguish between the technical inefficiency and scale inefficiency in the total inefficiency was made by Rangan, Grabowski, Aly and Pasurka (1988). They derived the scale efficiency from the VRS and CRS efficiency scores. It is explained with the Figure 4.8.1.

Figure 4.8.1 Measurement of Scale Efficiency



In the figure, for given level of output, CRS efficiency for the STU *i* is $0X/0X_1$ and its VRS efficiency is $0X_0/0X_1$. The discrepancy between the two measures is defined according to the extent of the gap between the two frontiers. This can be expressed as the ratio:

$$(0X/0X_1) / (0X_0/0X_1) = 0X / 0X_0$$

This is simply the ratio of the CRS and VRS efficiency scores and is proposed by

Rangan *et al* as an indicator of scale efficiency (S); whence for a branch i:

$S_i = CRS_i / VRS_i$

In the figure S_i is less than one, indicating that production at this point is not scale efficient. Moreover, were production displaced onto the VRS boundary at C, S_i would remain less than unity. At point C the STU has pure technical efficiency (VRS efficiency) but still carries scale inefficiency.

The Rangan et al indicator shows by what proportion total costs could be reduced after the attainment of pure technical efficiency on the VRS boundary.

Banker (1984) showed that the inefficiency at C can be examined in terms of its average productivity or scale properties. Specifically, this point is scale inefficient because average productivity - the ratio of output to input - has not been maximised. That is, for output 0A, $0A / 0X_0$ is less than its theoretical maximum $0E / 0X_0$ which is defined along the CRS frontier. Thus in order to attain maximum average productivity for output 0A an additional contraction in input, $0X_0$ - 0X, would be necessary to bring production to point B on the CRS boundary. This contraction in inputs (further to that $0X_1$ - $0X_0$, to eliminate pure technical efficiency) eliminates that wastage attributable to scale inefficiency.

Banker demonstrated that sum of the weights on the branches in the optimal basis of the CRS version of the DEA programme can be used as an indicator of the local returns to scale at the current level of operations.

Both the Rangan et al measure of scale efficiency and the Banker measure of Returns to scale are presented in the table 4.8.1.

The Rangan et al indicator shows that 25 out of 30 STUs are scale inefficient. KSRTC has a high level of scale efficiency (.99530) which says that it has to make a reduction of inputs only of (1 - .99530) ie, .0047% from the point of VRS efficiency. The lowest scale inefficiency is of SBSTC, .36403, which means that a reduction of 63.6% of inputs from the point of VRS efficiency is required.

Table 4.8.1 Scale Efficiency in the STUs

No.	STU	Rangan et al	Banker
1	MSRTC*	.58060	13.36412 (DRS)
2	APSRTC*	.63342	14.42569 (DRS)
3	KnSRTC*	.06861	7.81942 (DRS)
4	GSRTC*	1.00000	1.00000 (CRS)
5	UPSRTC*	.90319	2.04263 (DRS)
6	RSRTC*	.67016	4.00329 (DRS)
7	STHAR@	1.00000	1.00000 (CRS)
8	KSRTC*	.99530	1.45681 (DRS)
9	MPSRTC*	.88622	1.63264 (DRS)
10	STPJB@	.81471	1.85040 (DRS)
11	PRC#	.95410	1.10482 (DRS)
12	CTC#	.94774	1.19413 (DRS)
13	PRTC*	.93004	.84704 (IRS)
14	NBSTC*	.55419	.60942 (IRS)
15	OSRTC*	.51234	.49781 (IRS)
16	DCTC#	.96524	.99069 (IRS)
17	TTC#	1.00000	1.00000 (CRS)
18	JTC#	.99868	1.19512 (DRS)
19	KTC#	.99536	1.01694 (DRS)
20	TPTC#	.96008	.93642 (IRS)
21	ATC#	.97227	.90996 (IRS)
22	CRC#	.92977	.95101 (IRS)
23	MPTC#	.97130	.96758 (IRS)
24	PATC#	.93332	.76579 (IRS)
25	MGRTC#	1.00000	1.00000 (CRS)
26	RMTC#	1.00000	1.00000 (CRS)
27	NTC#	.84114	.61960 (IRS)
28	ASTC#	.87623	.71258 (IRS)
29	SBSTC*	.36403	.14365 (IRS)
30	KDTC#	.39759	.16479 (IRS)

Source:

1. The Rangan et al (1988) scale efficiency is the ratio of CRS to VRS efficiency scores derived from, respectively tables 4.6.2 and 4.6.3.
2. Banker's (1984) measure of returns to scale is the sum of the weight on STUs in the unconstrained CRS programme.

Out of the 14 VRS efficient STUs, only 5 are CRS efficient and these 5 STUs are the only scale efficient STUs.

The Banker measure of returns to scale shows that out of the total 30 STUs, 5 are experiencing CRS, 13 are operating with IRS and the rest 12 are facing DRS. The STUs with CRS indicate that their current level of operation can be maintained. The STUs with IRS are to be advised to increase their scale of operation. Similarly, the STUs with DRS should curtail their scale of operation.

To sum up, Data Envelopment Analysis generates the *firm specific* quantitative measure of X-efficiency in different STUs in India; and thus facilitates the search for *firm specific* reasons behind inefficiency. That is, with the DEA measures, now one is able to have a look inside the "black box".

Chapter 5

BEHIND THE X-INEFFICIENCY IN STATE TRANSPORT UNDERTAKINGS

5.1 Inside the Black Box

After observing huge X-inefficiency in the STUs, a naturally inquisitive mind would turn to the question 'why?'. The answer requires a theoretical frame which allows for the close examination of 'all the factors' of inefficiency that can be identified which may be well beyond generalisations, due to the uniqueness in the mode of production within each firm. The need of the moment is an approach which can recognise the factors of transformation process within the firms and can identify relations and interrelations which cause inefficiency. In short we require a micro micro approach; a purpose X-efficiency theory serves.

Firm is a bundle of capabilities and inputs; and production is a process of transforming this bundle into outputs. The transformation is characterised by, among others, the interactions and interrelations among different inputs. This aspect of the process within the firm causes the inefficiency in one input to the excess use of other inputs; which in turn raises the cost within the firm and ultimately inefficiency.

Leibenstein thought of a production schema[1] within firms in which organisational aspects and different norms, conventions and institutions create an environment for each firm. Different organisational forms define unique contractual relations through which the principal-agent relations differ. What results is varying pressure levels in firms which in turn decide the effort level of inputs and cost of production process. Simply this fixes up the efficiency in firms.

---

1 It is discussed at length in Chapter 2, Section 2.4 and 2.5.

Actually, the environment created by the institutional factors inside and outside the firms together with the degree of pressure it creates within the firms define an 'inert area of production. This inert production level is nothing but the result of inert level of the usage of different inputs.

In the case of STUs, this inert area is much below the potential which causes them to remain highly inefficient. Identification of the causes of this inertia in production will lead us to the inertia in the usage of different inputs. A quantitative guide to the inert levels of the input usage and thereby an attempt to point to the existence of institutional factors causing inefficiency is what we aim at.

5.2 Does Organisaton Matter?

The environment of the STUs created by the institutional factors *inside* and *outside* them can be viewed from supply side and demand side. The Demand side is kept away by analysing only the mofussils services and by taking Seat Kilometers as output. Turning to the supply side, ie, inside the firm, the STUs have different organisatonal forms and the resulting institutional features within them.

The STUs in India have mainly the following organisational forms. (1) Departmental Undertakings directly under the state governments (2) Municipal undertakings owned and controlled by the Municipal corporations (3) Road Transport Corporations formed under the Road Transport Corporations Act of 1950 (4) Companies or Corporations formed under the Indian Companies Act (1956). Each organisational form is characterised by varying government control in such a way that, from Departmental undertakings to Companies autonomy increases. Each organisational form sets different principal-agent relations and thereby different "pressure" levels in the STUs. This results in the variation of non-maximising behaviour of the STUs and ultimately variations in X-efficiency. It is clear from the results of DEA presented in Chapter 4. The efficiency variation over different organisational forms are substantial when we used the output variable Passenger Kilometers. It is presented in the Table 5.2.1.

Table 5.2.1 Mean Efficiency Score of Different Organisational Forms of STUs (Under VRS Assumption) When Output is Passenger Kilometers

Organisational Form	Mean Efficiency Score*	
	iota	theta
1. Departmental Undertakings	.20716	.22579
2. Corporations	.27673	.28786
3. Companies	.69192	.69717

*Mean difference is significant at 10% level

Source: Computed from Table 4.6.1.

The efficiency score variation over different organisational forms is revealed by the mean efficiency scores. From the Departmental Undertakings to the Companies the efficiency score is increasing for both iota and theta as evident from the Table 5.2.1. The statistical difference of the efficiency scores were tested with ANOVA and the difference was asserted at 10% level of significance.

Frequency distribution of STUs over the efficiency scores presented in Table 5.2.2 makes the variation clearer.

Table 5.2.2 Frequency Distribution of STUs According to Efficiency Score When Output is Passenger Kilometers (Under VRS Assumption)

Efficiency Score Classes	Departmental-Undertakings	Corporations	Companies
0 - .2	1	8	0
.2 - .4	1	0	1
.4 - .8	0	2	10
.8 - 1	0	1	3
Equal to 1	0	1	2
	2	12	16

Source: Computed from Table 4.6.1.

It is clear that from departmental undertakings to corporations and companies, the concentration of STUs increases in the higher efficiency score classes.

But the introduction of Seat Kilometers as output, shows that the two departmental undertakings are efficient; and the variation in mean efficiency scores rate the corporations less efficient than companies. It is to be noted that the introduction of the new output measure rates the departmental undertakings efficient. It says that they are operating in more kilometers without revenue-earning purpose. This result is much surprising in the sense, it is clearly opposite to the general perception that, the government interference has negative impact on the performance of STUs. The mean efficiency score of different organisational forms when seat kilometers was taken as output are presented in Table 5.2.3.

Table 5.2.3 Mean Efficiency Scores of Different Organisational Forms of STUs when Output is Seat Kilometers

Organisational Form	Mean Efficiency Score*			
	VRS		CRS	
	iota	theta	iota	theta
1. Departmental Undertakings	1.00000	1.00000	0.90736	0.90829
2. Corporations	0.83621	0.91305	0.61087	0.80860
3. Companies	0.93090	0.94818	0.86205	0.88931

*Mean efficiency scores are significantly different at 5% level under VRS assumption and at 1% level under CRS assumption.

Source: Computed from Tables 4.6.2 and 4.6.3.

The mean efficiency differences are found statistically significant and we again arrive at the conclusion that efficiency variations are significant from corporations to companies.

Again, the frequency distribution of STUs over the efficiency scores with seat kilometers as output confirms the conclusion, which is presented in Table 5.2.4.

Table 5.2.4 Frequency Distribution of STUs According to Efficiency Scores (Under VRS Assumption) When Output is Seat Kilometers

Efficiency Score Classes	Departmental-Undertakings	Corporations	Companies
Less than .6	0	1	0
.6 - .7	0	1	0
.7 - .8	0	3	1
.8 - .9	0	2	6
.9 - 1	0	0	2
Equal to 1	2	5	7
	2	12	16

Source: Computed from Table 4.6.2

Coming to the scale efficiency aspect, the efficiency variation is becoming more evident. Banker measure also suggests that there are variations in the performance of STUs over the organisational forms. The mean of Rangan measure of scale efficiency and the number of STUs with different returns to scale are presented in the Table 5.2.5.

Table 5.2.5 Mean Scale Efficiency and the No. of STUswith Different Returns to Scale

Organisational-Form of STUs	Mean Scale Efficiency	Returns to Scale (No. of STUs)		
		DRS	CRS	IRS
Dept.Undertaking	0.90735	1	1	0
Corporations	0.67484	7	1	4
Companies	0.92141	4	3	9

Source: Computed from Table 4.8.1.

According to the Banker measure, among the departmental undertakings one is with diminishing returns to scale and the other is operating on constant returns to scale. Among the Corporation, majority is showing diminishing returns while only 4 are showing increasing returns to scale. With regard to Companies, majority is operating with increasing returns to scale and only 4 are with diminishing returns to scale and 3 are having constant returns to scale.

All these lead us to the conclusion that there is no *specific pattern* of efficiency variation over organisational forms. This conclusion reduces to the fact that though variations are there over organisational forms, it is not in a fixed pattern. It means the reasons behind inefficiency are to be enquired beyond generalisations. Specific analysis of each firm and the institutional set up within the STUs along with the understanding of the organisational form only can reveal the complete picture behind inefficiency.

Though it is evident and can be concluded that the Averch-Johnson result which says efficiency decreases with government control stands right when the output is passenger kilometers, it is rejected when we consider seat kilometers as output. Since seat kilometers is the output which is consistent with the public sector motive, for STUs in India, it is in all way reasonable to reject the hypothesis.

5.3 Institutions and Inert Areas in STUs

Each organisational form and the institutional factors define the input relations and interrelations in its own way specifically to each firm. It gives uniqueness to its production mode in which a specific environment is peculiar to the firm.

The environment exerts pressure upon the inputs which determines the effort level chosen by the inputs. But human input is the only rational input in the firm; which is found not maximising its effort. It is simply because of the fact that *some* forms of decision making such as habits, conventions, moral imperatives, standard procedures, rules of thumb or emulation, can be and frequently are of a non-maximising nature. The reason is that they are not based on careful calculations.

The interests of the agents are not the same as that of the principal. The existence of effort discretion with the human inputs while the principal does not have wage discretion, creates inert areas of effort and thereby of output in STUs. These inert areas are made to persist by the existence of moral hazards within STUs

A crucial aspect of the non-maximising nature of the human input is that it also fixes the usage level and effort position of non-human inputs. Lack of adequate pressure leads to lower levels of effort levels for human inputs which results in excess usage or wastage of non-human inputs. The result is that more and more excess inputs are used. In short, the human input creates inert areas not only in its own effort levels but also with respect to different inputs. These inert areas will comprise different norms, conventions and in short the institutional aspects of the firm. Through time, these institutions set in to the blood of each STU and ensure the firm inefficient.

Ganley and Cubbin(1992) identifies the DEA efficiency score as a quantitative guide to the inertia of the production process in the firms. DEA also identifies the exact magnitude of the excess of each inputs in different STUs. It is found by taking the deviation between the required and the actual use of each input. Even after the radial reduction of these excess inputs what remains is identified as slack. The analysis of the excess inputs and their slack enable us to recognize the existence of institutional factors over different STUs.

The excess inputs existing in different STUs under VRS assumption are given in the Table 5.3.1. The percentage of excess inputs to the actual usage is given in parentheses.

Table 5.3.1 Excess inputs and their Percentage to Actual Usage (Under VRS Assumption)

No.	STU	CL	BU	FU	MC	TS	WS	AS
3	KnSRTC*	-194.16	-1980.93	-2133.86	-3136.70	-5948.77	-1321.69	-2927.61
		(27)	(20)	(23)	(30)	(14)	(11)	(44)
5	UPSRTC*	-170.11	-2608.33	-19782.30	-977.75	-10599.97	-7192.34	-973.94
		(33)	(32)	(14)	(16)	(28)	(48)	(28)
8	KSRTC*	-31.41	-1082.92	-19348.19	-769.55	-5293.20	-2761.19	-2392.53
		(22)	(31)	(22)	(22)	(32)	(43)	(61)
9	MPSRTC*	-236.44	-1310.32	-11199.27	-2456.35	-4514.52	-4587.76	-4428.67
		(79)	(49)	(24)	(61)	(41)	(71)	(84)
11	PRC#	-5.93	-184.41	-7303.94	-271.25	-1455.83	-260.56	-220.80
		(16)	(16)	(19)	(17)	(23)	(16)	(23)
12	CTC#	-2.07	-60.56	-6167.98	-413.59	-1066.24	-91.12	-555.69
		(06)	(06)	(17)	(24)	(18)	(06)	(43)
13	PRTC*	-15.82	-432.92	-2755.94	-117.57	-430.14	-381.67	-433.58
		(44)	(41)	(11)	(11)	(12)	(33)	(38)
15	OSRTC*	-53.73	-383.48	-3310.58	-167.66	-1947.44	-839.58	-1241.88
		(77)	(46)	(21)	(21)	(47)	(58)	(77)
16	DCTC#	-8.96	-35.47	-5852.09	-265.67	-625.06	-23.18	-13.74
		(30)	(05)	(20)	(20)	(15)	(02)	(02)
18	JTC#	-.80	-61.59	-5480.43	-183.25	-314.46	-38.21	-186.30
		(04)	(07)	(19)	(14)	(08)	(04)	(24)
19	KTC#	-2.95	-121.77	-4857.25	-162.55	-708.88	-242.30	-181.82
		(13)	(15)	(17)	(13)	(16)	(20)	(24)
20	TPTC#	-13.38	-104.29	-4778.70	-427.09	-848.27	-139.59	-81.82
		(40)	(13)	(17)	(29)	(19)	(13)	(13)
21	ATC#	-2.93	-171.53	-5322.38	-114.57	-1002.34	-454.61	-222.84
		(13)	(20)	(19)	(10)	(23)	(35)	(26)
22	CRC#	-5.33	-153.97	-7664.37	-542.93	-717.75	-253.90	-184.44
		(24)	(19)	(27)	(36)	(18)	(22)	(25)
23	MPTC#	-.18	-72.40	-4691.81	-424.55	-419.34	-125.61	-5.72
		(01)	(10)	(18)	(30)	(11)	(12)	(01)
29	SBSTC*	-4.09	-300.00	-43.28	-95.11	-820.00	-122.00	-46.00
		(21)	(50)	(01)	(21)	(38)	(23)	(16)

Source: Computed from the results of DEA

It is clear from the table that all the STUs are having excess in all the inputs. The magnitudes of the percentage of excess inputs tells us the story behind the inefficiency of STUs. KnSRTC is inefficient mainly because of the excess number of administrative (44%) staff with it. It does not lessen the 'contribution' of other inputs to the inefficiency score of this STU. MPSRTC shows huge excess of all the inputs like it uses 79% of capital in excess, 84% of administrative staff in excess. This excess of different inputs gives an idea about the inert position in output generated from the inert positions of inputs.

Now, if the inert areas are the product of institutions inside and outside of the STU, organisation wise there should be clear variation in the percentages of excess inputs. That was enquired into and the result is given in the Table 5.3.2.

Table 5.3.2 Statistics of Percentages of Excess Inputs (Under VRS Assumption) Over Different Organisational Forms of STUs

Inputs	Corporations	Companies
CL		
Minimum	21.00	01.00
Maximum	79.00	40.00
Mean	43.29	16.33
BU		
Minimum	20.00	05.00
Maximum	50.00	20.00
Mean	38.29	12.33
FU		
Minimum	01.00	17.00
Maximum	24.00	27.00
Mean	16.57	19.22
MC		
Minimum	11.00	10.00
Maximum	61.00	36.00
Mean	26.00	21.44
TS		
Minimum	12.00	08.00
Maximum	47.00	23.00
Mean	30.29	16.78
WS		
Minimum	11.00	02.00
Maximum	71.00	35.00
Mean	41.00	13.33
AS		
Minimum	16.00	01.00
Maximum	84.00	43.00
Mean	49.71	20.11

Source: Computed from Table 5.3.1

It gives us a picture how efficiently each input is used in different STUs and endorses the fact that institutional factors are varying over the organisational forms of Corporations and companies, causing variations in the use of inputs and thereby in efficiency scores.

Since both the departmental undertakings are rated efficient, it is taken that they do not have no input in excess. For the corporations and companies, there are clear differences in the percentage of excess inputs used. It is only with input fuel that the corporations are doing better than companies. For all other inputs, the corporations are having institutional set up which 'eat up' large quantities of those inputs

The slack of each excess input presented in Table 5.3.3 gives us an idea about the gravity of the excess inputs with each firm. It shows that even after the radial reduction of the excess inputs, there remains excess and more attention is to be given to the management of that particular input.

Table 5.3.3 Slack analysis Under VRS Assumption.

No.	STU	CL	BU	FU	MC	TS	WS	AS
3	KnSRTC*	117.65	891.75	27852.04	1991.43	1232.21	.00	2207.75
5	UPSRTC*	99.70	1472.93	.00	128.28	5450.95	5131.80	501.30
8	KSRTC*	.00	298.19	.00	.00	1586.70	1318.48	1513.35
9	MPSRTC*	165.26	672.56	.00	1491.13	1854.23	3050.41	3173.00
11	PRC#	.00	.00	1485.39	24.25	483.83	.00	69.27
12	CTC#	.00	.00	3948.26	310.15	712.71	.00	477.28
13	PRTC*	11.68	311.38	.00	.00	23.70	248.59	304.73
15	OSRTC*	38.88	206.25	.00	.00	1074.90	533.36	897.20
16	DCTC#	8.28	17.70	5190.63	235.24	525.97	.00	.00
18	JTC#	.00	31.67	4436.70	137.55	166.71	.00	157.79
19	KTC#	.00	10.77	1076.73	.00	128.41	76.47	78.19
20	TPTC#	9.15	.20	1283.97	241.09	290.68	.00	.00
21	ATC#	.64	83.74	2449.57	.00	548.14	317.44	131.61
22	CRC#	1.41	8.99	2576.86	272.33	.00	52.25	54.04
23	MPTC#	.00	64.78	4424.61	410.04	380.60	115.15	.00
29	SBSTC*	3.95	295.63	.00	91.75	804.33	118.15	43.88

Source: DEA Results

In all the STUs, except for CRC, traffic staff is showing excess. Also, the number of buses are problems with all STUs except PRC and CTC. The case of administrative staff also is a problem even after the radial reduction for STUs other than DCTC, TPTC and MPTC.

With the VRS assumption, what we are getting is a picture of the inefficiency which can be corrected in the short run for the STU to be rated efficient. But when the assumption is of CRS naturally the input adjustment require more reduction and it asks for large scale and many basic changes in input usages. The excess inputs used, the mean variation of the percentage of excess inputs to the used, and the slacks are presented in the Tables 5.3.4., 5.3.5., and 5.3.6 respectively.

Table 5.3.4 Excess inputs and their Percentage to Actual Usage (Under CRS Assumption)

NO.	STU	CL	BU	FU	MC	TS	WS	AS
1	MSRTC*	-967.75 (81)	-6497.13 (42)	-47855.36 (14)	-2589.77 (16)	-26442.37 (37)	-13415.57 (53)	-7812.00 (51)
2	APSRTC*	-1009.98 (81)	-5674.38 (37)	-26557.10 (08)	-3637.72 (20)	-36932.38 (43)	-10984.02 (46)	-2390.33 (23)
3	KnSRTC*	-576.95 (81)	-4784.43 (47)	-55679.83 (25)	-2729.25 (26)	-17011.78 (39)	-5185.88 (42)	-2263.67 (34)
5	UPSRTC*	-225.76 (44)	-3019.94 (37)	-20297.24 (14)	-871.58 (14)	-12319.22 (33)	-7799.83 (52)	-814.34 (24)
6	RSRTC*	-256.80 (79)	-1755.77 (39)	-2394.66 (03)	-1163.82 (22)	-4020.77 (23)	-1191.03 (25)	-1486.15 (40)
8	KSRTC*	-40.77 (29)	-1367.96 (39)	-31164.69 (36)	-998.85 (29)	-6167.40 (37)	-3536.08 (55)	-2662.32 (68)
9	MPSRTC*	-270.20 (91)	-1560.07 (58)	-11511.72 (25)	-2391.93 (59)	-5557.71 (50)	-4956.36 (77)	-4331.83 (82)
10	STPJB@	-7.81 (18)	-1080.80 (46)	-13931.25 (25)	-593.52 (24)	-1442.32 (18)	-1159.61 (40)	-629.23 (37)
11	PRC#	-7.87 (21)	-260.28 (22)	-9906.73 (26)	-328.13 (21)	-1652.36 (26)	-434.82 (26)	-286.34 (29)
12	CTC#	-11.11 (33)	-157.30 (16)	-6969.51 (19)	-418.82 (25)	-1390.19 (24)	-236.66 (16)	-554.83 (43)
13	PRTC*	-19.81 (55)	-455.72 (43)	-5099.20 (21)	-147.32 (14)	-509.31 (14)	-353.93 (30)	-638.13 (57)
14	NBSTC*	-2.49 (20)	-557.81 (57)	-6373.98 (33)	-288.58 (32)	-2371.87 (53)	-1154.30 (68)	-335.90 (49)
15	OSRTC*	-61.51 (88)	-496.49 (60)	-4808.98 (31)	-287.56 (36)	-2408.48 (59)	-991.98 (69)	-1341.74 (83)
16	DCTC#	-8.86 (30)	-36.46 (05)	-5986.62 (21)	-270.19 (20)	-625.65 (15)	-25.03 (02)	-14.84 (02)
18	JTC#	-2.17 (10)	-92.50 (11)	-4773.73 (16)	-180.86 (14)	-404.03 (10)	-103.39 (10)	-104.88 (13)
19	KTC#	-3.39 (15)	-114.94 (14)	-5712.99 (20)	-168.32 (14)	-751.08 (17)	-287.10 (23)	-191.46 (25)
20	TPTC#	-12.89 (39)	-113.44 (14)	-5767.97 (21)	-459.76 (31)	-860.29 (20)	-155.94 (14)	-89.17 (14)
21	ATC#	-2.53 (12)	-161.00 (19)	-6510.31 (24)	-126.92 (12)	-950.16 (22)	-405.73 (31)	-336.37 (39)
22	CRC#	-4.11 (19)	-155.49 (19)	-7660.27 (27)	-544.10 (36)	-750.99 (19)	-252.53 (22)	-187.75 (26)
23	MPTC#	-.33 (02)	-78.64 (11)	-4990.84 (19)	-436.82 (31)	-438.35 (12)	-135.16 (13)	-10.54 (02)
24	PATC#	-1.30 (05)	-70.16 (09)	-4730.21 (19)	-148.23 (14)	-168.57 (05)	-117.03 (11)	-24.57 (05)
27	NTC#	-2.10 (14)	-149.33 (25)	-5723.41 (29)	-107.08 (14)	-947.65 (29)	-260.49 (30)	-239.18 (40)
28	ASTC#	-7.47 (38)	-87.90 (15)	-4301.94 (22)	-109.85 (13)	-538.88 (18)	-73.07 (10)	-48.16 (10)
29	SBSTC*	-17.05 (88)	-501.60 (84)	-2823.64 (48)	-316.01 (69)	-1657.15 (77)	-398.43 (75)	-209.12 (72)
30	KDTC#	-12.61 (82)	-187.28 (63)	-2323.14 (39)	-199.61 (55)	-765.08 (58)	-257.36 (63)	-151.23 (62)

Source: Computed from the results of DEA

Table 5.3.5 Statistics of Percentages of Excess Inputs (Under CRS Assumption) Over Different Organisational Forms of STUs

Inputs	Departmental-Undertakings	Corporations	Companies
CL			
Minimum		20.00	02.00
Maximum		91.00	82.00
Mean	18.00	67.00	24.61
BU			
Minimum		37.00	05.00
Maximum		84.00	63.00
Mean	46.00	49.36	18.69
FU			
Minimum		03.00	16.00
Maximum		48.00	39.00
Mean	25.00	23.45	23.23
MC			
Minimum		14.00	12.00
Maximum		69.00	55.00
Mean	24.00	30.64	23.08
TS			
Minimum		14.00	05.00
Maximum		77.00	58.00
Mean	18.00	42.27	21.15
WS			
Minimum		25.00	02.00
Maximum		77.00	63.00
Mean	40.00	53.82	20.85
AS			
Minimum		23.00	02.00
Maximum		83.00	62.00
Mean	37.00	53.00	23.85

Source: Computed from Table 5.3.4.

Table 5.3.6 Slack Analysis (Under CRS Assumption)

No.	STU	CL	BU	FU	MC	TS	WS	AS
1	MSRTC*	798.40	4287.75	.00	310.42	16215.72	9798.60	5634.15
2	APSRTC*	911.75	4462.42	.00	2213.01	30178.63	9102.28	1565.99
3	KnSRTC*	401.51	2286.86	.00	103.07	6196.39	2155.17	612.98
5	UPSRTC*	153.51	1854.99	.00	.00	7036.17	5685.65	329.40
6	RSRTC*	248.08	1635.50	.00	1024.02	3545.32	1061.83	1385.52
8	KSRTC*	.00	349.41	6051.38	.00	1356.50	1663.49	1521.17
9	MPSRTC*	197.03	904.53	.00	1399.78	2823.19	3376.12	3041.13
10	STPJB@	.00	646.25	3868.40	134.32	.00	631.33	318.32
11	PRC#	.00	15.30	2177.18	.00	361.13	88.68	85.04
12	CTC#	5.73	.00	1204.07	150.15	471.96	.00	351.18
13	PRTC*	14.62	303.41	1645.68	.00	.00	187.17	476.66
14	NBSTC*	.00	368.07	2551.99	112.24	1502.30	821.32	203.21
15	OSRTC*	39.94	239.05	.00	44.01	1141.03	547.17	841.05
16	DCTC#	8.12	17.27	5272.18	237.32	518.62	.00	.00
18	JTC#	.00	11.54	1949.44	57.20	4.22	.00	27.73
19	KTC#	.33	.00	1798.17	.00	149.99	115.38	84.15
20	TPTC#	8.29	.00	1959.09	257.04	252.58	3.80	.00
21	ATC#	.00	63.75	3327.82	.00	446.99	253.77	235.29
22	CRC#	.00	3.80	2337.16	260.96	.00	41.55	51.31
23	MPTC#	.00	64.58	4498.23	410.07	366.92	115.87	.00
24	PATC#	.12	34.42	3560.24	98.08	.00	67.94	.00
27	NTC#	.00	64.18	2929.52	.00	493.37	138.25	154.59
28	ASTC#	5.42	29.10	2254.10	24.86	233.49	.00	.00
29	SBSTC*	7.79	216.46	.00	96.70	635.09	147.08	71.07
30	KDTC#	6.54	69.31	.00	55.37	241.53	97.18	54.96

Source: DEA Results

The pattern of inefficiency and the existence of excess inputs shows that the reasons for inefficiency remain the same both in the VRS and CRS assumptions.

All these indicate the presence of certain institutions peculiar to each organisational form. The analysis and tackling of each institutional factors in each STU will enable us to sort out the problems with them; which is by all reasons beyond the scope of this work. DEA makes possible the measurement of the magnitude of X-efficiency in each STU and provides a quantitative indicator to the existence of institutional factors associated with each input used. This allows us to make intrafirm analysis which is an essential requirement for meaningful interfirm analysis.

Chapter 6

SUMMARY AND CONCLUSION

Efficiency has been an active area of research for economists from the theoretical as well as applied points of view. But the conceptualization of efficiency and its measurement remained vague and underdeveloped till recent times. The Farrell conceptualization of efficiency was a break through in all senses - theoretically and empirically. But the economic reasoning to the inefficiency in different firms remained unanswered or partially answered till Leibenstein put forth his X-Efficiency concept. Deviating from the neo-classical view, he attributed the inefficiency to 'X' factors which could capture all the factors - tangible and intangible - as the causes of inefficiency. The X-efficiency theory allows us to recognize the importance of institutional factors and their role in the efficient transformation of inputs into outputs in a firm.

Even after the recognition that X-efficiency theory got from the economic intelligentsia, it remained unexploited simply because of the reason that the factors it identifies are not empirically traceable. In other words, there was the lack of an adequate measuring rod for X-efficiency measurement. The development of Data Envelopment Analysis (DEA) could solve this difficulty to a large extent. A tool based on linear programming, it could rate the firms according to their efficiency in a closed interval 0 to 1. The use of DEA sore as an indicator of the inert areas in the production sphere of the firms and thus as the quantitative measure of X-efficiency are well recognized and accepted by many theoreticians including Leibenstein himself.

In this study, an attempt was made to understand the X-efficiency concept and the DEA technique. Equipped with these two concepts, a measurement of X-efficiency in State Transport Undertakings (STUs) in India was done. Though there are a number of studies attempting the performance analysis of STUs in India none of them have enquired into the X-efficiency in STUs.

The study was done for the cross section data of the year 1994-95. To keep the demand side uniform, the study was limited by excluding the transport services in hilly and city services. Thirty mofussil services were taken which include three organisational forms of state transport undertakings in India viz, departmental undertakings, corporations and companies. From the organisational point of view the government control comes down from the departmental undertaking to the companies.

The study identified seven inputs of importance to be included in the study. They were capital and liabilities, number of buses, fuel, material cost, number of traffic staff, number of workshop staff and number of administrative staff. Initially, passenger kilometer was taken as the output for the analysis. The software IDEAS version 5.1.15 was used for the analysis and the results showed the frightening picture of huge inefficiency in STUs. Only 3 among the 30 STUs were rated efficient. But based on the argument that the output concept passenger kilometers is not consistent with the public sector policies; and there are intolerable approximations in the calculation of this output, the analysis was repeated by taking seat kilometers as the output. Now, the number of efficient firms increased to 14 under the VRS assumption and 5 under the CRS assumption. For the inefficient firms, DEA projects the 'model' efficient firms from which they can adopt better management techniques. The scale efficiency and the returns to scale among the STUs were found out from which we could put forward suggestions to the STUs on the aspect of their scales of operations.

Now, getting into the reasons behind the inefficiency in STUs, we started with the organisational difference among the STUs. It is a received wisdom that the organisational form is setting up different institutional factors within the firm. In that sense, the analysis of organisational difference was taken with much importance. The analysis of results shows that there is significant differences between the efficiency scores of departmental undertakings, corporations and companies. The analysis with the passenger kilometers as output endorses the Averch- Johnson result that efficiency will increase as government control comes down. But the analysis with seat kilometers as output reject the Averch- Johnson result. Though there are variations over different organisational forms, no fixed pattern can be observed in the variations of efficiency over the organisational forms and thereby over varying degrees of government control. This result calls for the close analysis of institutional factors in each STU for a meaningful analysis.

The magnitude of the excess of each input used in different STUs gives us an idea about the institutional factors that inhibit the achievement of potential efficiency. In our study DEA identifies that there are excess in all the inputs with all the STUs. The variations in the excess inputs over different organisations also point to the existence and importance of institutions inside the STUs. The identification and analysis of these institutions allow us to make the intrafirm and interfirm analysis in a relative and more reasonable way. The tackling of all the institutions associated with each input in each STU is well beyond the scope of this work (that being a major limitation to this study); and calls for further research in a wider framework.

The study concludes with the identification and measurement of intrafirm efficiency of 30 STUs in India which allows for interfirm analysis by taking into account the existence of institutional factors associated with them.

Appendix - I

DATA SET

STU	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
MSRTC*	572270.87	813462.50	1192.53	15558	336988.0	16050.78	72014	25470	15336
APSRTC*	699836.00	878079.90	1252.62	15455	338657.0	18168.00	86124	23996	10512
KnSRTC*	406794.00	475961.57	708.47	10086	224853.0	10605.36	43676	12239	6666
GSRTC*	313174.00	532318.04	560.45	8987	193029.5	8020.01	42593	12401	3738
UPSRTC*	221891.00	341371.00	510.38	8230	143393.3	6157.44	37323	14936	3426
RSRTC*	175723.32	243677.04	324.14	4470	89005.9	5196.14	17672	4802	3740
STHAR@	193213.00	227664.32	411.29	3800	101154.0	5204.54	12554	5796	2713
KSRTC*	144889.00	153489.60	140.01	3498	86246.1	3430.34	16522	6431	3919
MPSRTC*	78152.10	99377.20	297.66	2667	46833.8	4036.40	11125	6429	5251
STPJB@	76127.55	114642.18	42.59	2369	54859.0	2503.38	7863	2880	1695
PRC#	77443.00	76109.23	8. 21	1189	37515.4	1592.59	6267	1680	977
CTC#	72898.95	76109.23	33.89	991	36323.0	1692.66	5785	1491	1283
PRTC*	40144.00	53487.07	36.28	1064	24126.0	1029.19	3558	1165	1128
NBSTC*	25077.26	37095.00	12.74	971	19558.8	902.42	4450	1704	679
OSRTC*	22422.00	30301.00	69.88	834	15579.0	788.97	4106	1441	1622
DCTC#	60830.60	63925.39	29.70	772	28737.3	1321.95	4305	1007	597
TTC#	70386.30	82620.12	33.96	831	43988.8	1458.64	5461	2028	918
JTC#	57914.00	65378.48	22.29	830	28956.0	1267.82	4099	1060	791
KTC#	52114.34	63237.69	22.04	828	28200.7	1212.53	4330	1237	773
TPTC#	59190.00	60951.94	33.20	818	27464.5	1461.77	4382	1097	643
ATC#	55794.75	58852.14	21.83	839	27456.5	1095.00	4341	1311	872
CRC#	53663.00	58727.46	22.09	816	28636.0	1523.15	4040	1135	734
MPTC#	62238.74	59596.01	17.41	747	26179.0	1421.83	3796	1025	560
PATC#	55092.00	56010.96	25.02	755	24714.7	1059.37	3561	1037	519
MGRTC#	47388.00	60869.16	16.82	678	21635.0	1007.25	3410	902	563
RMTC#	47844.00	55695.27	22.16	651	22915.3	938.45	3227	785	784
NTC#	38785.00	39790.32	14.91	606	19883.1	762.05	3233	870	602
ASTC#	47619.81	42984.50	19.86	569	19815.2	822.42	2955	707	466
SBSTC*	6606.00	8744.00	19.47	599	5931.6	460.70	2147	528	290
KDTC#	7250.36	10030.36	15.38	299	5888.3	365.59	1327	406	244

(1) Passenger Kilometers (in Lakhs)
(2) Seat Kilometers (in Lakhs)
(3) Capital and Liabilities (in Rs Crores)
(4) Number of Buses
(5) Fuel (HSD Oil) Consumption (in Kilolitres)
(6) Material Cost Other than Fuel (in Rs Lakhs)
(7) Number of Traffic Staff
(8) Number of Workshop Staff
(9) Number of Administrative Staff

Source: *State Transport Undertakings: Profile and Performance 1994-95*, Published by Central Institute of Road Transport (CIRT), Pune, for Association of State Road Transport Undertakings (ASRTU)..

Appendix - II

DEFINITIONS & EXPLANATIONS OF VARIABLES USED AND RELATED CONCEPTS

1. State Transport Undertaking (STU)

State Transport Undertaking means any undertaking providing road transport service, where such' undertaking is carried by-

(i) the Central Government or Satate Government,
(ii) any Road Transport Corporation established under Sec. 3 of the Road Transport Corporations Act, 1950 (64 of 1950),
(iii) any Municipality or any Municipal Corporation,
(iv) any company set up under the Companies Act (Act1 of 1956) owned by the Central Government or one or more State Governments or by the Central Government and one or more State Government.

2. Effective Kilometers

Kilometers actually operated by public service buses for purpose of earning revenue are known as effective kilometers. Total effective kilometers relate to revenue earning kilometers actually operated by buses during any specific period for:

(i) Operation of trips as per schedule
(ii) Operation of extra trips for Fairs, Jathras and other special occasions.
(iii) Operation of casual contracts.

3. Seat Kilometeres Offered

The weighted average seating capacity multiplied by the effective kilometeres operated gives the seat kilometeres offered.

4. Passenger Kilometers

Passenger kilometeres represents the volume of traffic in terms of total offered kilometeres actually occupied. It is the sum total of the length of journeys performed by all the passengers carried.

Passenger kilometeres is usually calculated by dividing the ernings from passengers by the fare per kilometere, when the fare structure is of a uniform rate. Thus;

$$\text{Passenger Kilometeres} = \frac{\text{Traffic revenue}}{\text{Fare per Kilometre}}$$

For calculating the passenger kilometeres, only the revenue from passengers, i.e. sale of tickets are taken into account. The earnings from luggage adn parcels carried and postal mails are omitted. Smiliarly, passenger kilometres for city and mofussil services and for Express/Ordinary and Luxury services are calculated separately as fares charged are different for these different types of services.

5. Capital and Liabilities

Capital and liabilities include the state government contribution, central government contribution, general and other reserves, cumulative profits/loss, debentures, loan from IDBI, loan from other banks & LIC, public deposits, others and current liabilities including short term provision and borrowings. It gives us the total assets with the STU as current as well as fixed assets.

6. Total Number of Buses or Fleet Held

The total number of buses held by the Unit (Depo/Division/Undertaking) at a particular point of time will be under any of the following conditions, viz,

(i) Buses on road
(ii) Buses held as spares
(iii) Buses in workshops
(iv) Bus awaiting scrapping
(v) Buses in transit

All buses held by the unit either for operaion or traffic and workshop spares are included irrepective of the fact whether such buses are in a roadworthy condition or not. Buses awaiting for scrapping are included in Fleet Held, unless they are actually taken out of the fleet. Hired buses are not included in the counting.

7. Fuel (HSD Oil) Consumption

It represents the total quantity of fuel (HSD Oil) consumed by the buses for performance of the kilometeres. Fuel consumed includes:

(i) Fuel drawn by buses from Home Depot.
(ii) Fuel drawn by buses from outside Depot of Home Dn.
(iii) Fuel drawn by buses from outside Dns./Depots.
(iv) Fuel drawn by buses from outside agencies (Privae Pumps) and other State Transport Undertakings.

Fuel consumed in the workshops for testing, assemble cleaning etc. is not included in calculating the fuel consumed for operations. Similarly, fuel consumed by departmental vans, cars etc. is accounted separately.

8. Material Cost

It is the summation of the cost for fuel (diesel), lubricants, springs, auto spareparts,tyres & tubes, batteries, general items and reconditioned items. In this study, material cost is calculated as the total cost of all of the above items except fuel.

9. Staff Employed

The total staff actually woring in various units (Depot/ Division/ Region/ Head Office) as on last day of a specified period will represent the total staff employed. It will include permanent, temporary and daily wage employees. The staff employe are grouped into:

(a) Traffic Staff (Including drivers, conductors, checkers, bus station staff and traffic supervisory staff)
(b) Workshop Staff or Repairs and Maintenence Staff (Including staff for preventive maintenence, various overhauls & dockings, reconditioning of buses and assemblies)
(c) Administration and others (Including staff for personnel, accounts, audit, stores, planning, computer, security, public relations, departmental vehicles, legal, training and labour & welfare etc).

REPORT OF PROGRAMME EXECUTION FOR DEA

1. DEA Model with Passenger Kilometers as Output and VRS Assumption

```
Multiple runs(1=yes,0=no)        0
NUMBER OF UNITS            30
NUMBER CATEGORICAL VARIABLES    0
NUMBER DISCRETIONARY OUTPUTS    1
NUMBER DISCRETIONARY INPUTS     7
NUMBER OF OUTPUTS               1
NUMBER OF INPUTS                7

MODEL: VRS/INPUT /INVARIAN-

NUMBER OF RATIOS          0
NUMBER OF VARIABLES      39
NUMBER OF DMUS TO BE ANALYSED       30
MEASURE        LOW VALUE        HIGH VALUE

PK             6606.00          6083060.00
CL               12.74             1252.62
BU              299.00            15558.00
FU             5888.28           338657.00
MC              365.59            18168.00
TS             1327.00            86124.00
WS              406.00            25470.00
AS              244.00            15336.00
Tolerances:
EPS12:    1.000000000000000E-009
EPSRAT:   1.000000000000000E-009
EPS06:    1.000000000000000E-006
EPSPRC:   1.000000000000000E-005
Low:       12.740000000000000
High:   6083060.000000000000000
  PREPROCESSING: DOMINATED UNITS
  UNIT   1  MSRTC*
  UNIT   2  APSRTC*
  UNIT   3  KnSRTC*
  UNIT   4  GSRTC*
  UNIT   5  UPSRTC*
  UNIT   6  RSRTC*
  UNIT   7  STHAR@
  UNIT   8  KSRTC*
  UNIT   9  MPSRTC*
  UNIT  10  STPJB@
  UNIT  11  PRC#
  UNIT  12  CTC#
  UNIT  13  PRTC*
  UNIT  17  TTC#
  UNIT  20  TPTC#
  UNIT  22  CRC#
  UNIT  29  SBSTC*
      17 UNITS ARE DOMINATED

    PROGRAM    1 ...DMU  16
                         DCTC#    ...    2    4
    PROGRAM    2 ...DMU  30
                         KDTC#    ...    1    4
    PROGRAM    3 ...DMU  28
                         ASTC#    ...    6   10
    PROGRAM    4 ...DMU  14
                         NBSTC*   ...    1    7
```

```
PROGRAM    5 ...DMU  23
                 MPTC#     ...   5   9
PROGRAM    6 ...DMU  24
                 PATC#     ...   5   9
PROGRAM    7 ...DMU  25
                 MGRTC#    ...   6  10
PROGRAM    8 ...DMU  20
                 TPTC#     ...   7  11
PROGRAM    9 ...DMU  26
                 RMTC#     ...   8  12
PROGRAM   10 ...DMU  11
                 PRC#      ...   7  10
PROGRAM   11 ...DMU  18
                 JTC#      ...   8  12
PROGRAM   12 ...DMU  21
                 ATC#      ...   9  13
PROGRAM   13 ...DMU  12
                 CTC#      ...   6  10
PROGRAM   14 ...DMU  27
                 NTC#      ...   8  12
PROGRAM   15 ...DMU   7
                 STHAR@    ...   5   7
PROGRAM   16 ...DMU  22
                 CRC#      ...   9  13
PROGRAM   17 ...DMU  19
                 KTC#      ...   9  13
PROGRAM   18 ...DMU   2
                 APSRTC*   ...   6   8
PROGRAM   19 ...DMU   6
                 RSRTC*    ...   5   7
PROGRAM   20 ...DMU   3
                 KnSRTC*   ...   5   7
PROGRAM   21 ...DMU  17
                 TTC#      ...   8  12
PROGRAM   22 ...DMU  13
                 PRTC*     ...   7  11
PROGRAM   23 ...DMU   8
                 KSRTC*    ...   5   7
PROGRAM   24 ...DMU   1
                 MSRTC*    ...   5   7
PROGRAM   25 ...DMU   4
                 GSRTC*    ...   5   7
PROGRAM   26 ...DMU  10
                 STPJB@    ...   7  11
PROGRAM   27 ...DMU   5
                 UPSRTC*   ...   6   8
PROGRAM   28 ...DMU   9
                 MPSRTC*   ...   4   7
PROGRAM   29 ...DMU  15
                 OSRTC*    ...   5   8
PROGRAM   30 ...DMU  29
                 SBSTC*    ...   3   6
RANGE OF PRICES
PK          .00000      .00015
CL          .00080    12.82894
BU          .00006      .01760
FU          .00000      .03993
MC          .00006      .27958
TS          .00001      .00668
WS          .00004      .01724
AS          .00007      .03172
  SOLUTION STATISTICS
  TOTAL NUMBER OF ITERATIONS.........        272 AVG:        9
  NUMBER OF TIMES ADVANCED BASIS USED                  2
  NUMBER NOT ANALYSED                          0
  NUMBER PRICED......................     1379
  START 13: 24:  9: 73
  END    3: 24: 10: 23
```

2. DEA Model with Seat Kilometers as Output and VRS Assumption

```
Multiple runs(1=yes,0=no)          0
NUMBER OF UNITS                   30
NUMBER CATEGORICAL VARIABLES       0
NUMBER DISCRETIONARY OUTPUTS       1
NUMBER DISCRETIONARY INPUTS        7
NUMBER OF OUTPUTS                  1
NUMBER OF INPUTS                   7

MODEL: VRS/INPUT /INVARIAN-

NUMBER OF RATIOS    0
NUMBER OF VARIABLES      39
NUMBER OF DMUS TO BE ANALYSED          30

MEASURE        LOW VALUE        HIGH VALUE

SK             8744.00          878079.90
CL               12.74            1252.62
BU              299.00           15558.00
FU             5888.28          338657.00
MC              365.59           18168.00
TS             1327.00           86124.00
WS              406.00           25470.00
AS              244.00           15336.00
Tolerances:
EPS12:     1.000000000000000E-009
EPSRAT:    1.000000000000000E-009
EPS06:     1.000000000000000E-006
EPSPRC:    1.000000000000000E-005
Low:       12.740000000000000
High:      878079.900000000000000

PREPROCESSING: DOMINATED UNITS

UNIT   13  PRTC*
UNIT   21  ATC#
UNIT   22  CRC#
UNIT   29  SBSTC*
    4 UNITS ARE DOMINATED

PROGRAM    1 ...DMU  26
                RMTC#     ...   5    7
PROGRAM    2 ...DMU  30
                KDTC#     ...   1    4
PROGRAM    3 ...DMU   7
                STHAR@    ...   5    9
PROGRAM    4 ...DMU   6
                RSRTC*    ...   1    5
PROGRAM    5 ...DMU   4
                GSRTC*    ...   1    6
PROGRAM    6 ...DMU  17
                TTC#      ...   7   13
PROGRAM    7 ...DMU  25
                MGRTC#    ...   1    4
PROGRAM    8 ...DMU   2
                APSRTC*   ...   8   10
PROGRAM    9 ...DMU  24
                PATC#     ...   2    5
PROGRAM   10 ...DMU  23
                MPTC#     ...   4    6
PROGRAM   11 ...DMU  18
                JTC#      ...   9   12
PROGRAM   12 ...DMU  10
                STPJB@    ...   1    7
PROGRAM   13 ...DMU  16
```

		DCTC# ...	4	6
PROGRAM	14 ...DMU 19	KTC# ...	11	14
PROGRAM	15 ...DMU 20	TPTC# ...	4	6
PROGRAM	16 ...DMU 28	ASTC# ...	3	6
PROGRAM	17 ...DMU 1	MSRTC* ...	5	8
PROGRAM	18 ...DMU 13	PRTC* ...	7	10
PROGRAM	19 ...DMU 21	ATC# ...	5	9
PROGRAM	20 ...DMU 12	CTC# ...	8	11
PROGRAM	21 ...DMU 5	UPSRTC* ...	4	6
PROGRAM	22 ...DMU 22	CRC# ...	6	8
PROGRAM	23 ...DMU 11	PRC# ...	9	12
PROGRAM	24 ...DMU 3	KnSRTC* ...	7	10
PROGRAM	25 ...DMU 27	NTC# ...	5	7
PROGRAM	26 ...DMU 14	NBSTC* ...	6	9
PROGRAM	27 ...DMU 9	MPSRTC* ...	4	6
PROGRAM	28 ...DMU 8	KSRTC* ...	9	12
PROGRAM	29 ...DMU 15	OSRTC* ...	6	9
PROGRAM	30 ...DMU 29	SBSTC* ...	3	5

RANGE OF PRICES

SK	.00001	.00227
CL	.00080	.84131
BU	00006	.00334
FU	00000	.00017
MC	.00006	.17631
TS	.00001	.00075
WS	.00004	.03184
AS	.00007	.11688

SOLUTION STATISTICS
TOTAL NUMBER OF ITERATIONS......... 242 AVG: 8
NUMBER OF TIMES ADVANCED BASIS USED 5
NUMBER NOT ANALYSED 0
NUMBER PRICED...................... 3790
START 13: 27: 57: 67
END 13: 27: 58: 33

3. DEA Model with Seat Kilometers as Output and CRS Assumption

```
DEA:
Multiple runs(1=yes,0=no)          0
NUMBER OF UNITS                   30
NUMBER CATEGORICAL VARIABLES       0
NUMBER DISCRETIONARY OUTPUTS       1
NUMBER DISCRETIONARY INPUTS        7
NUMBER OF OUTPUTS                  1
NUMBER OF INPUTS                   7

MODEL: CRS/INPUT /INVARIAN-

NUMBER OF RATIOS   0
NUMBER OF VARIABLES     39
NUMBER OF DMUS TO BE ANALYSED        30

MEASURE          LOW VALUE        HIGH VALUE

SK               8744.00          878079.90
CL                 12.74            1252.62
BU                299.00           15558.00
FU               5888.28          338657.00
MC                365.59           18168.00
TS               1327.00           86124.00
WS                406.00           25470.00
AS                244.00           15336.00
Tolerances:
EPS12:    1.000000000000000E-009
EPSRAT:   1.000000000000000E-009
EPS06:    1.000000000000000E-006
EPSPRC:   1.000000000000000E-005
Low:         12.740000000000000
High:    878079.900000000000000

PREPROCESSING: DOMINATED UNITS

UNIT  13  PRTC*
UNIT  21  ATC#
UNIT  22  CRC#
UNIT  29  SBSTC*
     4 UNITS ARE DOMINATED

PROGRAM    1 ...DMU  26
                RMTC#    ...   4   6
PROGRAM    2 ...DMU   7
                STHAR@   ...   2   4
PROGRAM    3 ...DMU   4
                GSRTC*   ...   1   4
PROGRAM    4 ...DMU  17
                TTC#     ...   2   4
PROGRAM    5 ...DMU  25
                MGRTC#   ...   1   4
PROGRAM    6 ...DMU   6
                RSRTC*   ...   3   5
PROGRAM    7 ...DMU   2
                APSRTC*  ...   3   5
PROGRAM    8 ...DMU  24
                PATC#    ...   3   5
PROGRAM    9 ...DMU  23
                MPTC#    ...   3   5
PROGRAM   10 ...DMU  18
                JTC#     ...   6   8
PROGRAM   11 ...DMU  16
                DCTC#    ...   3   5
PROGRAM   12 ...DMU  19
                KTC#     ...   6   8
```

PROGRAM 13 ...DMU 20
TPTC# ... 3 5
PROGRAM 14 ...DMU 28
ASTC# ... 4 7
PROGRAM 15 ...DMU 1
MSRTC* ... 3 5
PROGRAM 16 ...DMU 13
PRTC* ... 6 8
PROGRAM 17 ...DMU 21
ATC# ... 5 7
PROGRAM 18 ...DMU 12
CTC# ... 5 8
PROGRAM 19 ...DMU 5
UPSRTC* ... 4 6
PROGRAM 20 ...DMU 22
CRC# ... 4 6
PROGRAM 21 ...DMU 10
STPJB@ ... 5 7
PROGRAM 22 ...DMU 11
PRC# ... 4 6
PROGRAM 23 ...DMU 3
KnSRTC* ... 3 5
PROGRAM 24 ...DMU 27
NTC# ... 5 7
PROGRAM 25 ...DMU 14
NBSTC* ... 5 7
PROGRAM 26 ...DMU 9
MPSRTC* ... 3 5
PROGRAM 27 ...DMU 8
KSRTC* ... 5 7
PROGRAM 28 ...DMU 15
OSRTC* ... 3 5
PROGRAM 29 ...DMU 30
KDTC# ... 3 5
PROGRAM 30 ...DMU 29
SBSTC* ... 3 5

RANGE OF PRICES

SK	.00000	.00621
CL	.00080	.07849
BU	.00006	.01779
FU	.00000	.00017
MC	.00006	.05088
TS	.00001	.10957
WS	.00004	.02940
AS	.00007	.02968

SOLUTION STATISTICS
TOTAL NUMBER OF ITERATIONS......... 174 AVG: 5
NUMBER OF TIMES ADVANCED BASIS USED 1
NUMBER NOT ANALYSED 0
NUMBER PRICED...................... 2670
START 13: 26: 33: 3
END 13: 26: 33: 42

BIBLIOGRAPHY

Afrait S N (1972), "Efficiency Estimation of Production Function", **International Economic Review**, 13: 568-98.

Ahluwalia I J (1985), **Industrial Growth in India: Stagnation Since the Mid-Sixties**, New Delhi: Oxford University Press.

Aigner D and S Chu (1968), "On Estimating the Industry Production Function", **American Economic Review**, 58: 826-839.

Aigner D J, C A K Lovell and P J Schmidt (eds) (1980), "Specification and Estimation of Frontier Production, Profit and Cost Functions", **Journal of Econometrics**, 13: 1-138.

Aigner D J, C A K Lovell and P J Schmidt (1977), "Formulation and Estimation of Stochastic Frontier Production Function Models", **Journal of Econometrics**, 6: 21-37.

Alchian A A and H Demesetz (1972), "Production, Information Cost and Economic Organization", **American Economic Review**, 4: 239-243

Alessi L (1993), "Property Rights, Transaction Costs and X-Efficiency: An Essay in Economic Theory", **American Economic Review**, 73: 64-81.

Arora S K (1987), **Economics of Management in Road Transport Industry**, New Delhi: Deep & Deep Publications.

Arrow K J (1974), **The Limits of Organizations**, New York: W.W. Norton & Co.

Bagade M V (1981), "Types of Organisations and their Effectiveness", **Journal of Transport Management**, 4: 213-226

Bagade M V and V P Paranjpe (1994), **Forms of STUs and their Functioning: A Comparative Study**, Working Paper No.5, Central Institute of Road Transport, Pune.

Banker R (1984), "Estimating the Most Productive Scale Size Using Data Envelopment Analysis", **European Journal of Operational Research**, 17: 35-44.

Banker R (1989), "Econometric Estimation and Data Envelopment Analysis", **Research in Governmental and Nonprofit Accounting**, 5: 231-243.

Banker R (1988), "**Stochastic Data Envelopment Analysis**", mimeo, School of Urban and Public Affairs, Carnegie Mellon University.

Banker R (1993), "Maximum Likelihood, Consistency and Data Envelopment Analysis: A Statistical Foundation", **Management Science**, 39: 1265-73.

Banker R, R Conrad and R Struss (1986), "A Comparative Application of Data Envelopment Analysis and Translog Methods: An Illustrative Study of Hospital Production", **Management Science**, 32: 30-44.

Banker R and A Maindiratta (1986), "Piecewise Loglinear Estimation of Efficient Production Surfaces", **Management Science**, 32: 126-135.

Banker R and A Maindiratta (1988), "Nonparametric Analysis of Technical and Allocative Efficiencies in Production", **Econometrica**, 56: 1315-32.

Banker R, A Charnes and W W Cooper (1984), "Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis", **Management Science**, 30: 1078-1092.

Banker R, A Charnes, W W Cooper, J Swarts and D Thomas (1990) "An Introduction to Data Envelopment Analysis with Some of its Models and their Uses", **Research in Governmental and Nonprofit Accounting**, 5: 125-163.

Bardhan P K (1984), **The Political Economy of Development in India**, Oxford: Basil Blackwell.

Barrow M G and A Wagstaff (1989), "Efficiency Measurement in the Public Sector: An Appraisal", **Fiscal Studies**, 10: 72-79.

Basu P K (1991), **Performance Evaluation for Performance Improvement**, New Delhi: Allied Publishers Ltd.

Battese G and G S Corra (1977), "Estimation of a Production Frontier Model with Application to the Pastrol Zone of Eastern Australia", **Australian Journal of Agricultural Economics**, 21(3): 169-79.

Bauer P W (1990), "Recent Developments in the Econometric Estimation of Frontier", **Journal of Econometrics**, 46: 39-56.

Bennett R L (1967), "Surplus Agricultural Labour and Development Facts and Theories: Comment", **American Economic Review**, 57: 194-202.

Bhagwati J N (1993), **India in Transition: Freeing the Economy**, Oxford: Claredon Press.

Bhaya H (1990), " Management Efficiency in the Private and Public Sectors in India", in Heath J (ed.), **Public Enterprise at the Crossroads**, London: Routledge.

Bhoothalingam S (1993), **Reflections on an Era: Memoirs of a Civil Servant**, Madras: Affiliated East-West Publishers.

Blois K J (1972), "A Note on X-Efficiency and Profit Maximisation", **Quarterly Journal of Economics**, LXXXVI: 310-326.

Blois K J (1974) " Some Comments on the Theory of Inert Areas and the Definition of X-Efficiency", **The Quarterly Journal of Economics**, LXXX VIII: 681-86.

Button K J (1985), "Potential Differences in the Degree of X-inefficiency Between Industrial Sectors in the United Kingdom", **Quarterly Review of Economics and Business**, 25: 85-95.

Button K J and T G Weyman-Jones (1992), "Ownership Structure, Institutional Organization and Measured X-Efficiency, **American Economic Review**, 82: 439-445.

Central Institute of Road Transport (1989), **Compendium of Transport Terms**, Pune: Central Institute of Road Transport.

Central Institute of Road Transport (1996), **State Transport Undertakings: Profile and Performance 1993-94 & 1994-95**, Pune: Central Institute of Road Transport.

Chand M (1982), "Financial Performance of Road Transport Undertakings", **Lok Udyog**, April.

Charnes A and W W Cooper (1962), "Programming with Linear Fractional Functionals", **Naval Research Logistics Quarterly**, 9: 181-185.

Charnes A and W W Cooper (1973), "An Explicit General Solution in Linear Fractional Programming", **Naval Research Logistics Quarterly**, 20.

Charnes A and W W Cooper (1984), "The Non-Archimedean CCR Ratio for Efficiency Analysis: A Rejoinder to Boyd and Fare", **European Journal of Operational Research**, 15: 333-334.

Charnes A and W W Cooper (1985), "Preface to Topics in Data Envelopment Analysis", **Annals of Operations Research**, 2: 59-94.

Charnes A, W W Cooper, A Y Lewin and and L M Seiford (1993), **Data Envelopment Analysis: Theory, Methodology and Applications**, Boston, MA: Kluwer Academic Publishers.

Charnes A, C Clarke, W W Cooper and B Golany (1985), "A Developmental Study of Data Envelopment Analysis in Measuring the Efficiency of Maintenance Units in the US Air Force", **Annals of Operations Research**, 2: 95-112.

Charnes A, W W Cooper, D Divine, T Ruefili and D Thomas (1989), "Comparisons of DEA and Existing Ratio and Regression Systems for Effecting Efficiency Evaluations of Regulated Electric Co-operative in Texas", **Research In Governmental and Nonprofit Accounting**, 5: 187-210.

Charnes A, W W Cooper and E Rhodes (1978), "Measuring the efficiency of Decision-Making Units", **European Journal of Operational Research**, 2: 429-444.

Charnes A, W W Cooper and E Rhodes (1979), " Measuring the Efficiency of Decision-Making Units", **European Journal of Operational Research**, 3: 339.

Charnes A, W W Cooper and E Rhodes (1981), "Evaluating Program and Managerial Efficiency: An Application of Data Envelopment Analysis to Program Follow Through", **Management Science**, 27: 668-697.

Charnes A, W W Cooper, B Golany, L Seiford and J Stutz (1985) "Foundations of Data Envelopment Analysis for Pareto-koopmans Efficient Empirical Production Functions", **Journal of Econometrics**, 30: 91-107.

Coase R H (1992), "The Institutional Structure of Production", **American Economic Review**, 82: 713-719.

Coase R H (1988), **The Firm, The Market, and the Law**, Chicago: University of Chicago Press.

Collins A E L (1949), **United State of Travancore and Cochin State Transport Services**, Government of Travancore and Cochin.

Comanor W and H Leibenstein (1969), "Allocative Efficiency, X-Efficiency, and the Measurement of Welfare Losses." **Economica** 36: 304-309.

Cook W D, Y Roll and A Kazakov (1990), "On the measurement of the Relative Efficiency of a set of Decision Making Units", in Weirmair K and M Perlman (eds), **Studies in Economic Rationality: X-Efficiency Examined and Extolled**, Ann Albar: University of Michigan Press, 351-368.

Cyert R M and J G March (1963), **A Behavioural Theory of the Firm**, New Jersey: Englewood Cliffs, Prentice Hall.

Danilin V I, I S Materov, S Rosefielde and C A K Lovell, (1985), "Measuring Enterprises Efficiency in the Soviet Union: a Stochastic Frontier Analysis", **Economica**, 52:225-33.

Davis H S (1955), **Productivity Accounting**, Research Studies 37, Wharton School of Finance and Commerce, University of Pennsylvania, Philadelphia.

Debreu G (1951), "The Coefficient of Resource Allocation", **Econometrica**, 19: 273-292.

Demsetz H (1988), **Ownership, Control and the Firm, Vol.1**, Oxford: Blackwell.

DES (Department of Education and Science) (1984), "School Standards and Spending: A Further Application", **Statistical Bulletin No. 13/84**, London: HMSO.

Diewert W and C Parkan (1983), "Linear Programming Tests of Regularity Conditions for Production Functions", in Eichhorn W, R Henn, K Neumann, and R Shephard (eds), **Quantitative Studies on Production and Prices**, Vienna: Physica-Verlag.

Dorfinan J et al (1963), **Institutional Economics**, Berkeley: University of California Press.

Dorfman R (1984), **Prices and Markets**, New Delhi: Prentice-Hall of India Pvt. Ltd.

Dugger R (1974), "An Application of Bounded Non-parametric Estimating Functions to the Analysis of Bank Cost and Production Functions", PhD Thesis, University of North Carolina, Chapel Hill, NC.

Dunlop W (1985) "**The Elusive Concept, Efficiency: a Survey of the Conceptual and Measurement Issues**", Occasional Paper No. 109, Department of Economics, University of Newcastle, N S W, Australia.

Fare R and C A K Lovell (1978), "Measuring the Technical Efficiency of Production", **Journal of Economic Theory**, 19: 150-162.

Fare R and S Grosskopf (1983), "Measuring Output Efficiency", **European Journal of Operational Research**, 13: 173-179.

Fare R, S Grosskopf and C A K Lovell (1983), " The Structure of Technical Efficiency", **Scandinavian Journal of Economics**, 85: 181-190.

Fare R, S Grosskopf and C A K Lovell (1985), **The Measurement of Efficiency of Production**, Boston: Kulwer-Nijhoff.

Farrell M J (1957), "The Measurement of Productive Efficiency", **Journal of Royal Statistical Society**, Series A, 120(3): 253-82.

Feldstein M S (1967), **Economic Analysis for Health Service Efficiency: Econometric Studies of the British National Health Service**, Amsterdam: North-Holland

Ferrier G and C A K Lovell (1990), "Measuring Cost Efficiency in Banking: Econometric and Linear Programming Evidence", **Journal of Econometrics**, 46: 229-245.

Ford R and P Poret (1991), **Infrastructure and Private-sector Productivity**, Working Paper No. 91, Department of Economics and Statistics, OECD.

Forsund F, C A K Lovell and P J Schmidt (1980), "A Survey of Frontier Production Functions and of their Relationship to Efficiency Measurement", **Journal of Econometrics**, 13: 5-25.

Forsund F and E Jansen (1977), "On Estimating Average and Best Practice Homothetic Production Functions via Cost Function", **International Economic Review**,18: 463-476.

Forsund F and L Hjalmarsson (1979), " Generalised Farrel Measures of Efficiency: An Application to Milk Processing in Swedish Diary Plants", **Economic Journal**, 89: 294-315.

Frantz R (1988), **X-efficiency: Theory, Evidence and Applications**. Norwell, MA: Kluwer Academic Press.

Ganley J A and J S Cubbin (1992), **Public Sector Efficiency measurement: Applications of Data Envelopment Analysis**, Amsterdam: North-Holland.

Ganley J (1988), **Relative Efficiency Measurement in the Public Sector with Data Envelopment Analysis**, Ph. D. Thesis, Queen Mary College, University of London.

Green A and Mayer D (1991) "Technical Inefficiency in Manufacturing Industries", **Economic Journal**, 101: 523-38.

Greene W H (1983), "Simultaneous Estimation of Factor Substitution, Economies of Scale Productivity, and Non-Neutral Technical Change", in Dogramaci (ed.), **Studies in Productivity Analysis: 1, Productivity Analysis: A Range of Perspectives**, Boston: Martinus Nijhoff Publishing.

Grosskopf and Valdmanis (1987), "Measuring Hospital Performance: A Non-parametric Analysis", **Journal of Health Economics**, 6: 89-107.

Grossman G (1979), **Economic Systems**, New Delhi: Prentice-Hall of India Pvt. Ltd.

Hammond C (1986), "Estimating the Statistical Cost Curve: An Application of the Stochastic Frontier Technique", **Applied Economics**, 18: 971-984.

Harris C M and R W Phillips (1984), "Productivity Trends in the Australian Manufacturing Sector", in Scherer and Malone (eds) (1986), **The Measurement of Productivity Growth**, Proceedings of a Workshop, Canberra: Australian Government Publishing Service.

Haskel J and A Sanchis (1995), "Privatisation and X-Efficiency: A Bargaining Approach", **The Journal of Industrial Economics**, XLIII: 301-321.

Herberger A C (1959), " Using the Resources at Hand More Efficiently", **American Economic Review**, 49: 134-46.

Hodgson G M (1988). **Economics and Institutions**, Cambridge: Polity Press.

Holmstro B and J Tirole (1989), "The Theory of the Firm", in Schmalensee R and R D Willig (eds), **Handbook of Industrial Organisation**, Amsterdam: North-Holland.

Ibrahim P (1978), "Transportation Development in Kerala", **Social Scientist**, 6: 235-248.

Jalan B (1991), **India's Economic Crisis: The Way Ahead**, New Delhi: Oxfod University Press.

Jayadevadas P (1971), **Administration of K S R T C**, Unpublished Ph. D Thesis, University of Kerala, Trivandrum.

Jethanandari K (1997), "Competitive Power of Institutions", **The Economic Times** (Bangalore), Feb 1: 4.

Jha R and B S Sahni (1992), "Measures of Efficiency in Private and Public Sectors in India: The Case of India", **Annals of Public and Co-operative Economics**, 63: 489-495.

Jiang J and Y M Zou (1990), "Efficiency Analysis of Township and Village Enterprises of Jiangsu Province", **Academic Periodical of Nanjing University**, 4: 124-9.

Jondrow J, C A K Lovell, I S Materov and P J Schmidt (1982), "On the Estimation of Technical Inefficiency in the Stochastic Production Function Model", **Journal of Econometrics** 19: 233-8.

Kadam V A (1995), "Models for Inter-state Transport Undertakings Comparison", **Indian Journal of Transport Management**, 19: 773-781.

Kendrick J (1956), "Productivity Trends: Capital and Labour", **Review of Economics and Statistics**, 37: 248-57.

Kendrick J (1961), **Productivity Trends in the United States**, Princeton: Princeton University Press.

Keshava G P (1972), "Measurement of Management Contribution to Profitability: Case Study of a Bihar State Road Transport Corporation", **Economic and Political Weekly**, 7: 35- 26.

Khera S S (1977), **Government in Business**, New Delhi: National Publishing House.

Kopp R (1981), "The Measurement of Productive Efficiency: A Reconsideration", **Quarterly Journal of Economics**, 96: 477-503.

Kopp R and E Diewert (1982), "The Decomposition of Frontier Cost Function Deviations into Measures of Technical and Allocative Efficiency", **Journal of Econometrics**, 19: 319-331.

Kulshrestha D K (1989), **Management of State Road Transports in India**, New Delhi: Mittal Publications.

Leibenstein H (1960), **Economic Theory and Organisational Analysis**, New York: Harper.

Leibenstein H (1966), "Allocative Efficiency vs. 'X-Efficiency", **American Economic Review**, 56: 392-415.

Leibenstein H (1969), "Organisational or Frictional Equilibria, X-Efficiency, and the Rate of Innovation." **Quarterly Journal of Economics**, 83: 599-623.

Leibenstein H (1972), "Comment on the nature of X-Efficiency", **Quarterly Journal of Economics**, 86: 327-331.

Leibenstein H (1973), "Competition and X-Efficiency: reply." **Journal of Political Economy**, 81: 765-777.

Leibenstein H (1974), "Comment on Inert Areas and the Definition of X-Efficiency." **Quarterly Journal of Economics**, 88: 689-691.

Leibenstein H (1975), "Aspects of the X-Efficiency Theory of the Firm." **Bell Journal of Economics**, 6: 580-606.

Leibenstein H (1976), **Beyond Economic Man**, London: Harvard University Press.

Leibenstein H (1976), "The Problem of Characterising Aspirations." **Population and Development Review**, 2: 427-431.

Leibenstein H (1977), "X-Efficiency, Technical Efficiency, and Incomplete information Use: A Comment." **Economic Development and Cultural Change**, 25: 311-316.

Leibenstein H (1977), " X-Efficiency Theory, Conventional Entrepreneurship, and Excess Capacity Creation in LDCs", **Economic Development and Cultural Change**, 25(Supplement): 288-299.

Leibenstein H (1978), "On the Basic Proposition of X-Efficiency Theory." **American Economic Review - Papers and Proceedings**, 68: 328-332.

Leibenstein H (1978), **General X-Efficiency Theory and Economic Development**, New York: Oxford University Press.

Leibenstein H (1978), "X-Inefficiency Xists - Reply to an Xorcist." **American Economic Review**, 68: 203-211.

Leibenstein H (1979), "X-Efficiency: From Concept to Theory", **Challenge**, 22: 13-22.

Leibenstein H (1979), "A Branch of Economics is Missing: Micro-Micro Theory." **Journal of Economic Literature**, 17: 477-502.

Leibenstein H (1979), "The General X-Efficiency Paradigm and the Role of the Entrepreneur." in Rizzo, M J (ed.), **Time, Uncertainty, and Disequilibrium: Exploration of Austrian Themes**, Lexington: Lexington Books.

Leibenstein H (1980), "Notes on the X-Efficiency Approach to inflation, Productivity and Employment." in Weisbrod, Burton and H Hughes (eds), **Human Resources, Employment and Development. Vol.3: The Problems of Developed Countries and the International Economy**, Mexico City: Proceedings of the Sixth World Congress of the International Economic Association.

Leibenstein H (1980), "X-Efficiency, Intrafirm Behaviour, and Growth", in Maital, S and Meltz, N M (eds), **Lagging Productivity Growth: Causes and Effects**, Cambridge: Ballinger.

Leibenstein H (1981), "Microeconomics and X-Efficiency Theory" in Daniel, Bell and I Kristol (eds), **The Crisis in Economic Theory**, New York: Basic Books.

Leibenstein H (1981), "X-Efficiency Theory, Productivity and Growth", in Giersch H (ed.), **Towards an Explanation of Economic Growth**, Symposium 1980, Institut fur Welwirtschaft Keil, FGR.

Leibenstein H (1982), "On Bull's Eye-Painting Economics." **Journal of Post Keynesian Economics**, 4: 460-465.

Leibenstein H (1982), "Worker Motivation and X-Efficiency Theory: A Comment." **Journal of Economic Issues**, 72: 872-873.

Leibenstein H (1982), "The Prisoner's Dilemma in the Invisible hand: An Analysis of Intrafirm Productivity." **American Economic Review**, 72: 92-97.

Leibenstein H (1983), "Property Rights and X-Efficiency: Comment." **American Economic Review**, 73: 831-842.

Leibenstein H (1983), "Intrafirm Productivity: Reply [to M. Shamid Alam]." **American Economic Review**, 73: 822-823.

Leibenstein H (1984), "The Japanese Management System: An X-Efficiency - Game Theory Analysis", in Akoi M (ed.), **The Economic Analysis of the Japanese Firm**, Amsterdam: Elsevier.

Leibenstein H (1984), "On the Economics of Conventions and Institutions: An Exploratory Essay", **Journal of Institutional and Theoretical Economics**, 140: 74-86.

Leibenstein H (1985), "On Relaxing the Maximum Postulate." **Journal of Behavioural Economics**, 14: 5-20.

Leibenstein H (1986), "Organisational Economics and Institutions as Missing Elements in Economic Development Analysis", Presented at a Conference on The Role of Institutions in Economic Development, Cornell University.

Leibenstein, H (1987), "X-Efficiency Theory." in Eatwell J, M Milgate and P Newman (eds), **The New Palgrave**, New York: Stockton Press.

Leibenstein H (1987), **Inside the Firm: The Inefficiencies of Hierarchy**, London: Harvard University Press.

Leibenstein H (1987), "Entrepreneurship, Entrepreneurial Training and X-Efficiency Theory", **Journal of Economic Behaviour and Organisation**, 8: 191-205.

Leibenstein H (1988), "X-Efficiency, Managerial Discretion and the Nature of Employment Relations: A Game Theoretical Approach", in Dlugos G, W Dorow and K Weirmeir (eds), **Management Under Differing Labour Market and Employment Systems**, New York: de Gruyter.

Leibenstein H and S Maital (1992), "Empirical Estimates and Partitioning of X-Efficiency: A Data Envelopment Approach", **American Economic Review** (Papers and Proceedings), 82: 428-433.

Levitt M S and M A S Joyce (1987), **The Growth and Efficiency of Public Spending**, Cambridge: Cambridge University Press.

Lewin A and R Morey (1981), "Measuring the Relative Efficiency and Output Potential of Public Sector Organisations: An Application of Data Envelopment Analysis", **International Journal of Policy Analysis and Information Systems**, 5: 267-285.

Lovell C A K and P J Schmidt (1988), "A Comparison of Alternative Approaches to Measurement of Productive Efficiency", in Dogramaci A and R Fare (eds),

Applications of Modern Productivity Theory: Efficiency and Productivity, Boston: Kluwer Academic Publishers.

Mahesh C (1980), "Current Issues in Public Road Transport Management", **Lok Udyog**, August.

Maindiratta A (1990), "Largest Size-efficient Scale and Size Efficiencies of Decision-making Units in Data Envelopment Analysis", **Journal of Econometrics**, 46: 57-72.

Majumdar S K (1994), "Assessing Firms, Capabilities: Theory and Measurement", **Economic and Political Weekly**, 29: M83-M89.

Majumdar S K (1995a), " Public, Joint and Private Sectors in Indian Industry: Evaluating Relative Performance Differences", **Economic and Political Weekly**, 30: M25-M32.

Majumdar S K (1995b), " Does New Technology Adoption Pay? Electronic Switching Patterns and Firm Level Performance in US Telecommunications", **Research Policy**, 26: 803-822.

Majumdar S K (1995c) " X-Efficiency in Emerging Competitive Markets: The Case of US Telecommunication", **Journal of Economic Behaviour and Organisation**, 26: 129-144.

Majumdar S K (1996a), " Government Policies and Industrial Performance: An Institutional Analysis of the Indian Experience", **Journal of Institutional and Theoretical Economics**, 142: 380-411.

Majumdar S K (1996b), " Fall and Rise of Productivity in Indian Industry: Has Economic Liberalisation Had an Impact?", **Economic and Political Weekly**, 31: M46-53.

Malkiel B G (1987), "Efficient Market Hypothesis." in Eatwell J, M Milgate, and P Newman (eds), **The New Palgrave**, New York: Stockton Press.

Marathe S S (1989), **Regulation and Development**, New Delhi: Sage Publications.

March J and H Simon (1958). **Organizations**, New York: Wiley.

Mariamma S G (1993), **Performance of the Public Road Transportation System: A Case Study of the Kerala State Road Transport Corporation**, Unpublished M.Phil Thesis, Centre for Development Studies, Trivandrum.

Meeusen W and J Broeck (1977), "Efficiency Estimation from Cobb Douglas Production Function with Composed Error", **International Economic Review**, 18(2): 435-44.

Mishra R K and R Nandagopal (1991a), "Efficiency and Organisations Innovativeness in Passenger Organisation", **Management Review**, 6:

Mishra R K and R Nandagopal (1991b), "Efficiency through Competition in Passenger Road Transport in India: The Case of Tamil Nadu State Transport Undertakings", **The Journal of Institute of Public Enterprise**, 14: 1-22.

Mishra R K and R Nandagopal (1991c), "Privatisation of State Transport Undertakings in India: Scope and Modalities", **The Journal of Institute of Public Enterprise**, 14: 33-46.

Nadiri I and M A Schankerman (1981), "The Structure of Production, Technological Change, and the Rate of Growth of Total Factor Productivity in the U S Bell System", in Cowing and Stevenson (eds), **Productivity Measurement in Regulated Industries**, London: Academic Press.

Naidu R K (1990), **Organisation, Management and Control in Public Sector in India**, New Delhi: Ashish Publishing House.

North D C (1990) **Institutions, Institutional Change and Economic Performance**, New York: Cambridge University Press.

Pack H (1984), "Productivity and Technical Choice: Application to the Textile Industry", **Journal of Development Economics**, 16: 153-76.

Pagin M (1965), "Surplus Agricultural Labour and Development: Facts and Theories", **American Economic Journal Review**, 55: 815-34.

Parajape H K (1971), **Performance of Public Enterprises**, Bombay: Popular Prakasan.

Pearce W D (ed) (1992), **Dictionary of Modern Economics**, London: Macmillan.

Peltzman S (1991), "The Handbook of Industrial Organisation: A Review Article", **Journal of Political Economy**, 99: 201-217.

Penrose E T (1959), **The Theory of the Growth of the Firm**, Oxford: Blackwell.

Perlman M (1986), "Subjectivism and American Institutionalism." in Kirzner I M (ed.), **Subjectivism, Intelligibility, and Economic Understanding: Essays in Honour of Ludwig M. Lachmann on His Eightieth Birthday**, New York: New York University Press.

Philips D, A Ravindran and J Solberg (1976), **Operations Research: Principles and Practice**, New York: Wiley.

Pillai V K P (1956), **Report on the Travancore Cochin State Transport**, Government of Travancore and Cochin.

Pitt M M and L F Lee (1981), "The Measurement and Source of Technical Inefficiency in the Indonesian Weaving Industry", **Journal of Development Economics**, 9: 43-64.

Porter M E (1980), **Competitive Strategy**, New York: Free Press.

Porter M E (1991), " Towards a Dynamic Theory of Strategy", **Strategic Management Journal**, 12: 95-117.

Prahalad C K and G Hamel (1990), " The Core Competence of the Corporation", **Harvard Business Review**, 68: 79-91.

Prakash A B (1977), **An Economic Assessment of the Performance of K S R T C: 1959-71**, Unpublished PhD Thesis, University of Kerala, Trivandrum.

Rajeshwar R K (1982), "Management Effectiveness in Transport Operations: A Case Study of Delhi Transport Corporation", **Lok Udyog**, July.

Ramanadhan V V (1963), **The Efficiency of Public Enterprises**, Bombay: Allied Publishers.

Ramanandham V V (1948), **Road Transport in India**, Lucknow: The Universe Publishers Limited.

Ramaswamy K and W Renforth (1994), "Evaluating the Performance of State Owned Enterprises and Privately Owned Firms: The Indian Experience", **Academy of Management Proceedings**, 297-301.

Ramaswamy T (1972), **Public Enterprises in India**, Meerut: Meenakshi Prakasan.

Rangan N, R Grabowski, H Aly and C Pasurka (1988), " The Technical Efficiency of Us Banks", **Economic Letters**, 28: 169-176.

Rao R (1982) "Management Effectiveness in Transport Operations: A Case Study of Delhi Transport Corporation", **Lok Udyog**, July.

Raja Kumar J D (1991), **Effectiveness of Incentive Schemes in Kattabomman Transport Corporation Ltd., Thirunelveli**, Unpublished Post Graduate Project Report, Department of Commerce, St. Xavier's College, Palayamkottai.

Ray S C and M Kankana (1995), "Comparing Parametric and Nonparametric Measures of Efficiency: A Reexamination of the Christeensen-Greene Data", **Journal of Quantitative Economics**, 11: 155-168.

Retter S (1987), "Efficient Allocation." in Eatwell J, M Milgate, and P Newman (eds), **The New Palgrave**, New York: Stockton Press.

Robbins L (1932), **The Nature and Significance of Economic Science**, London: Macmillan.

Samuels W J (1987), "Institutional Economics." in Eatwell J, M Milgate and P Newman (eds), **The New Palgrave**, New York: Stockton Press.

Schmidt P J (1986), "Frontier Production Functions", **Econometric Reviews**, 4: 289-328.

Schmidt P J and C A K Lovell (1979), "Estimating Technical and Allocative Inefficiency Relative to Stochastic Production and Cost Frontier", **Journal of Econometrics**, 9: 343-366.

Schmidt P J and T Lin (1984), " Simple Tests of Alternative Specifications in Stochastic Frontier Models", **Journal of Econometrics**, 24: 349-361.

Schmooker J (1952), "The Changing Efficiency of the American Economy: 1869-1938", **Review of Economic and Statistics**, 34: 214-31.

Schwartzman D (1973), "Competition and Efficiency: Comment", **Journal of Political Economy**, 81: 756-764.

Seiford L M and R M Thrall (1990), "Recent Developments in DEA: the Mathematical Approach to Frontier Analysis", **Journal of Econometrics**, 46: 7-38.

Seiford L M and M Lawrence (1990) **A Bibliography of Data Envelopment Analysis (1978-1989)**, Working Paper, Department of Industrial Engineering and Operations Research, University of Massachusetts, Amherst.

Seitz W (1970), "The Measurement of Efficiency Relative to a Frontier Production Function", **American Journal of Agricultural Economics**, 52: 505-511.

Sen A (1983), "Carrots Sticks and Economics: Perceptions, Problems and Incentives", **Indian Economic Review**, 18: 1-17.

Sengupta J (1987a), "Efficiency Measurement in Non-market Systems Through Data Envelopment Analysis", **International Journal of Systems Science**, 18: 2279-2305.

Sengupta J K (1987b), "Production Frontier Estimation to Measure Efficiency: a Critical Evaluation in Light of Data Envelopment Analysis", **Managerial and Decision Economics**, 8: 93-99.

Sengupta J K and R Sfeir (1988), "Efficiency Measurement by Data Envelopment Analysis with Econometric Application", **Applied Economics**, 20: 285-93.

Shephard R (1953), **Theory of Cost and Production Functions**, Princeton: Princeton University Press.

Shephard R (1970), **Theory of Cost and Production Function,** Princeton: Princeton University Press.

Shephard R (1974), **Indirect Production Functions. Mathematical Systems in Economics**, No. 10. Meisenheim Am Glad: Verlag Anton Hain.

Simon H A (1959), "Theories of Decision Making in Economics and Behavioural Science", **American Economic Review**, 49: 252-83.

Simon H A (1978), "Rationality as Process and Product of Thought", **American Economic Review**, 68: 1-15.

Smith P and D Mayston (1987), "Measuring Efficiency in the Public Sector", **Omega: the International Journal of Management Science**, 15: 181-189.

Solow R M (1957), "Technical Change and the Aggregate Production Function", **Review of Economics and Statistics**, 39(3): 312-20.

Srivastava V (1996), **Liberalization, productivity and Competition: A Panel Study of Indian manufacturing**, Delhi: Oxford University Press.

Stigler G (1976), "The Xistence of X-Efficiency." **American Economic Review**, 66: 213-216.

Thanassoulis E, R Dyson and M Foster (1987), " Relative Efficiency Assessments Using Data Envelopment Analysis: An Application to Data on Rates Departments", **Journal of the Operational Research Society**, 38: 397-412.

Tidric G (1986), "Productivity Growth and Technological Change in Chinese Industry", **World Bank Working Papers, No. 761**, Washington, DC: World Bank.

Tinbergen J (1985), **Production Income and Welfare: The Search for an Optimal Order,** Brighton: Harvester Press.

Todd D (1971), "The Relative Efficiency of Small and Large Firms", **Research Report No. 18**, London: Committee of Inquiry on Small Firms, HMSO.

Varian H (1978), **Microeconomic Analysis**, London: Norton and Co.

Varian H (1984), "The Non-parametric Approach to Production Analysis", **Econometrica,** 52: 579-597.

Vijayakumar K C (1982), "A Corporate Model of K S R T C", **Lok Udyog,** August.

Weiermair K and M Perlman (eds) (1990), **Studies in Economic Rationality: X-Efficiency Examined and Extolled,** Michigan: The University of Michigan Press.

Williamson O E (1985). **The Economic Institutions of Capitalism,** New York: The Free Press.

Williamson O E and S G Winter (eds) (1991), **The Nature of the Firm, Origins, Evolution and Development,** Oxford: Oxford University Press.